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TABLE OF CONTENTS

**Articles In English**

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using a Compact Scintillation NaI(Tl) Detector to Study the Environmental Radiation</td>
<td>Jehad K. Mulhem and Jabbour N. Jabbour</td>
<td>189</td>
</tr>
<tr>
<td>Borate Glass with Lead and Nickel Oxides for Radiation Attenuation</td>
<td>Fawzi A. Ikraiam, A. El-Sayed Abdo, A. Abd El-Latif and M. El-Desoky</td>
<td>195</td>
</tr>
<tr>
<td>Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils</td>
<td>Mohammad. I. Awadallah and Dia-Eddin. M. Arafah</td>
<td>207</td>
</tr>
<tr>
<td>Radon Monitoring at Khartoum Using the Charcoal Technique</td>
<td>Osman Mustafa Mukhtar and Abd Elmoniem Ahmed Elzain</td>
<td>225</td>
</tr>
<tr>
<td>Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles</td>
<td>Nidal M. Ershaidat</td>
<td>237</td>
</tr>
<tr>
<td>Influence of Nd-YAG Laser Pulses on Aluminium Alloys. Study of Chemical Distribution of Elements</td>
<td>Layla Baziz, Abdul-Kader Nouiri and Yaser A. Yousef</td>
<td>257</td>
</tr>
<tr>
<td>Performance Evaluation of AES/Triple-DES/Blowfish Ciphers under W2K and Linux Operating System Platforms</td>
<td>Najib A. Kofahi</td>
<td>265</td>
</tr>
<tr>
<td>Two Enhanced Fuzzy Similarity Approaches for Arabic Web Pages Classification</td>
<td>Ahmad T. Al-Taani and Noor Aldeen K. Al-Awad</td>
<td>287</td>
</tr>
<tr>
<td>Improving the Effectiveness of Web Caching at the Client’s Site</td>
<td>Samia Abul-Rub and Sami Serhan</td>
<td>303</td>
</tr>
<tr>
<td>Mathematical Model of Real Physical Processes in Control Systems</td>
<td>Mamoun S. Al Rababaa</td>
<td>319</td>
</tr>
<tr>
<td>Geology of the Dhafer (Bargish) Cave System, NW Jordan</td>
<td>Nizar Abu-Jaber, Hakam Mustafa and Deema Melhem</td>
<td>351</td>
</tr>
<tr>
<td>Modeling and Measurement of One-Phase Mixture Using Microwave Frequencies</td>
<td>Aied K. M. Al-Samarrie</td>
<td>377</td>
</tr>
</tbody>
</table>
Using a Compact Scintillation NaI(Tl) Detector to Study the Environmental Radiation

Jehad K. Mulhem* and Jabbour N. Jabbour*

Received on Oct. 24, 2005 Accepted for publication on May 14, 2006

Abstract

There is a possibility of using a compact scintillation NaI(Tl) detector, long-term stable and reliable, to monitor the components of the environmental radiation, in the range 0.28-2.8 MeV. The energy spectra recorded at physics department – Lattakia show the peaks are due to very low energy secondary cosmic radiation and to the airborne radioactivity. No anomaly radiation was detected. These results are achieved with cooperation of physical group in Bologna University - in Italy.

Keywords: Secondary cosmic radiation – environmental radiation – scintillation detector.

Introduction:

The environmental radiation (ER) [1,2] originates mainly from the most degraded secondary cosmic rays, airborne radioactivity, the surrounding material and from the detector itself. It gives an energy, which can be exceed more than 50keV [1-11], by an organic or inorganic scintillation detector.

The real time monitoring of the ER, raises warning in real time of possible radiation anomalies of artificial origin (nuclear reactor accidents, nuclear bombs, pollutants, ..etc.) or astrophysical and physical origin (solar flare effects, solar activity). It is surely important for those activity to distinguish between the ER in itself and the background radiation because it can seriously interfere, for instance, with the operation of a health diagnostic apparatus.

Experimental Method:

The detector used belongs to Bologna University, it was borrowed by Tishreen University – Physics Department – for more than six months. A sketch of the structure of scintillation detector is shown in fig.1.
Figure (1): Drawing of the detector. The NaI(Tl) mono-crystal, together with its PMT are embedded in a box of thermal insulator [1, 7, 8].

The monocrystal of NaI(Tl), which has a diameter of 8" and a height of 4", has been supplied by Bicron Corp., New bury (OH, USA), the scintillations of the crystal are seen through a light guide by a photomultiplier tube (PMT) of 5" diameter also supplied by Bicron Corp. The PMT is surrounded a multi-metal shield in order to avoid gain variation due to the varying magnetic field. The PMT photocathode is electrically connected to its metalized glass and to the multi-metal shield.

The output signals from the PMT are sent to a charge preamplifier and energy analyzer. The energy analysis is obtained through a multichannel analyzer of 1024 channels of variable width, 7.5-100 keV/channel.

The important feature of the detection system is its time stability. It has been achieved by a back-feed gain control based upon the electric pulse height, corresponding to a photoelectric gain. After fixing the channel in which the peak is desired to be, the possible variations of the corresponding pulse height are recognized and corrected by electronic by means of a feedback on the high voltage supply of the PMT. In our case we have considered the peak corresponding to the 1.461 MeV gamma line of 40K, naturally present in the surrounding solid material and in the detector itself. By this system the overall pulse height gain can be stabilized within a few permill, as shown in table 1.
Using a Compact Scintillation NaI(Tl) Detector to Study the Environmental Radiation

Table (1): The pulse height stability relation to the photo peaked $^{40}$K and $^{208}$Tl for all the 191 hourly spectra of the considered interval.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>$\gamma$ - line energy</th>
<th>$^{40}$K 1.461 MeV</th>
<th>$^{208}$Tl 2.615 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order number of channel (14keV/channel)</td>
<td>103;104;105</td>
<td>181;182;183;184;185</td>
<td></td>
</tr>
<tr>
<td>Frequency of order number</td>
<td>0;576;0</td>
<td>0;42;477;7;0</td>
<td></td>
</tr>
</tbody>
</table>

Results and Discussions:

Fig. (2). shows, in decimal semi-logarithmic coordinates, the behaviour of the average spectrum and also of the minimum and the maximum spectra in the energy interval corresponding to channels $n = 16$ to $n = 200$ with 14keV/channel, obtained during the time interval 00:00 h May 1994 to 24.00 h 9th June 1994, altogether 191 three hourly intervals; the monitor was located on the roof of the building of the Physics Department of Bologna University, under a layer of material not greater than 2g/cm$^2$ [3,4,12,13].

Fig. (2). Three hourly pulse spectra for channel interval 16 to 200.
Some Measurements at Physics Department – Tishreen University:

The detector used can be easily dismounted and assembled. The upper shield surrounding only the NaI crystal can be easily removed. It was put in the first floor at Physics Department near the window. The PM high voltage supplied by the ACQ card coupled to a personal computer is very stable. It can accumulate 2048 channel every minute with tunable energy resolution. On-line programs allow a quick look analysis and graphical inspection of data collected in different pre-set energy bands. In fig. 3 we present the data acquisition during the period 21/03/2001 to 20/5/2001.

For the calibration of the detector, we used two sources: the first is $^{40}$K, and the second $^{208}$Tl, were positioned on the detector to allow adjustment of the $^{40}$K photo peak and $^{208}$Tl photo peak positions in the spectrum by means of the feedback device which provided adequate correction to possible deviations of the HV of the phototube. It has therefore been possible to the $^{40}$K photo peak, $^{208}$Tl photo peak, absolutely stable at the same channel of the spectrum for the entire duration of the experiment.

Fig. 3. Plot of the data acquisition quick look for two months, each point represent a spectrum, and each data for 15 minutes.

Fig. 4. Energy spectrum of gamma radiation detected by the detector, 2.8keV/channel.
Using a Compact Scintillation NaI(Tl) Detector to Study the Environmental Radiation

Fig. 4. Shows the energy spectrum of gamma radiation in the energy interval (0-3MeV). The peak of 1.461MeV gamma line belongs to $^{40}$K which is present in the surrounding solid material part land cement has about 2% of $^{40}$K. While the peak of 2.615MeV belongs to $^{208}$Tl (one of the Thorium chain product) which is mainly due to the building material.

The other photo-peak corresponding to the $^{214}$Bi (934keV, 609.3keV) and $^{214}$Pb (351.9keV) daughter products from the $^{238}$U are easily identifiable. The second peak is due to $^{212}$Pb (238.6keV) and/or backscattered Compton photons. The first one is probably due to the counter Pb-flourscent X-rays at 77keV.

Conclusion:

The detector we have used for the continuous monitoring of the ER has provided its reliability being able to work continuously, but with the few interruptions due to human interference.

The analysis of the data collected is at present very preliminary and we hope to present an updated and more complete analysis in the future.

The main conclusion that the radiation detected is essentially due to cosmic radiation and to the airborne radioactivity. No anomaly behaviour was observed, which means the absence of artificial radiation sources, and hence, the Lattakia environment is safe and clean.

NaI(Tl)

ثانية ومضى من نوع

للدراسة الإشعاعات البيئية

جهاد كامل ملحم و جبور نوفل جنور

ملخص

توجد امكانية لاستخدام كاشف ومضي مدمج، NaI(Tl)، فعال، ويعتمد بنزمن استقرار طويل، لدراسة مكونات الإشعاعات الطبيعية، في مدى الطاقة0.28-2.8 مليون الكترون فولت (MeV).

تشير أطاف الطاقة التي تم تسجيلها، في قسم الفيزياء، في كلية العلوم (جامعة تشرين – اللاذقية - سورية)، أن الخطوط الطيفية كان سببا الإشعاعات الكونية الثانوية والشعاعات البيئية. ذات الطاقة المنخفضة، بالإضافة إلى ذلك، لم تكشف أي أشعة غير طبيعية.

إنه هذه النتائج التي عرضها تم الحصول عليها بالتعاون مع المجموعة الفيزيائية في جامعة بولونيا في إيطاليا التي تعمل في هذا المجال.

الكلمات المفتاحية: إشعاع كوني ثانوي - إشعاع بيئي - كاشف ومضي.
References


Borate Glass with Lead and Nickel Oxides for Radiation Attenuation

Fawzi A. Ikraiam*, A. El-Sayed Abdo, A. Abd El-Latif and M. El-Desoky

Received on April 24, 2005 Accepted for publication on Jan. 28, 2006

Abstract

This work deals with the gamma ray attenuation through borate glass xNa2B4O7 (10) PbO:NiO used in many different applications for radiation shielding. Investigation has been performed by measuring the gamma ray fluxes through samples of borate glass with different concentrations of lead and nickel oxides. Measurements have been carried out using sodium iodide crystal and Geini 2000 gamma ray spectrometer with 60Co gamma ray source. The linear attenuation (μ) and total mass attenuation (μ/ρ) coefficients have been evaluated based on the measured results. The total mass attenuation coefficient (μ/ρ) has also been calculated using the X COM program and database cross-section. A comparison between measured and calculated results has been carried out and a reasonable agreement was found. This agreement makes possible the usage of such results in absorbing or decreasing radiation doses in the field of industrial technology of screens for computers and televisions.

Keywords: Radiation shielding, gamma ray flux, linear attenuation coefficient, masses attenuation coefficient.

Introduction

The fact that radiation could be harmful has lead to the development of a wide variety of shields to protect against its adverse effects. As the technology advances there is a need to develop materials, which can be used under most hazardous conditions such as nuclear exposure. The attenuation coefficients are important parameters for characterizing the penetration and diffusion of X- and gamma rays in multielement materials. Gamma ray attenuation coefficients are required in variety of nuclear science technologies and medical applications[1]. Several special glasses have been claimed for engineering applications[2]. In the design of high intensity radiation sources and other radiation generating equipment, a variety of shielding materials are used to minimize exposure to individuals. Among these materials, lead and lead glass are best for radiation shielding of gamma ray due to their high densities and atomic numbers. Commercial and
barium-enriched cement, apart from better compressive strength, smoother surface finish and high abrasion resistance, offers adequate shielding to gamma radiation. Attenuation coefficients for photons in lead, lead glass and barium-enriched cement have been studied for photons in the energy range from 364 keV to 1332 keV[3]. The described glass formulations contain high concentrations of $^6$Li and are suitable for use as thermal neutron shielding. The lithium silicate glasses can be formed into a variety of shapes using conventional glass fabrication techniques. Both in–beam and in-core experiments have been performed to study the use and durability of $^6$Li silicate glasses. In-core experiments show that the glass can withstand intense radiation fields near the core of the reactor. The neutron attenuation of the glasses used in these experiments can tolerate the gamma ray and neutron fields near experiments[4].

Glass has been developed to accomplish the double task of allowing visibility and absorbing radiation, like gamma rays and neutrons[5]. A good shielding glass should have high absorption cross-section for radiation and, at the same time, irradiation effects on its mechanical and optical properties should be small.

Data for compiling information on photon attenuation (cross section) has been derived from many sources as the results of a combination of experimental investigations and theoretical calculations. Therefore, in the present work, the linear attenuation ($\mu$) and the total mass attenuation ($\mu/\rho$) coefficients have been evaluated based on the measured gamma ray fluxes through borate glass with different concentrations of lead and nickel oxides. The total mass attenuation coefficients ($\mu/\rho$) have also been calculated for the mentioned borate glass using the X COM program and database cross section.

**Experimental Method and Calculation**

**Materials and Samples Preparation**

The investigated samples of borate glass were prepared by mixing appropriate percentages of di-sodium tetraborate (base), lead and nickel oxides according to weight composition. $\text{Na}_2\text{B}_2\text{O}_7$ was used according to composition weight of 90% and the additives (nickel and lead oxides) were added according to the following composition ratio: $x\text{NiO}(10-x)\text{PbO}$; where $x = 0, 2, 3, 4, 6, 8$ and 10 % by weight. Nickel oxide has been used for making smoky colored glasses, for decolouring lead crystal glasses and, in conjunction with cobalt oxide, for glasses transmitting only in the ultraviolet region of the spectrum[6].

Each mixture was melted in a platinum crucible for one hour at about 1000 °C. The melt was poured into a stainless steel plate at about 400 °C. The compound was left to cool down to room temperature and, then, extracted out for attenuation measurements. Mix design of the borate glass with lead and nickel oxides is given in Table 1.

The density ($\rho$) has been obtained according to the following equation[7];
Table 1. Mixing and chemical composition of the borate glass samples.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Composition weight percentage</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Na₂B₄O₇</td>
<td>PbO</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>90</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>90</td>
<td>10</td>
</tr>
</tbody>
</table>

\[ \rho = \frac{W_a \rho_t}{W_a - W_t} \]  

where: \( \rho_t \) is the density of toluene, \( W_a \) and \( W_t \) are the weights of the sample in air and in toluene, respectively.

Gamma Ray Fluxes Measurement

Gamma ray fluxes behind borate glass samples with different concentrations of nickel and lead oxides (numbers from 1 to 7, Table 1) have been measured. Measurements have been carried out using a collimated beam of the point isotropic \(^{60}\text{Co}\) (100 mCi) gamma ray source with two lines of energy; \( E_1 = 1.17 \text{ MeV} \) and \( E_2 = 1.33 \text{ MeV} \). The leakage gamma ray fluxes behind the investigated samples have been carried out using sodium iodide crystal NaI (Tl) detector with dimension 3’ x 3’ and Genie 2000 gamma ray spectrometer. Both the detector and the source were provided with adequate lead shielding. The measured transmitted fluxes were performed under narrow beam geometry, where two lead collimators of about 12-cm long before and after the sample were used. The incident and transmitted intensities were determined for a fixed preset time in each measurement by choosing a narrow symmetrical region with respect to the centered photo peak. The measurements had been carried out 3 to 4 times and the average was taken in order to decrease statistical errors.

Evaluation of the Attenuation Coefficients (\( \mu \)) and (\( \mu/\rho \))

The linear attenuation coefficient (\( \mu \)) is best described with reference to an experiment which uses narrow beam geometry. The distinctive feature of a narrow beam (i.e. one having a good geometry) is that only the source radiation which traverses the specimen absorber without experiencing any interaction of any kind, reaches the detector. For example, any scattered radiation is prevented from reaching the detector. The fraction reduction of gamma ray flux, \(-d\Phi/\Phi\), is found experimentally to be proportional to the linear thickness \( dx \). Thus, for a homogeneous medium[8],

\[ \Phi(t) = \Phi_0 \exp(-\mu t) \]
where: \( \Phi_0 \) and \( \Phi(t) \) are the measured fluxes for bare and sample, respectively, and \( t \) is the sample thickness. The linear attenuation coefficients \( (\mu) \) of the sample numbers, 1 to 7, have been evaluated using formula (2). Whereas, the mass attenuation coefficients \( (\mu/\rho) \) (cm\(^2\).g\(^{-1}\)) have been estimated using the \( \mu \) values and the sample density \([9,10]\).

**Calculation of the Total Mass Attenuation Coefficient \((\mu/\rho)\)**

The density does not have a unique value but depends on the physical state of the material as, for example, in case of borate glass under investigation. To obviate the effects of variations in the density of the material, the linear attenuation coefficient is, for reference purposes, expressed as a mass attenuation coefficient \((\mu/\rho)\); which is the linear attenuation coefficient per unit mass of the material \([9]\). Table 2 shows the total mass attenuation coefficients \((\mu/\rho)\) (cm\(^2\).g\(^{-1}\)) of gamma ray for the different samples with the possible uncertainties.

**Table 2.** Total mass attenuation coefficients \((\mu/\rho)\) (cm\(^2\).g\(^{-1}\)) of gamma ray for the different samples with uncertainties.

<table>
<thead>
<tr>
<th>Sample Nos.</th>
<th>((\mu/\rho) + \Delta (\mu/\rho))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \mu_1 )</td>
</tr>
<tr>
<td>1</td>
<td>0.0571±0.0009</td>
</tr>
<tr>
<td>2</td>
<td>0.0571±0.0006</td>
</tr>
<tr>
<td>3</td>
<td>0.0573±0.0011</td>
</tr>
<tr>
<td>4</td>
<td>0.0574±0.0006</td>
</tr>
<tr>
<td>5</td>
<td>0.0575±0.0006</td>
</tr>
<tr>
<td>6</td>
<td>0.0578±0.0006</td>
</tr>
<tr>
<td>7</td>
<td>0.0580±0.0009</td>
</tr>
</tbody>
</table>

The mass attenuation coefficient \((\mu/\rho)\) is of special interest in energy ranges from 0.1 to 10 MeV. For the lightest elements and medium mass-number elements in energy ranges from 0.2 to 3 MeV, Compton effect is dominant. Since the number of electrons present in a given quantity of matter is roughly proportional to the mass, Compton interaction will approximately vary with the mass. Hence, in the specified energy range, the mass attenuation coefficient is essentially independent of the nature of the absorbing material\([10]\). For a mixture of known composition, the total mass attenuation coefficient \((\mu/\rho)\) can be determined by \([8, 9]\);

\[
\mu = \Sigma_i \mu_i = \Sigma_i N_i \sigma_i \text{ .......................................................... (3)}
\]

where: \( \mu \) is the total linear attenuation coefficient (cm\(^{-1}\)), \( N_i \) is number of atoms (cm\(^{-3}\)) and \( \sigma_i \) is microscopic cross section (cm\(^2\)).

The total mass attenuation coefficient for element is given by:

\[
\mu/\rho \text{ (cm}^2\text{.g}^{-1}\text{)} = \Sigma_i \sigma_i \text{ (cm}^2\text{ /atom)/[u (g) A]} = \Sigma_i \sigma_i \text{ (b /atom) } 10^{-24}/[u \text{ (g) A]} \text{ .......................................................... (4)}
\]
Borate Glass with Lead and Nickel Oxides for Radiation Attenuation

where: \( u (g) \) is the atomic mass unit, \( A \) is the relative atomic mass of the target element, and \( \rho \) is the element density \([11, 12]\).

\[
\mu / \rho = \sum_i W_i \left( \mu / \rho \right)_i
\]

where: \( \rho_i \) is the density of the \( i^{th} \) constituent \((g. cm^{-3})\) and \( W_i \) is the proportion by weight of \( i^{th} \) constituent \([9, 10]\).

The total mass attenuation coefficient \( \mu / \rho \) has been calculated for the mentioned borate glass using the X COM (version 3.1, copyright 1999) program and data base cross-section for elements from \( Z = 1 \) to 100 at energy ranges from 10 keV to 15 MeV \([13]\). The fractions by weight of the constituent elements of the investigated samples are given in Table 3 and the calculated total mass attenuation coefficients are given in Table 4.

**Table 3.** Fraction by weight of the constituent elements for borate glass samples.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Fractional weight of the constituents elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Na</td>
</tr>
<tr>
<td>1</td>
<td>0.228509519</td>
</tr>
<tr>
<td>2</td>
<td>0.219458645</td>
</tr>
<tr>
<td>3</td>
<td>0.216114421</td>
</tr>
<tr>
<td>4</td>
<td>0.212756221</td>
</tr>
<tr>
<td>5</td>
<td>0.209556064</td>
</tr>
<tr>
<td>6</td>
<td>0.206450431</td>
</tr>
<tr>
<td>7</td>
<td>0.206169</td>
</tr>
</tbody>
</table>

**Table 4.** Total mass attenuation coefficients \( \mu / \rho \) \((cm^2.g^{-1})\) of gamma ray for borate glass samples.

<table>
<thead>
<tr>
<th>Energy (MeV)</th>
<th>Total mass attenuation coefficients ( \mu / \rho ) ((cm^2.g^{-1})) of glass samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00E-02</td>
<td>7.14E+00 1.46E+01 1.52E+01 1.59E+01 1.65E+01 1.72E+01 1.79E+01</td>
</tr>
<tr>
<td>2.00E-02</td>
<td>1.02E+00 2.16E+00 3.48E+00 4.76E+00 6.00E+00 7.20E+00 8.47E+00</td>
</tr>
<tr>
<td>3.00E-02</td>
<td>4.19E-01 7.84E-01 1.25E+00 1.71E-00 2.15E+00 2.58E+00 3.0E+00</td>
</tr>
<tr>
<td>4.00E-02</td>
<td>2.73E-01 4.32E-01 6.56E-1 8.74E-01 1.08E-01 1.29E+00 1.50E+00</td>
</tr>
<tr>
<td>5.00E-02</td>
<td>2.19E-01 3.01E-01 4.27E-01 5.49E-01 6.67E-01 7.82E-01 9.02E-01</td>
</tr>
<tr>
<td>6.00E-02</td>
<td>1.92E-01 2.40E-01 3.19E-01 3.94E-01 4.68E-01 5.39E-01 6.14E-01</td>
</tr>
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## Results and Discussion

The measured gamma ray fluxes were used to calculate the linear attenuation coefficient ($\mu$) using formula (2), then the mass attenuation coefficients ($\mu/\rho$) using the sample density and formula (5). Figure 1 shows the change of the linear attenuation coefficient ($\mu$) (at the two energy lines $E_1 = 1.17$ MeV and $E_2 = 1.33$ MeV) with different concentration of lead and nickel oxides (i.e. sample numbers from 1 to 7). It is shown that the linear attenuation coefficient ($\mu$) values vary with the variation of the lead concentration and photon energy. The linear attenuation coefficient ($\mu$) values varies from 0.151 to 0.162 cm$^{-1}$ by changing rate 6.8% for $E_1$ and from 0.142 to 0.152 cm$^{-1}$ by changing rate 6.3% for $E_2$. The average relaxation length ($\lambda$), half value layer ($t_{1/2}$) and one-tenth value layer ($t_{1/10}$) are 17.4 cm, 12.1 cm and 40.1 cm, respectively, for $E_1$ and 18.44 cm, 12.8 cm and 42.5 cm for $E_2$.

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200
Borate Glass with Lead and Nickel Oxides for Radiation Attenuation

Fig. 1. Effect of lead and nickel oxides concentration on gamma attenuation coefficient (µ).

Fig. 2. Calculated total mass attenuation coefficients (µ/ρ) of gamma ray for borate glass without and with 10 wt% concentration of nickel oxides and lead (samples nos. 1, 2 and 7).
Figure 2 shows the calculated total mass attenuation coefficients ($\mu/\rho$) of the gamma rays for borate glass without and with 10 wt% concentration of nickel and lead oxides (sample numbers: 1, 2, and 7). It is clear that the $\mu/\rho$ values sharply decrease with increasing photon energy starting at 0.05 MeV for the three samples. This may be attributed to the two main predominant interactions in this region. These are photoelectric effect and Compton scattering. Photoelectric effect is the dominant interaction at the energy range from 0.01 to 0.1 MeV for an absorber with atomic number 20, and Compton scattering is the dominant interaction at energy range from 0.1 to 100 MeV [9]. For energy ranges 0.6 to 15 MeV, $\mu/\rho$ values are almost equal for the three samples, and slowly decrease with increasing photon energy. This may be attributed to the fact that Compton scattering and pair production are the predominant interactions in this range. Compton scattering is predominant for photon energy with energies in the range 1 to 10 MeV for elements of low and intermediate atomic numbers and pair production is predominant at photon energies from 0.5 to 5 MeV for atomic number 60 [10]. Therefore, in this region (0.6 to 15 MeV) it may be considered that the main interaction is the Compton scattering cross section. The observed peak at about 0.1 MeV for borate glass with 10% of lead oxide is ascribed to K-edge photoelectric absorption. In addition, this concentration has the largest $\mu/\rho$ values and the pure borate glass has the smallest values at all photon energies (see Fig. 2).

Figure 3 shows the calculated total mass attenuation coefficients ($\mu/\rho$) for borate glass with 2, 4, 6 and 8 wt% concentrations of lead and nickel oxides (samples numbers 3 to 6). The $\mu/\rho$ values have the same shape and profile as presented in Fig. 2 for 10 wt% concentration of lead oxide. Its sharp and slow decrease is as previously explained for Fig. 2. The height of the observed peaks at about 0.1 MeV of the K-edge photoelectric absorption for borate glass with 2, 4, 6 and 8 wt% of lead oxide are proportional to the lead concentration. It is shown that the largest values of $\mu/\rho$ occur for sample no. 6 (i.e. 8 wt% of lead) and the smallest values of $\mu/\rho$ occur for sample no. 3 (i.e. 2 wt% of lead).

Fig. 4 provides evaluated (based on the measured results) and calculated $\mu/\rho$ values for each sample number of borate glass with different concentrations of lead and nickel oxides for the two lines of gamma energy. It is shown that the evaluated and calculated $\mu/\rho$ values are in reasonably good agreement. The deviation has the range from 0.21 to 0.75 % at $E_1$ and from 0.18 to 1.28 % at $E_2$, where the range is given by [9]

$$\text{Range} = \left(\frac{\text{largest value} - \text{smallest value}}{\text{largest value}}\right) \times 100.$$
Borate Glass with Lead and Nickel Oxides for Radiation Attenuation

Fig. 3. Calculated total gamma ray mass attenuation coefficients ($\mu/\rho$) for borate glass with different concentrations of lead and nickel oxides (samples nos. 3 to 6).

Fig. 4. Evaluated and calculated total gamma ray mass attenuation coefficients ($\mu/\rho$) for borate glass with different concentration of lead and nickel oxides.
Conclusions

In this work and based on the measured and calculated results it was concluded that attenuation coefficients (µ) and (µ/ρ) increase with increasing PbO concentrations, whereas they are decreasing with the photon energy. The calculated µ/ρ values sharply decrease with increasing photon energy from 0.01 to about 0.05 MeV and slowly decrease from 0.06 to 15 MeV. The closeness between measured and calculated µ/ρ values confirmed the measured and calculated results and also the employed methods. These results may be useful when these materials are to be used in radiation shielding applications.

Zجاج البوارض المضاف إليه أكسيد الرصاص وأكسيد النينكلا لفرض توهين الإشعاعات

فوزي أكريم، عبد الوهاب، عبد اللطيف، الدسوقى

ملخص

يتناول هذا البحث دراسة توهين أشعة جاما خلال زجاج البوارض حيث ان عينات الزجاج تم تحضيرها بخلط ثلاثي صوديوم البوتاطس (كمركب أساسي) مع أكسيد الرصاص وأكسيد النينكلا لإضافات وفقاً للنظام التالي:

\[ X = 90\% \text{ (wt)} \ Na_2 B_4 O_7 : NiO(10-X) PbO \]

بالوزن. وقد تم قياس فيض أشعة جاما خلف العينات تحت الارتفاع بتركيزات مختلفة من أكسيد الرصاص والنيكل وذلك باستخدام أشعة جاما 2000 Geine وقى قياسات الفيض في اشكال هندسية تبين العلاقة بين فيض أشعة جاما مع نسب أكسيد الرصاص وأكسيد النينكلا. كذلك تم في هذا البحث عمل حسابات نظرية لمعامل توهين أشعة جاما الكتلي (µ/ρ) باستخدام كود X.COM في مدى من طاقة أشعة جاما من 10 keV إلى 15 MeV وقد تم المحاكاة بين القياسات العملية والنظرية لمعامل الهاوية الكتلي (µ/ρ) حيث وجد كبير بين تلك النتائج، مما يعني إمكانية التطبيق التكنولوجي للنتائج المتعلقة في مجال صناعة الشاشات الممتازة للإشعاع أو لتقليل الجرعة الإشعاعية خصوصا في شاشات الكمبيوتر أو التليفزيون.
References


Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils

Mohammad. I. Awadallah 1* and Dia-Eddin. M. Arafah 2

Received on Dec. 4, 2005 Accepted for publication on June 4, 2006

Abstract

Soil-to-plant transfer factor (SPTF) integrates a number of soil chemical, soil biological, hydrological, physical and plant physiological processes. SPTF of selected natural and artificial radionuclides were studied for three plants in Jordanian soils, namely; apples, chickpeas and wheat. Plant samples with their root soils were collected from different regions in the kingdom. The activity concentrations of U-238, Th-232, K-40 and Cs-137 were measured in plants and soils using gamma spectrometry, through HPGe detectors. The average temperatures and annual rainfall of the selected regions were studied with the transfer factors. The transfer factor of K-40 to apple was the largest (2.2), while the least for wheat (0.9). U-238 showed less transfer by the half of k-40 for all studied plant samples. Uranium transfer to plants correlated with the rainfall in the sampling regions. Wheat was the cleanest plant regarding radionuclides transfer factor. Cs-137 transferred least to wheat (< 0.1) and most to apple (0.25).

Keywords: Soil to plant transfer factor (SPTF), Uranium, γ-ray spectrometry, activity concentration.

Introduction

Plant roots absorb elements from the surrounding soils. The type of the plant, the types and concentrations of radionuclides in the planted soils and the weather conditions constitute factors that determine the fraction of radionuclide transferred to the plant. The primary application of soil-to-plant transfer factors is in food chain models. It is used for calculating radiological consequences from routine or accidental release of radioactive substances to the environment [1]. These models are usually designed to give conservative assessments.

Plants can eventually become contaminated with radionuclides via three pathways: root uptake, foliar absorption, and surface adhesion of re-suspended contamination on leaves and stems [2].
Naturally occurring radionuclides, namely, U-238 series, Th-232 series, and K-40, exist in different concentrations in almost all types of soils. In a similar manner to the case of artificial radionuclides, these are transferred to plants with different transfer factors. Plants absorb various elements depending on their needs. Hence, the radioactive isotopes of these elements sneak into the plant. Consequently, the plant is found to contain certain amounts of natural or artificial radionuclides.

K-40 is a natural isotope of potassium that is intimately tied to stable potassium. Since potassium is an essential macronutrient, it is a desirable component in soils and in produce. Any attempt to reduce intake of K-40 will result in the elimination of potassium from soil and from diet, which is a negative outcome.

The soils of natural or semi-natural areas are often poor in nutrients. Soil characteristics are such that a high uptake of artificial radionuclides by the plants is facilitated [3]. The presence of different radionuclides, however, induces competition in plants uptakes [4].

Following the Chernobyl fallout, a primary source of wood contamination in mid and Western Europe, was the direct deposition of aerosol-derived radiocesium on the canopy and its further translocation from foliar surface to structural components [5]. Cs-137 is a nutrient analog of potassium. Thus, uptake of cesium is for use as potassium in the plant. Thus, it is expected that plants will uptake Cs-137 at higher rates in soils deficient in potassium.

Different types of soils offer a wide variety of minerals. For most elements, ions are taken from the soil solution and transported into the xylem. Solutes are transported to the plant roots by mass flow and diffusion. If, however, root uptake rates of a solute exceed mass flow rates, depletion of the solute at the root soil interface initiates additional diffusional transport of the surrounding solute towards the roots. Consequently, a depletion zone around the absorbing root develops, which in the long term reduces uptake rates of the solute [6].

For plants and root soil samples taken from the same spot of the planted zone, the soil-to-plant transfer factor (SPTF) for a nuclide is defined as [1]:

\[
SPTF = \frac{\text{activity concentration of the nuclide per kg dry plant mass}}{\text{activity concentration of the nuclide in dry soil within the rooting zone}}
\]

Concentrations in the crops refer to the concentrations in the edible part at harvest time; the concentration in the soil refers to the upper 20cm of soil for all crops [6].

Natural series are broken since one of the daughters in each series is the radon gas. Rn-222 from the Uranium series and Rn-220 from the Thorium series can leave the sample and hence reduce the concentration of the following daughters of the series. To keep the concentrations of such daughters, the sample containers are well sealed for a period of time (seven times the half life of radon) in order to achieve the secular equilibrium of the concentrations of these daughters with the parent ones.
Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils

Many daughters in the natural radioactive series are emitters of α and β in addition to γ-radiation. The internal emission of radiation which occurs in the human body by the ingested food raises the internal dose to which the human is exposed. The α-emitting Pb-210 and Po-210 of the U-238 series and Bi-212 and Po-212 of the Th-232 series can contribute a significant dose to the plant consumers.

Most concern in literature is given to studying the plant contents of artificial radionuclides [2, 5-7]. But studies that have investigated the natural contents of radionuclides in some plants do exist [8]. In Jordan, no previous work concerning SPTF of radionuclides was published. This paper investigates the transfer of radionuclides from soil to three main plants in Jordan, namely wheat, chickpeas and apples.

Sampling and experimental work.

Plants chosen in this study, namely apples, chickpeas and wheat, were collected in the harvesting season from various regions in Jordan.

Sampling

Wheat samples were collected from 24 different sites in the Kingdom. Three sub-samples were taken from each site, with minimum separation of 1 meter. Harvesting was made by root-unsling; where the whole plant was taken; i.e. roots, stem, nails and seeds. Root-soil within 20×20×20 cm was taken simultaneously with the plant. The harvesting period was spanned over about two months (May 13 to July 15) depending on the harvesting region.

Chickpea samples were collected from sixteen different sites, during the harvest season (May 15 to June 26). Three different samples were taken from each site with distance of at least 10 m from each other. Samples were taken by roots-unsling. The soil surrounding the roots by (20×20×20cm) was taken.

Apple samples were taken from thirteen different sites across the Kingdom. Samples from three different trees were taken in each site. Each sample consisted of 5-6 apples. Simultaneously, for each tree, three surface soil samples were taken; one at the trunk of the tree, and the others at two meters lateral distance from the trunk at two opposite points. The sampling regions are shown on the map in figure (1).
Fig. 1 Sampling regions in different sites of Jordan.
Sample preparation

With plants, it is required to maximize the density of the sample, and to have a uniform geometry similar to that of the calibration source. Therefore wheat and chickpea samples were dried naturally by exposing to sunlight in isolated and dry conditions for about three months. Wheat spikes were then cut and threshed manually. Seeds were separated from straw, packed and sealed for secular equilibrium. While chickpea seeds were left until became brittle then milled into powder. Further drying of the milled powder was made to minimize moisture remnants, and finally the chickpea’s powder was packed in Petri-dishes, sealed and left to attain secular equilibrium.

Apple fruits were sliced into thin chips and exposed to sunlight for periods of 3 to 5 weeks in isolated dry conditions. Each fruit sample was dried until hardened, then compressed for a period of 20 hours in a hot mold using the apparatus shown in figure 2. Samples were then kept in a well-sealed Petri-dish, for periods exceeding 21 days; the time needed for secular equilibrium.

Counting

The experimental part of this study was carried out at the Radiation Measurements Laboratory at Al-Balqa’ Applied University. Gamma ray spectroscopy was used to determine the radioactive contents within the collected samples, using two EG&G Ortec High Purity Germanium (HPGe) detectors. One is an n-type gamma-x ray detector, with energy resolution and relative efficiency of 2.02 keV and 56.9% respectively, at 1.33 MeV. The second detector is a p-type well detector with energy resolution of 2.09 keV at 1.33 MeV.

Counting and analysis were carried out using the EG&G Ortec software “Gamma Vision- 5.00”. For transfer factors of the order of $10^{-2}$, long counting periods were
necessary to achieve a sufficient number of counts. Counting times varied for different plant samples, and ranged between 24-36 hours for most of the samples. Analysis was carried out using IAEA soil-6 and density-corrected grass standard calibration sources.

Results and Discussion

Methodology

Plant samples were acquired with long counting times that often exceeded 24 hours, and for some samples, up to 72 hours, to achieve the relevant numbers of counts. Naturally dried chickpea, wheat and apple spectra were analyzed to extract the activity concentrations of different radionuclides in each sample. The natural radioactive series were tracked through their daughters, after achieving secular equilibrium.

For the uranium series starting with U-238, the activities of the daughters Ra-226, Bi-214 and Pb-214 were investigated. The thorium series of parent Th-232 was tracked through the daughters Ac-228, Tl-208, and Pb-212. The activities of parent radionuclides were calculated from the activities of their daughter radionuclides according to the procedure followed by [9]. The activity of Th-232 for instance is given by:

\[
C(\text{Th, 63.9}) = \frac{\varepsilon(63.9) \times I(\text{Th, 63.9})}{\varepsilon(338.3) \times I(\text{Ac, 338.3})} \times C(\text{Ac, 338.3}) \quad \text{(2)}
\]

Where \( C(X, E_\gamma) \) is the activity arising from the \( \gamma \)-ray of energy \( E_\gamma \) (keV), emitted by the nuclide \(^X\). While \( I(X, E_\gamma) \) is the emission probability and \( \varepsilon(E_\gamma) \) is the detection efficiency for the \( \gamma \)-ray of \( E_\gamma \).

The concentration of the actinium series that starts with U-235 was very low, so it was excluded. The activity concentrations of the parent radionuclides, namely U-238 and Th-232 in addition to K-40 and Cs-137, constituted the set of radionuclides investigated in each measured sample.

The activity concentration of each plant sample was compared with that of the root soil of the plant. SPTF was calculated as the ratio of plant to soil activity concentrations, equation (1).

Results

Plant uptake of different materials may be affected by the environmental conditions of the planting region. Weather conditions at the sampling region are important in investigating the variations in the SPTF for different regions. The annual precipitation rates and average temperatures in the sampling regions were extracted from the Jordanian Meteorology Department [10].

The activity concentrations of the root soils of the studied plants and the activity concentrations of the plant samples for the selected radionuclides were measured. Table (1) below lists the activity concentrations of both the root soils and the plants for apple samples.
Table.1 The activity concentration of the root soils and the apple samples. For each sample region, the activity of the root soil (up) and the activity of the plant (down) are listed for each radionuclide.

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</tr>
<tr>
<td>Athroh-2 Ma'an</td>
<td>Q2</td>
<td></td>
<td>39.33 ± 7.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>48.76 ± 1.46</td>
</tr>
<tr>
<td>Diesa-1 Ma'an</td>
<td>Q5</td>
<td></td>
<td>119.60 ± 22.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>64.58 ± 17.83</td>
</tr>
<tr>
<td>Diesa-2 Ma'an</td>
<td>Q5</td>
<td></td>
<td>91.09 ± 15.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>55.48 ± 20.27</td>
</tr>
<tr>
<td>Quira Aqaba Q4</td>
<td></td>
<td></td>
<td>16.63 ± 2.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.13 ± 1.50</td>
</tr>
<tr>
<td>Shobak-1 Ma'an</td>
<td>Q2</td>
<td></td>
<td>24.65 ± 5.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.45 ± 5.61</td>
</tr>
<tr>
<td>Shobak-2 Ma'an</td>
<td>Q2</td>
<td></td>
<td>24.65 ± 6.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7.15 ± 6.61</td>
</tr>
<tr>
<td>Wadi Mosa Ma'an</td>
<td>Q2</td>
<td></td>
<td>33.25 ± 8.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30.26 ± 3.58</td>
</tr>
</tbody>
</table>

The main geological texture of each sampling region was considered in terms of a group joins the main types of soil in the region [12]. These groups are listed in table 2.

Table.2 Groups of soils contain the geological composition of the sampling regions.

<table>
<thead>
<tr>
<th>Code</th>
<th>Geological composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>Sandy limes and dolomites, marls, shales, varical, sandstone, white sandstone.</td>
</tr>
<tr>
<td>C2</td>
<td>Limestone, sandy limes, dolomites, nodular limestone, shales, and gypsum.</td>
</tr>
<tr>
<td>C3</td>
<td>Chalk, marls, bitumen, limestone, phosphorites, siscif limestone, cherts.</td>
</tr>
<tr>
<td>C+t1</td>
<td>Limestone, marls, shales, dolomites, cherts.</td>
</tr>
<tr>
<td>Q2</td>
<td>Flaviatile gravels, lacustrine limestones, sandy limestone, marls, gypsum.</td>
</tr>
<tr>
<td>Q4</td>
<td>Pelitic sediments in mud flats.</td>
</tr>
<tr>
<td>Q5</td>
<td>Terrestrial, laviatile and lacustrine unconsolidated sediments.</td>
</tr>
</tbody>
</table>
Samples from different farms in the same regions were coded with the name of the region. Variations in the soil activity concentrations are obvious from one farm to another. Diesa region contains relatively higher concentrations of U-238, Th-232 and K-40. This can be attributed to the different rock formation of the region, where the mountains of Wadi-Rum surround the apple farms there. Shobak and Wadi-Mosa regions have the least activity concentration of the selected radionuclides. The relatively high precipitation rates and the large height from sea level may point out to continuous washing of such radionuclides from the soil of the regions.

Figure 3 shows the STPF in apples for each of the selected radionuclides. The annual precipitation and the average temperature of each sampling region are plotted below for comparison. The maximum values of SPTF are that of K-40. Although the concentration of K-40 in the soil of Athroh is not the highest, apples in that region have the highest transfer factor which exceeds 2.5.

The SPTF values that exceed unity mean that the plant concentrates the radionuclide in its body. This may be one of the long-term methods to clean the environment from specific radionuclides by growing such plants that absorb and concentrate it in the plant’s body, where it can then be appropriately treated.

While Diesa and Wadi-Mosa apple samples have a lower SPTF of K-40, which is less than 2.0. U-238 records a similar behavior, but with SPTF fluctuating around 1.0. The apple farms, for which the samples were taken, irrigate the apple trees by dripping water in a 1m-diameter basin around the trunk. But the extension of the roots of the apple trees reflects an obvious effect of the rainwater on the elemental matrix of the root soil.

A general correlation between rainfall and SPTF is obvious through the well seen in K-40 at Diesa region. Where the low SPTF can be attributed to high contents of potassium (the denominator of the SPTF) added as fertilizers soils in the area. The U-238 shows a similar behavior both at high and low rainfall rates. Comparing with temperature, SPTF of U-238 may be affected with lower temperature. Since the mobility of U-238 in the moisture surrounding the root is increased with temperature [11].

Although the behavior of Cs-137 shows a little higher rate of leakage into apple than Th-232, both of them has a much lower SPTF of less than 0.3. The data presented for apples shows a negative correlation between soil K-40 content and Cs-137 in the apple group (figure.3c). This is an irony of trying to lower the content of potassium in the soil.
Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils

Fig. 3 (a) Soil to plant transfer factor of Apple samples (b) The corresponding averages of precipitation and temperature in the sampling regions, (c) Negative correlation of K-40 vs Cs-137

$\text{K-40 (Bq/kg)}$ $\text{Cs-137 (Bq/kg)}$

$y = -88.833x + 306.91$

$R^2 = 0.1543$
The sampling regions of chickpeas are mostly in the northern part of the kingdom. The soils of these regions are naturally fertile and the irrigation depends completely on rainfall. The major composition of the soils in these regions is dominated by calcium carbonate with high concentrations of iron oxides. Therefore the distributions of the four studied radionuclides are close to be homogeneous, as seen in table (3).

The highest activity concentration of U-238 is seen in Hoson-2 region, while the lowest is in Quseir-1. For K-40, the highest activity concentration is found in Yarqa south of the previous regions. While the lowest K-40 is found at Hoson-2. In general, there is some homogeneity in the distribution of each of the radionuclides under study in the sampling regions.

Table 3: The activity concentration of the root soils and the chickpea samples. Activity of the root soil (up) and activity of plant (down).

<table>
<thead>
<tr>
<th>Sampling region</th>
<th>Govt.</th>
<th>Geology</th>
<th>Activity (Bq/kg)</th>
<th>U-238</th>
<th>Th-232</th>
<th>K-40</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eidoon</td>
<td>Irbid</td>
<td>C2</td>
<td>36.11 ± 3.29</td>
<td>33.15 ± 4.12</td>
<td>269.73 ± 74.65</td>
<td>2.17 ± 0.21</td>
<td>0.64 ± 0.20</td>
</tr>
<tr>
<td>Hoson-1</td>
<td>Irbid</td>
<td>Q5</td>
<td>34.63 ± 3.15</td>
<td>34.99 ± 1.94</td>
<td>266.62 ± 44.79</td>
<td>2.26 ± 0.10</td>
<td>0.31 ± 0.10</td>
</tr>
<tr>
<td>Hoson-2</td>
<td>Irbid</td>
<td>Q5</td>
<td>115.33 ± 15.20</td>
<td>12.93 ± 1.36</td>
<td>128.91 ± 37.13</td>
<td>3.70 ± 0.32</td>
<td>1.15 ± 0.31</td>
</tr>
<tr>
<td>Majar-1</td>
<td>Jerash</td>
<td>C1</td>
<td>16.82 ± 2.72</td>
<td>29.62 ± 3.88</td>
<td>298.60 ± 85.00</td>
<td>3.24 ± 0.21</td>
<td>0.13 ± 0.21</td>
</tr>
<tr>
<td>Majar-2</td>
<td>Jerash</td>
<td>C1</td>
<td>13.88 ± 1.02</td>
<td>16.66 ± 1.91</td>
<td>228.36 ± 74.22</td>
<td>10.49 ± 0.89</td>
<td>0.61 ± 0.89</td>
</tr>
<tr>
<td>Majar-3</td>
<td>Jerash</td>
<td>C1</td>
<td>11.82 ± 1.03</td>
<td>14.34 ± 0.99</td>
<td>201.07 ± 64.75</td>
<td>2.43 ± 0.14</td>
<td>0.16 ± 0.14</td>
</tr>
<tr>
<td>Majar-4</td>
<td>Jerash</td>
<td>C1</td>
<td>16.82 ± 1.66</td>
<td>29.62 ± 3.09</td>
<td>298.60 ± 82.00</td>
<td>3.24 ± 0.26</td>
<td>1.37 ± 0.24</td>
</tr>
<tr>
<td>Quseir-1</td>
<td>Jerash</td>
<td>C1</td>
<td>11.50 ± 1.25</td>
<td>15.88 ± 1.63</td>
<td>165.39 ± 58.88</td>
<td>1.73 ± 0.13</td>
<td>0.16 ± 0.13</td>
</tr>
<tr>
<td>Quseir-2</td>
<td>Jerash</td>
<td>C1</td>
<td>11.93 ± 1.64</td>
<td>16.09 ± 3.21</td>
<td>172.12 ± 63.84</td>
<td>1.68 ± 0.16</td>
<td>0.73 ± 0.14</td>
</tr>
<tr>
<td>Yarqa</td>
<td>Balqa</td>
<td>C3</td>
<td>27.49 ± 7.04</td>
<td>28.40 ± 6.14</td>
<td>425.86 ± 135.26</td>
<td>10.88 ± 1.11</td>
<td>0.45 ± 1.11</td>
</tr>
<tr>
<td>Hoshan</td>
<td>Madaba</td>
<td>C3</td>
<td>22.49 ± 1.25</td>
<td>31.61 ± 3.76</td>
<td>258.53 ± 92.50</td>
<td>6.86 ± 0.37</td>
<td>0.47 ± 0.36</td>
</tr>
<tr>
<td>Moshaqar-1</td>
<td>Madaba</td>
<td>C2</td>
<td>21.35 ± 1.20</td>
<td>30.78 ± 3.72</td>
<td>226.71 ± 72.55</td>
<td>4.73 ± 0.39</td>
<td>0.56 ± 0.39</td>
</tr>
<tr>
<td>Moshaqar-2</td>
<td>Madaba</td>
<td>C2</td>
<td>17.41 ± 1.35</td>
<td>26.28 ± 2.50</td>
<td>238.00 ± 96.67</td>
<td>3.67 ± 0.23</td>
<td>0.52 ± 0.23</td>
</tr>
<tr>
<td>Areesh</td>
<td>Madaba</td>
<td>Q5</td>
<td>16.06 ± 1.25</td>
<td>25.92 ± 2.80</td>
<td>235.30 ± 75.02</td>
<td>3.59 ± 0.25</td>
<td>0.59 ± 0.25</td>
</tr>
<tr>
<td>Faisalia</td>
<td>Madaba</td>
<td>Q5</td>
<td>21.78 ± 2.07</td>
<td>25.92 ± 3.47</td>
<td>234.56 ± 68.51</td>
<td>3.15 ± 0.17</td>
<td>0.09 ± 0.17</td>
</tr>
<tr>
<td>Ma'in</td>
<td>Madaba</td>
<td>C3</td>
<td>21.57 ± 1.55</td>
<td>25.83 ± 3.28</td>
<td>263.06 ± 85.44</td>
<td>2.07 ± 0.22</td>
<td>0.14 ± 0.22</td>
</tr>
</tbody>
</table>
Figure 4 shows the SPTF of chickpeas for the selected radionuclides. With an average of 1.8, K-40 seems to be the most favorite radionuclide in the chickpeas. The fluctuations in the value of SPTF can be compared with that of rainfall shown under the graph. The higher transfer may correspond to lower rainfall rates, especially with the average temperatures of close values for all sampling regions.

**Fig. 4** (a) Soil to plant transfer factor of Chickpea samples (b) The corresponding averages of precipitation and temperature in the sampling regions.
Awadallah and Arafah

Uranium has a similar behavior to that of K-40 with an average around 0.8, and with the highest SPTF value in Hosban region. The geological group of this region is dominated by chalk, marls, and limestone. Although Yarqa and Main regions have similar geological groups, the transfer of U-238 is of much lower rate. The lower precipitation rates in the right part of the graph may have slightly increased the transfer of U-238 as of K-40 to chickpeas. While in the other regions, higher rainfall rates may have reduced such process.

Wheat sampling regions span a wider area compared to that of apples and chickpeas. The soil textures are much more diverse and the properties of the regions vary in temperature, rainfall, elevation, and geologic features. However, in most sampling regions, the abundance of radionuclides indicated by activity concentrations in table (4), are not widely different. Nevertheless, adjacent regions may have distinct concentrations, as seen in U-238 in Sarow regions.

Table.4 The activity concentration of the root soils and the wheat samples. Activity of the root soil (up), and activity of plant (down).

<table>
<thead>
<tr>
<th>Sampling region</th>
<th>Govt.</th>
<th>Geology</th>
<th>Activity (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>U-238</td>
</tr>
<tr>
<td>S. Irbid</td>
<td>Irbid</td>
<td>C2</td>
<td>27.91 ± 8.18</td>
</tr>
<tr>
<td>Hoson</td>
<td>Irbid</td>
<td>Q5</td>
<td>16.30 ± 2.12</td>
</tr>
<tr>
<td>Kufranjah Ajloun</td>
<td>Ajloun</td>
<td>C+t1</td>
<td>29.80 ± 9.05</td>
</tr>
<tr>
<td>Quseir</td>
<td>Jerash</td>
<td>C1</td>
<td>12.04 ± 3.97</td>
</tr>
<tr>
<td>Baq'a</td>
<td>Balqa</td>
<td>C2</td>
<td>31.02 ± 5.04</td>
</tr>
<tr>
<td>Sarow-1</td>
<td>Balqa</td>
<td>C1</td>
<td><strong>154.52 ± 32.00</strong></td>
</tr>
<tr>
<td>Sarow2</td>
<td>Balqa</td>
<td>C1</td>
<td>23.63 ± 5.41</td>
</tr>
<tr>
<td>Khalda</td>
<td>Amman</td>
<td>C2</td>
<td>27.24 ± 2.12</td>
</tr>
<tr>
<td>Ersal</td>
<td>Amman</td>
<td>C2</td>
<td>31.57 ± 5.91</td>
</tr>
<tr>
<td>Marj el - Hammam</td>
<td>Amman</td>
<td>C3</td>
<td>21.39 ± 4.97</td>
</tr>
<tr>
<td>Jubeil</td>
<td>Madaba</td>
<td>Q5</td>
<td>31.60 ± 6.16</td>
</tr>
<tr>
<td>Ma'in</td>
<td>Madaba</td>
<td>C3</td>
<td>24.73 ± 8.55</td>
</tr>
<tr>
<td>Ba'as</td>
<td>Madaba</td>
<td>C3</td>
<td>24.76 ± 6.70</td>
</tr>
<tr>
<td>U. Rasas</td>
<td>Madaba</td>
<td>C3</td>
<td>25.85 ± 4.89</td>
</tr>
<tr>
<td>Shebak</td>
<td>Ma'an</td>
<td>Q2</td>
<td>23.14 ± 7.40</td>
</tr>
</tbody>
</table>
The SPTF in wheat is shown in figure 5. A high similarity in behavior exists between U-238 and K-40, especially in the left part of the graph. However, for the regions of lower rainfall rates, the behavior becomes opposite. As in chickpeas, U-238 tends to transfer more to wheat in drier regions, while K-40 transfer to wheat is reduced in such regions. The transfer factor of U-238 into wheat shows similar values for Irbid, Jerash and Ma’an, although these three regions have different groups of soils, table(2).

Fig. 5 (a) Soil to plant transfer factor of wheat samples (b) The corresponding averages of precipitation and temperature in the sampling regions.
In comparison with apple and chickpea samples, the transfer of selected radionuclides to wheat is much lower. This indicates that the consumption of wheat is, by some means, safe.

The behavior of Th-232 and Cs-137 shows a high degree of coincidence within the experimental uncertainty. The SPTF of both does not exceed 0.1, which is a good indicator that wheat can be grown in regions with low contamination rates without much danger compared to apples for instance.

A comparison between the three plants; apples, chickpeas, and wheat, implies that wheat is the cleanest in radionuclides. While chickpeas concentrate a significant amount of K-40. However, apple is the plant that absorbs radionuclides in a slightly higher rate than the previous plants. Therefore the safety of planting apple trees in phosphate-rich regions or in regions contaminated with cesium needs to be more investigated.

The diversity of the values of the transfer factor is obvious, either for the plant absorption of different radionuclides or for the different plant absorption of a certain radionuclide. Hence, the high oscillatory behavior of SPTF dominates. This emphasizes that standard reference conditions are needed to clarify these behaviors for many plants. The main averages of SPTF values for each plant are shown in table (5).

Table 5. The average SPTF values of the studied plants.

<table>
<thead>
<tr>
<th>Plant</th>
<th>U-238</th>
<th>Th-232</th>
<th>K-40</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>0.781 ± 0.003</td>
<td>0.188 ± 0.007</td>
<td>2.174 ± 0.001</td>
<td>0.267 ± 0.049</td>
</tr>
<tr>
<td>Chickpeas</td>
<td>1.065 ± 0.007</td>
<td>0.091 ± 0.003</td>
<td>1.895 ± 0.001</td>
<td>0.157 ± 0.022</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.519 ± 0.004</td>
<td>0.056 ± 0.003</td>
<td>1.329 ± 0.001</td>
<td>0.082 ± 0.015</td>
</tr>
</tbody>
</table>

Fig.6 The SPTFs for Apple, chickpeas and wheat.
Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils

Comparison with other literature shows various SPTF values for different plants. Table 6 shows the transfer of some nuclides to selected plants. Most of the research in this direction is devoted for artificial radionuclides [13].

Table 6 Global values of SPTF for some plants.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Soil to Plant Transfer Factor</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil to Plant Transfer Factor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cs-137</td>
<td>U-238</td>
</tr>
<tr>
<td>Apple</td>
<td>8.3×10^{-3}</td>
<td>4.8×10^{-3}</td>
</tr>
<tr>
<td>Melon</td>
<td>4.8×10^{-3}</td>
<td>4.9×10^{-4}</td>
</tr>
<tr>
<td>Pandanus</td>
<td>3.2</td>
<td>4.9×10^{-4}</td>
</tr>
<tr>
<td>Copra nut</td>
<td>3.8</td>
<td>4.9×10^{-4}</td>
</tr>
<tr>
<td>Coconut</td>
<td>2.0</td>
<td>4.9×10^{-4}</td>
</tr>
<tr>
<td>Wheat</td>
<td>1.5×10^{-3}</td>
<td>4.0×10^{-3}</td>
</tr>
<tr>
<td>Chickpea</td>
<td>4.0×10^{-3}</td>
<td>4.0×10^{-3}</td>
</tr>
</tbody>
</table>

The dose rates accompanied with consuming contaminated plants can be estimated on the basis of the consumption rate of such plants. In the UK, an average consumer can receive an estimated dose of 1.5 µSv/Yr from Pb-210 and Po-210 in fruits, which can be compared to an average dose of 68µSv/Yr in all foods. If the UK measurements are assumed to be generally representative of Pb-210 and Po-210 in other fruits grown in other countries, the dose of these radionuclides would be near 50 µSv/Yr for high fruit consumers [15]. Meanwhile, the international standards for the public dose limits due to licensed activities by the American Nuclear Regulatory Commission (NRC) rounds to 1mSv/Yr [16].

Conclusions:

The soil to plant transfer factor of the three studied plants revealed a wide variation for the studied radionuclides. The transfer of K-40 to apples showed the highest factor of average 2.2. While it was the lowest in wheat with average of about 0.9. For U-238, SPTF has an obvious correlation with the rainfall rate in the studied regions. It has a higher transfer in the drier regions for the three studied plants. The transfer of Cs-137 and Th-232 is much lower than the previous radionuclides and is the highest in apples with SPTF of Cs-137 has an average of 0.25. Wheat is a relatively cleaner crop in terms of the studied radionuclides. It can be planted in different regions, including soil contaminated regions with relatively lower level of risk.
انتشار النويدات الطبيعية والصناعية إلى نباتات مختارة في التربة الأردنية

محمد إبراهيم عوض الله و ضياء الدين عرفة

ملخص

يجسد معامل انتقال النويدات من التربة للنبات عددا من العمليات الكيميائية والفيزيائية والحيوية والمائية والتشريحيه. وقد تم دراسة هذا المعامل لنويدات طبيعية وصناعية مختارة، عبر ثلاث نباتات في التربة الأردنية، هي التفاح، الحمص والقمش. وقد تم جمع عينات من النباتات مع تربة غذروها من مناطق مختلفة في المملكة، حيث تم قياس تركيز النشاطية لكل من البرونيوم-238، الكوربيوم-232، البوتاسيوم-40، والسيزيوم-137. في النباتات والترية بواسطة طيفية أشعة جاما. وذلك باستخدام كاشفي جراميوم عالي القوة (HPGe). وقد تم دراسة معدلات درجات الحرارة والهطول السنوي في المناطق المختارة مع معاملات الانتقال. فمعامل انتقال البوتاسيوم-40 للفلاح كان الأكبر (2.2)، أما القمح فكان الأقل (0.9). فيما كان معامل انتقال البرونيوم-238 لجميع النباتات المدروسة حوالي نصف ما كان للبوتاسيوم-40. وقد تأثر انتقال النباتات بمعدلات الأطوار في مناطق العينات. وكان القمح هو النبات الأدنى من حيث انتقال النويدات. أما السيزيوم-137 فقد كان معامل انتقاله أقل ما يمكن للقمح (0.1) وأكبر ما يمكن للفلاح (2.5).

5. References:


Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils


223
Radon Monitoring at Khartoum Using the Charcoal Technique

Osman Mustafa Mukhtar* and Abd Elmoniem Ahmed Elzain**

Received on Sept. 28, 2004 Accepted for publication on June 29, 2005

Abstract

The Radon concentration has been measured by charcoal canisters in selected dwellings of Khartoum town. Radon monitoring were studied in a number of 125 dwellings, which divided into two types: 44 measurements in mud houses and 81 measurements in red brick houses during winter season. Results showed that, the concentrations vary from 10 to 110 Bq/m$^3$, with arithmetic mean of 46.1Bq/m$^3$ and standard deviation of 2.48Bq/m$^3$ in red brick houses. In mud houses the concentrations ranged between 13 and 87 Bq/m$^3$, with an average 41Bq/m$^3$ and standard deviation of 3.1Bq/m$^3$. The overall radon concentration in both types was found to be with an arithmetic mean value of 44.3Bq/m$^3$ and standard deviation of 1.9Bq/m$^3$, and led to the conclusion that, the radon concentration in Khartoum town relatively low, not to be shared in serious environmental radiation problems. The Average Annual Effective Equivalent Dose (AAEED) at Khartoum town from the study was found to be 1.2mSv. The results of radon monitoring by charcoal canisters were compared with the results of SSNTDs, which agree within an error of 25%. At this work the activity in different charcoal canisters was measured by gamma spectrometry and the intensity of the 351 KeV line from $^{214}$Pb was determined. A graph of line intensity against concentrations was plotted, and by curve fitting the properties of the absorption function was found. The emanation power were also determined and found to be 0.11.

Keywords: Radon monitoring; charcoal canisters; absorption function; emanation power.

Introduction

Measurements of radon concentration in dwellings are of importance, because the radiational dose to the human populations due to inhalation of radon and its daughters contribute by 50% of the total dose from the natural radiatiional sources (UNSCEAR, 1988)[1]. In investigating radon levels in dwellings, many studies used active and passive dosimeters of different types were carried [2-5]. Radon is identified by its alpha emission, or gamma emission. The charcoal technique is one of the active methods to determined radon concentration for short-term measurements. Radon is adsorbed by charcoal [6, 7]. The charcoal is measured by gamma spectrometry. As for passive techniques, they are mainly SSNTDs for environmental or long-term measurements. The
SSNTDs is chemically etched and the tracks per unit area are calculated using optical microscope, then the radon concentration is determined. The charcoal technique is cheap, quick, and accurate.

The aim of this work was to study the charcoal technique and to use it to study the monitoring of radon in selected dwellings in Khartoum City. The results of radon concentration by charcoal technique was compared with the results of a survey in the same area using SSNTDs. The results was found to be agree with an error of 25%.

The Charcoal Technique

Properties Of Charcoal:

Charcoal absorbs noble gases actively from environment [6]. Radon is absorbed with gases from the atmosphere. In the charcoal radon decays into its daughters $^{214}$Pb and $^{214}$Bi. The daughters emit very intense gamma rays with energies: 351 KeV and 609 KeV respectively. While the coal in the canister is exposed, radon is absorbed and desorbed at the same time. During the exposure period the charcoal become saturated and the average absorption of the whole period is obtained [8]. The absorption time interval can be extended by covering the canister by mesh. The mesh extends the integration period by reducing the radon quantity entering into the canister. Increasing the quantity of coal will increase the radon quantity absorbed, but since the increase is small, it reduces the amount of radon per unit mass of coal, the efficiency drops, while the detector becomes bulky and costly. The diameter of the canister should be nearly equal in size to the gamma ray detector’s crystal.

Preparation, Distribution and Collection of The Charcoal Canisters:

The charcoal used is the normal coal used at Khartoum for cooking (Hashab Trees Wood- Araccia Sayal). The charcoal was ground manually into small particles of $2\text{mm} \times 2\text{mm}$. Then it was annealed for three hours at $120^\circ$ Celsius for activation. Then the coal was put in plastic containers and sealed. Before use its background reading was measured in gamma ray spectrometer to ensure the absence of any background contamination. The charcoal detectors were then distributed in different houses for radon monitoring. The detectors were then opened and exposed for 4 days. This is the time required for the detectors to reach maximum radon concentration. The detectors were then collected and measured for 4000 seconds by gamma spectrometer.

Radon Adsorption by Coal:

When the Uranium standard rock powder, which is used as a radon source, is put in the calibration chamber and closed, the $^{226}$Ra is decaying by the following:

$$N = N_0 \exp(-\lambda t) \quad \text{..........(1)}$$

Where: $N_0$ is the number of $^{226}$Ra nuclei at time $t = 0$ ; $\lambda$ is the decay constant of $^{226}$Ra. Radon growth is described by the following equation (Production – decay):

226
Radon Monitoring at Khartoum Using the Charcoal Technique

\begin{align*}
\frac{dN_2}{dt} &= \lambda_1 N_1 - \lambda_2 N_2 \\
&= \lambda N \\
\end{align*}

Where: \(N_2\) is the number of \(^{222}\text{Rn}\) atoms in the chamber; \(N_1\) is the number of \(^{226}\text{Ra}\) atoms in the rock sample; \(\frac{dN_2}{dt}\) is the derivative of \(N_2\) with respect to time; \(\lambda_1\) and \(\lambda_2\) are the decay constants of \(^{226}\text{Ra}\) and \(^{222}\text{Rn}\) atoms respectively. Taking into consideration that \(\lambda_1 = 0.0000012\ \text{day}^{-1}\) and \(\lambda_2 = 0.18\ \text{day}^{-1}\). The activity \(A\) is equal the number of nuclei \(N\) multiplied by the decay constant \(\lambda\) :

\[ A = \lambda N \]

The activity released from the source \(A_{\text{Rs}}\) is equal to the activity produced in the source \(A\), multiplied by the emanation power \(F\):

\[ A_{\text{Rs}} = AF \]

The solution of equation (1) (after putting into consideration that \(\lambda_2 \approx \lambda_1\)) is:

\[ A_1 = A_0 F (1 - \exp(-\lambda_2 t)) \]

Where: \(A_1\) is the \(^{222}\text{Rn}\) activity in Bq/kg released from the source; \(A_0\) is the \(^{226}\text{Ra}\) activity in the source; \(F\) is the emanation power, which is the fraction of radon emanated from the source (\(0 < F < 1\)); \(t\) is the exposure time.

This equation shows that the activity will grow exponentially in the chamber to reach a saturation value of \(A_0 F\), which is the asymptote of the above equation. It is attained in a period of 15 days with an accuracy of 6%. Charcoal put in the calibration chamber will absorb radon actively. The quantity of radon absorbed by charcoal depends on the activity of the standard source put in the chamber, the time of exposure, the emanation power of the source, which in turn depends on the nature of the source material and the thickness of the layer of the source material in the tray. It depends also on prevailing temperature and pressure.

The absorbed radon gas in a canister can be measured by finding the gamma line intensity of \(^{214}\text{Pb}\) (or/and \(^{214}\text{Bi}\)). The absorption (assuming that temperature and pressure are constant) can be described by a function of two variables \(R(C,t)\): these are the concentration of radon in the chamber \(C\) and the canister exposure time \(t\). \(R(C,t)\) can be expanded by Taylor’s series as follows :

\[ R(C,t) = R(0,0) + \left( \frac{\delta R}{\delta t} \right) t + \left( \frac{\delta R}{\delta C} \right) C + \frac{1}{2!} \left( \frac{\delta^2 R}{\delta t^2} \right) t^2 \]

\[ + 2 \left( \frac{\delta^2 R}{\delta t \delta C} \right) tC + \frac{1}{2!} \left( \frac{\delta^2 R}{\delta C^2} \right) C^2 + \cdots + K \]

\[ \cdots (6) \]
Where \( \frac{\delta R}{\delta t}, \frac{\delta R}{\delta C} \) and \( K \) are the partial derivative of \( R \) with respect to \( t \) and \( C \), and \( K \) is the residue of the series. At the initial time of exposure or at no concentration \( t=0 \) or \( C=0 \) or \( t=C=0 \) then: \( R(C,0) = R(0,t) = R(0,0) = 0 \). The coefficients in front of \( C \) and \( t \) was found in the above equation experimentally [10]. To find the coefficients in front of \( C \) and \( t \) in the above equation the following experiment was conducted: different masses of the uranium ore powder (weighting 25, 50, 100, 197, 238 grams) were put in identical canisters, and charcoal samples weighting 75 grams were put in a canisters and both the charcoal canister source and container were put in a large tin. The exposure time for charcoal canister in the presence of the uranium ore powder was varied every time. The charcoal canisters were collected after one day exposure time, then the same experiment was repeated for the following exposure times: 2, 3, 4, 5, 6, 7, 8, 9, and 10 days. The activity of the different charcoal canisters was measured after each of the above exposure time and the intensity of the 351 KeV line from \(^{214}\text{Pb}\) was determined every time (Figure 1 and Figure 2). Atypical radon absorption carve was plotted figure (3).

![Graph](image_url)

**Figure (1)** Line Intensity of \(^{214}\text{Pb}\) Vs source mass for radon absorption function determination.
Figure (2) Line Intensity of $^{214}$Pb Vs exposure time for radon absorption function determination.

Figure (3) Atypical radon absorption curve.

By curve fitting the absorption function $R(C, \tau)$ was found to have the following properties (the absorption curve is shown in Figure (3)):

1- For a fixed exposure time $\tau > 4$ days. It depends linearly on radon concentration $C$:

$$R(C, \tau) = kC \quad ....(7)$$

Where $k$ is a constant which can be determined empirically.
Mukhtar and Elzain

2- For a fixed concentration $C'$ it depends exponentially on the exposure time $t$:

$$R(C', t) = kC'(1 - \exp(-\alpha t)) \quad \ldots \ldots \quad (8)$$

Where $\alpha$ is a constant, which has such property: $\alpha \gg 1, \ \exp(-\alpha t) \ll 1$ for $t \geq 4$ days. Thus:

$$R(C, t) = kC(1 - \exp(-\alpha t)) \quad \ldots \ldots \quad (9)$$

For a given radon concentration $C'$ and an exposure time of $t > 4$ days:

$$R = kC' = \frac{kmA_0F}{V} \quad \ldots \ldots \quad (10)$$

Where: $m$ is the mass of uranium ore powder source put in the chamber; $A_0$ is the radon activity per unit mass produced in the source; $F$ is the emanation power for radon from the source; $V$ is the volume of the chamber.

**Calibration:**

A glove box of 142 liters volume was used for calibration. Samples were manipulated in and out through the gloves so as not to disturb the secular equilibrium in the chamber. The uranium source was put in a tray and left for 15 days to ensure the secular equilibrium of $^{222}$Rn and $^{226}$Ra. Charcoal calibration standard was put and after 4 days was collected, sealed, and measured. Its line intensity ($R_0$) of 351 KeV is directly proportional to the concentration of radon in the chamber (let $t_i$ to be $C_0$), within a fixed geometry and acquisition time. The samples distributed in houses were collected and measured at that fixed geometry (let its reading on that fixed geometry be $R$). The concentration of radon $C$, is found by the following equation:

$$C = \frac{C_0R}{R_0} \quad \ldots \ldots \quad (11)$$

(Note that $k = \frac{R_0}{C_0}$). Ideally a curve of $R$ vs $C$ is plotted and from the slope the concentration is found, thus subtracting any background present. To find concentration emanation power $F$ must be determined.

**The Emanation Power:**

To determine the emanation power a uranium ore powder source was sealed for 15 days to have a secular equilibrium between $^{222}$Rn, $^{226}$Ra and its daughters. The activity concentration $C_0$ of $^{222}$Rn, $^{226}$Ra and its daughters were measured in the sealed source by gamma spectrometry. Another source, which is left open in the chamber, was measured. The concentration $C_1$ of $^{222}$Rn daughters was determined. The difference in the concentration of the two samples is due to the radon gas that escaped from the source into the chamber. The emanation power $F$: 
Radon Monitoring at Khartoum Using the Charcoal Technique

\[ F = \frac{C_0 - C_1}{C_0} \] ...........(12)

Results And Discussion

The radon survey was carried at Khartoum city the capital of Sudan using the charcoal canisters. The number of houses monitored were 125: 81 red brick houses and 44 mud houses. The measurements of radon concentration were carried in winter season in January. A summary of results obtained of radon concentration in Khartoum town dwellings is given in table (2) and figures (4), (5), (6).

Table (2) The type of houses, number of measurement (N), radon concentration (C), maximum concentration, minimum concentration, and standard divination (s.d), of 222Rn monitoring results in dwellings at Khartoum City using charcoal Canisters.

<table>
<thead>
<tr>
<th>Type of house</th>
<th>N</th>
<th>C Bq/m³</th>
<th>Max. C Bq/m³</th>
<th>Min. C Bq/m³</th>
<th>s.d. Bq/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red brick</td>
<td>81</td>
<td>46.1</td>
<td>110</td>
<td>10</td>
<td>2.48</td>
</tr>
<tr>
<td>Mud</td>
<td>44</td>
<td>41</td>
<td>87</td>
<td>13</td>
<td>3.1</td>
</tr>
<tr>
<td>All types</td>
<td>125</td>
<td>44.3</td>
<td>110</td>
<td>10</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Figure (4) Frequency of radon concentration in mud houses in Khartoum City.
Concentration Bq/m$^3$

**Figure (5)** Frequency of radon concentration in red brick houses in Khartoum City.

Concentration Bq/m$^3$

**Figure (6)** Frequency of radon concentration in mud + red brick houses in Khartoum City.

Concentration Bq/m$^3$

It can be seen from table (2) and figure (5) that the radon concentration varies from 10 Bq/m$^3$ to 110 Bq/m$^3$, with an arithmetic mean of 46.1 Bq/m$^3$ and standard deviation of 2.48 Bq/m$^3$ in red brick monitored houses. In mud houses from table (2) and figure (4) the concentration ranges from 13 Bq/m$^3$ to 87 Bq/m$^3$, with an arithmetic mean of 41 Bq/m$^3$, and standard deviation of 301 Bq/m$^3$. The overall radon concentration in both red brick and mud houses as we can see from table (2) and figure (6) varies from 10 Bq/m$^3$
Radon Monitoring at Khartoum Using the Charcoal Technique

to 110 Bq/m³, with an arithmetic mean of 44.3 Bq/m³ and standard deviation of 1.99 Bq/m³. The relatively higher radon concentration, which occurs in the study, 110 Bq/m³, could be due to that the residents were an old couple who close the doors and windows to keep the house warm, so the house was poorly ventilated. The room opens into a closed hall in which the door was kept closed all the time, and through this hall people enter to the room. The mud houses seem to have a relatively lower radon concentrations, this because the ventilation in them is higher (these mud houses are of the cheapest type of houses in Sudan, with openings just below the roof for ventilation, which are designed to be open all the time). The Average Annual Effective Equivalent Dose (AAEED) at Khartoum city from the study (using charcoal technique) due to radon exposure based on UNSCAER (UNSCAER, 1991)[9] lung model with a conversion factor of 50 µSv/a per Bq/m³, assuming that people spend 12 hours /day indoors, is about 1.2 mSv. The results of the charcoal technique were compared with the results of a survey carried in the same area using the Solid State Nuclear Track Detectors SSNTDs. As for SSNTDs, they were provided by Landuear, U.S.A, through the International Atomic Energy Agency (IAEA). The SSNTDs were put in special holders and exposed for seven days and then collected, sealed, and sent for processing. The radon survey was carried at Khartoum City using the SSNTDs in 82 houses in the same area but at different times of the year in October. It can be seen from table (3) that the radon concentration measured by SSNTDs varies from 7 Bq/m³ to 100 Bq/m³, with an arithmetic mean of 33 Bq/m³ and standard deviation of 3 Bq/m³.

<table>
<thead>
<tr>
<th>Detector type</th>
<th>N</th>
<th>C Bq/m³</th>
<th>C Max Bq/m³</th>
<th>C Min Bq/m³</th>
<th>s.d. Bq/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charcoal Canister</td>
<td>125</td>
<td>44.3</td>
<td>110</td>
<td>10</td>
<td>1.9</td>
</tr>
<tr>
<td>SSNTDs</td>
<td>82</td>
<td>33</td>
<td>100</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>

The results agree well within an error of 25%, the lower values of concentrations with SSNTDs is due to that at October in Khartoum the dwellings are usually kept open to ensure ventilation and get rid form heat.

The emanation power was estimated using uranium ore powder samples of concentration 3.25 K Bq/m³ as a calibration source. The total activity of radon at secular equilibrium was 162.5 Bq in calibration chamber, which has a volume of 142 liters. The emanated radon is 125 Bq/m³. The emanation power was found to be 0.11.

**Conclusion**

The arithmetic mean value of radon concentration in Khartoum City dwellings, is 44.3 Bq/m³ with standard deviation of 1.9 Bq/m³ using the charcoal Canisters, and 33 Bq/m³ with standard deviation of 3 Bq/m³ using the SSNTDs. The comparison of the results of radon monitoring by charcoal canisters with the results of SSNTDs seems to be agreeing within an error of 25%. The difference between the two results is due to the properties of the absorption function and the seasonal variation of radon concentration in the city. The Average Annual Effective Equivalent Dose (AAEED) at Khartoum town
from the study was found to be 1.2mSv. The activity in different charcoal canisters was measured and the intensity of the 351 KeV line from $^{214}\text{Pb}$ was determined. A graph of line intensity against concentrations was plotted, and by curve fitting the properties of the absorption function was found. The emanation power was also determined and found to be 0.11.

**The Charcoal Technique**

The charcoal used is the normal coal used at Khartoum for cooking (Hashab Trees Wood- Araccia Sayal). The charcoal was ground manually into small particles of $2\times 2$mm. Then it was annealed for three hours at 1200 Celcius for activation. Then the coal was put in plastic containers and sealed. Before use its background reading was measured in gamma ray spectrometer to ensure the absence of any background contamination. The charcoal detectors were then distributed in different houses for radon monitoring. The detectors were then opened and exposed for 4 days. This is the time required for the detectors to reach maximum radon concentration. The detectors were then collected and measured for 4000 seconds by gamma spectrometer.
Radon Monitoring at Khartoum Using the Charcoal Technique

References


Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles

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Received on Dec. 28, 2005 Accepted for publication on April 17, 2006

Abstract

The longitudinal space charge impedance has been investigated in a smooth perfectly conducting cylindrical beam pipe in the presence of a uniformly distributed background of charged particles. Expressions for the longitudinal space charge impedance, at any point \( r \) from the beam axis and at the beam surface \( r = a \), have been obtained. Presence of the background particles introduces a new coupling between the beam and its environment and has been found to increase the longitudinal space charge impedance for low and moderate mode frequencies \( \omega \), while short wavelength modes are unaffected by the presence of the background. Variations of the impedance with the background plasma frequency show a maximum increase of two orders of magnitudes compared to the impedance value in the absence of the background. Numerical examples of the modifications on the longitudinal space charge impedance are shown graphically for an arbitrary choice of two representative beam energies of \( \gamma = 1.1 \) and \( \gamma = 2 \), and for a ring of circumference \( L = 216 \) m, beam pipe radius \( b = 0.1 \) m and beam radius \( a = 0.5 \) b.

Keywords: Beam Dynamics, Longitudinal Space Charge, Impedance, Plasma Frequency

Introduction

Behavior of a single beam particle interacting with electromagnetic fields induced inside the beam-pipe and the collective interaction of the whole beam with its surrounding is usually described in terms of coupling impedances [1].

Electrons accumulation in the vacuum chamber in which a positively charged bunched particle beam propagates can deteriorate the vacuum [2, 3] causing interference on the electrodes of beam pickup monitors [4] and can cause beam instabilities [5-14].

Photoemission and secondary emission are known to give rise to a quasistationary electron cloud inside the beam pipe through a beam-induced multipacting process. Rumolo, Ruggiero and Zimmermann [4] investigated the electron-cloud build up and related effects via computer simulation. It has been assumed that macro-particles

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representing photoelectrons are emitted synchronously with the passing proton or positron bunch and are subsequently accelerated in the field of the beam. As they hit the beam pipe, new macro-particles are generated, whose charges are determined by the energy of the incoming particles and by the secondary emission yield of the beam pipe. A quasistationary state of the electron cloud due to space charge was reached and then used as an input parameter for analyzing the electron-cloud driven single-bunch instability [4].

G. Rumolo et. al. [15] also considered the interaction between a low-density electron cloud and a circulating charged particle beam. It is found that particle beam's space charge attracts the cloud, enhancing the cloud density near the beam axis. It has also been shown that the charge enhancement and the image charges associated with the cloud charge and the conducting wall of the accelerator may have important consequences for the dynamics of the beam propagation. Tune shift due to the electron cloud has been obtained analytically and then compared with a numerical model (QUICKPIC) via sample numerical results.

In positron or proton storage rings with many closely spaced bunches, an electron cloud can build up in the vacuum chamber due to photoemission or secondary emission. Ohmi and Zimmermann [16] discussed the possibility of a single-bunch two-stream instability driven by this electron cloud. Depending on the strength of the beam-electron interaction, the chromaticity and the synchrotron oscillation frequency, it is found that this instability either resembles a linac beam breakup or a head-tail instability. Fischer et. al. [17] measured electron cloud densities by observing the coherent tune shift along the bunch train with different bunch spacings and intensities. From the measured coherent tune shifts, electron cloud densities were obtained and compared with densities obtained in electron cloud simulations.

The coupling impedance of straight, uniform beams in a concentric, cylindrical vacuum chamber, whose walls consist of many layers of different materials was treated by Zotter [18]. Zotter and Kheifets [19] derived an expression for the total impedance at the beam surface $r = a$. S. Kurennoy [20] and J. Wang [21] reviewed the definition of the longitudinal space charge impedance and the corresponding geometry factors for smooth chambers of perfectly conducting walls in the long wavelength approximation. Bisognano [22] has investigated solitary waves in non-relativistic particle beams, where an expression for the ratio of the Fourier transformed potential to density was derived. This ratio is the geometry factor of the longitudinal coupling impedance of a pipe of infinite wall conductivity.

Al-khateeb et. al. [23] calculated both the space charge and the resistive wall impedances for all wavelengths and arbitrary $\beta$. Expressions for the corresponding generalized and approximate geometry factors have been derived. For non-relativistic particle beams with a finite size, space charge and the resistive wall impedances are found to be of importance for the longitudinal beam dynamics and for the longitudinal beam instability analysis. Experimental determination of the geometry factor for longitudinal perturbations in a space charge dominated beam is found in J. Wang et. al.'
Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles

[24]. It was found that the geometry factor obeys the relation \( g = 2 \ln(b/a) \), where \( a \) and \( b \) are the beam and pipe radii respectively.

The presence of low frequency residual gas in the beam pipe introduces modifications on the space charge impedance (residual contribution). Such a modification will be examined analytically in this paper due to the lack of the quantitative investigation of the contribution of the residual particles to the coupling impedance. The paper is organized as follows: In Sec. II derivation of the electromagnetic fields in a perfectly conducting beam-pipe in the presence of a background of uniformly distributed charged particles will be presented. In Sec. III, expressions for the space charge impedance including the residual part and the corresponding generalized geometry factor will be derived and analyzed. Finally, discussions and conclusions will be presented in Sec IV.

Electromagnetic Fields in a Cylindrical Pipe (emf)

Consider the motion of a beam as rotationally symmetric lamina of particles of radius \( a \) and total charge \( Q \) in a smooth cylindrical pipe of radius \( b \). The beam moves with a constant longitudinal velocity \( \beta = \frac{v}{c} \) along the \( z \) axis through a background of \( n_g \) particles per unit volume, each of mass \( m_0 \), and of charge \( q_0 \). The beam current and charge densities \( j_b(r,t) \) and \( \rho_b(r,t) \) respectively, are related as follows,

\[
j_b(r,t) = \rho_b \beta c \hat{z} = \frac{Q}{\pi a^2} \delta(z - \beta c t) \hat{z},
\]

\[
\frac{\partial \rho_b(r,t)}{\partial t} + \nabla \cdot j_b(r,t) = 0
\]

We assume that the background particles are noninteracting and uniformly distributed within the beam pipe such that \( n_g = n_0 \). The bulk motion of the background particles in the electromagnetic fields \( (E, B) \) excited by the beam in the pipe give rise to a net current which, to first order, is approximated by \( j_g = q_0 n_0 v_g \). The velocity \( v_g \) is governed by the following equation,

\[
\frac{d v_g(r,t)}{dt} = \frac{q_0}{m_0} \left( E(r,t) + v_g(r,t) \times B(r,t) \right)
\]

Let the total current be \( J = j_b + j_g \), the total charge density be \( \rho = \rho_b + q_0 n_0 \), and upon using Faraday's and Ampere's laws, the wave equations satisfied by the magnetic \( B \) and electric \( E \) fields in nonconducting linear media with \( \varepsilon = \varepsilon_0 \) and \( \mu = \mu_0 \) (\( \varepsilon_0 \) and \( \mu_0 \) are, respectively, the permittivity and permeability of free space) are,
Due to the rotational symmetry, the only non-vanishing field components excited by the beam are $E_z(r,\omega)$, $E_r(r,\omega)$ and $B_\theta(r,z)$ [19, 23]. According to eq. (3), longitudinal and radial velocity components of the background particles are coupled via the magnetic field $B(r,t)$. By ignoring the cyclotron motion of the background particles so that they are taken as unmagnetized particles, only electric forces in the longitudinal and radial directions will act on them. This is justified as long as the background response to the beam wake fields is nonrelativistic. Accordingly, the in time Fourier-transformed current and charge densities for $\omega = k_r v$ are,

$$J(r,z,\omega) = \frac{Q}{\pi a^2} e^{ik_z z} z + i \frac{q_0^2 n_0}{m_0} \hat{e} E(r,z,\omega)$$

$$\rho(r,z,\omega) = \frac{Q}{\pi a^2} e^{ik_z z} + 2\pi q_0 n_0 \delta(\omega)$$

Since the time transformed $\rho_b(r,z,\omega)$ and $J_b(r,z,\omega)$ vary with $z$ as $e^{ik_z z}$, we assume that the fields $E$ and $B$ have the same variation with $z$, namely, $E(r,z,\omega) = E(r,\omega)e^{ik_z z}$ and $B(r,z,\omega) = B(r,\omega)e^{ik_z z}$. Upon Fourier transforming equations 4 and 5 in time, we get,

$$\begin{align*}
\left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial}{\partial r} \right) - k_z^2 \right] B(r,\omega) + \frac{\omega^2}{c^2} B(r,\omega) &= \frac{\omega^2}{c^2} B(r,\omega), \\
\left[ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial}{\partial r} \right) - k_z^2 \right] E(r,\omega) + \frac{\omega^2}{c^2} E(r,\omega) &= \left( -i \mu_0 \omega \beta c + \frac{i k_z}{\varepsilon_0} \right) \frac{Q}{\pi a^2} \hat{e} + \frac{\omega^2}{c^2} E(r,\omega)
\end{align*}$$

The nonvanishing field components are governed by the following scalar equations,
Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles

\[
\begin{bmatrix}
\frac{d^2}{dr^2} + \frac{1}{r} \frac{d}{dr} - \frac{k^2}{\gamma^2} \\
\frac{d^2}{dr^2} + \frac{1}{r} \frac{d}{dr} - \frac{k^2}{\gamma^2} \\
\frac{d^2}{dr^2} + \frac{1}{r} \frac{d}{dr} - \frac{k^2}{\gamma^2}
\end{bmatrix}
\begin{bmatrix}
E_z(r, \omega) \\
E_t(r, \omega) \\
B_\theta(r, \omega)
\end{bmatrix} =
\begin{bmatrix}
i \frac{Q k_z}{\pi a^2 \beta c} + \frac{\omega_p^2}{c^2} E_z(r, \omega) \\
\frac{\omega_p^2}{c^2} E_t(r, \omega) \\
\frac{\omega_p^2}{c^2} B_\theta(r, \omega)
\end{bmatrix}
\]

where the plasma frequency \( \omega_p \) of the background and the relativistic factor \( \gamma \) are defined as follows,

\[
\omega_p^2 = \frac{n_0 q_0^2}{\epsilon_0 m_0}, \quad \gamma^{-2} = 1 - \beta^2
\]

Introducing the parameter \( \Gamma_0 \) such that

\[
\Gamma_0^2 = \frac{k_z^2 - \omega_p^2}{\gamma^2} = \frac{\omega^2 + \omega_p^2 \beta^2 \gamma^2}{\gamma^2 \beta^2 c^2}
\]

The general solution for the \( z \) component of the electric field is

\[
E_z(r, \omega) =
\begin{cases}
A_1 I_0(\Gamma_0 r) + A_2 K_0(\Gamma_0 r) & r > a \\
A_3 I_0(\Gamma_0 r) - i \frac{Q}{\pi a^2 \epsilon_0 k_z \beta c} & r \leq a
\end{cases}
\]

where \( I_0 \) and \( K_0 \) are the modified Bessel functions of first and second kind, respectively, \( A_1, A_2 \) and \( A_3 \) are integration constants to be determined by the boundary conditions. The relations between the longitudinal electric field component \( E_z(r, z, \omega) \) and the transverse components \( E_t(r, z, \omega) \) and \( B_\theta(r, z, \omega) \), namely,

\[
\frac{\partial E_z(r, z, \omega)}{\partial r} = \frac{k_z c}{\beta \gamma^2} B_\theta(r, z, \omega), \quad E_t(r, z, \omega) = \frac{c}{\beta} B_\theta(r, z, \omega)
\]

Upon applying the boundary conditions on \( E_z \) and \( B_\theta \) at the beam surface \( r = a \) and at the pipe inner surface \( r = b \) for a perfectly conducting pipe wall, we get,
Longitudinal Coupling Impedance

We shall now calculate the longitudinal impedance as a volume integral over the transverse beam charge distribution. The longitudinal impedance of the beam is defined as follows [19, 23],

\[
Z_0(r, \omega, \omega_p) = \frac{1}{Q^2} \int_{V_{\text{beam}}} d^3x' E(r', z, \omega) \cdot J^*(r', z, \omega)
\]

\[
= \frac{2\pi L}{Q \pi a^2} \int_0^r E_z(r', \omega) r'r'dr' - i \frac{\omega_p^2 \varepsilon_0}{\omega} \frac{2\pi L}{Q^2} \int_0^r E_z(r', \omega) E_z^*(r', \omega)r'dr'
\]

(14)

Using \(J(r,z,\omega)\) in eq. (6) and the electric field in eq. (13), the impedance at any point \(r\) from the beam axis becomes,

\[
Z_0(r, \omega, \omega_p) = -i \frac{Lk_z}{\pi \Gamma_0 a^2 \varepsilon_0 \gamma^2} \beta e \left[ \frac{r^2}{\alpha^2} - \frac{2r}{a} \left( K_1(\Gamma_0 a) + \frac{K_0(\Gamma_0 b) K_1(\Gamma_0 a)}{K_0(\Gamma_0 b)} K_1(\Gamma_0 r) \right) \right] -
\]

\[
\frac{\omega_p^2}{\omega} \frac{Lk_z^2}{\pi \varepsilon_0 \gamma^2 c^2 \Gamma_0 a^2} \left[ \frac{r^2}{\alpha^2} \left( \frac{K_1(\Gamma_0 a) K_1(\Gamma_0 b)}{K_0(\Gamma_0 b)} \right) \frac{4\Gamma_0 r K_1(\Gamma_0 r)}{\Gamma_0 a^2} +
\]

\[
\frac{r^2}{\alpha^2} \left( K_1(\Gamma_0 a) + \frac{K_0(\Gamma_0 b) K_1(\Gamma_0 a)}{K_0(\Gamma_0 b)} \right) \left( K_2^2(\Gamma_0 r) + K_2^2(\Gamma_0 r) \right) \right]
\]

(15)

In the presence of a uniform background, equation (15) gives the beam-pipe coupling impedance at any point \(r\) from the beam axis for arbitrary \(\beta\). The presence of the background of density \(n_0\) is included in the parameters \(\Gamma_0\) and \(\omega_p\). For \(n_0 = 0\) or \(\omega_p = 0\) and \(r = a\), eq. (15) reduces into the following well known expression for the longitudinal coupling impedance [19, 22, 23],

\[
\text{Ershaidat}
\]
Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles

\[
Z_{\parallel}^{(0)}(\omega) = -i \frac{L}{\pi a^2 \varepsilon_0 k_z \beta c} \left[ 1 - 2 \left( K_i \left( \frac{k_z a}{\gamma} \right) + \frac{K_0 \left( \frac{k_z b}{\gamma} \right)}{I_0 \left( \frac{k_z a}{\gamma} \right)} I_1 \left( \frac{k_z a}{\gamma} \right) \right) \right]
\]

Introducing the harmonic number \( n \) such that \( n = k_z R \), the longitudinal impedance in eq. (15) takes the following form at the beam surface \( r = a \),

\[
Z_{\parallel}(\omega, \omega_p) = -i \frac{Z_0}{2 \gamma^2 \beta} \frac{4 \omega_p^2}{\Gamma_0^2 a^2} \left[ 1 - 2 \left( K_i(\Gamma_0 a) + \frac{K_0(\Gamma_0 b)}{I_0(\Gamma_0 b)} I_i(\Gamma_0 a) \right) \right] -
\]

\[
i \frac{Z_0}{2 \gamma^2 \beta} \frac{4 \omega_p^2}{c^2 \Gamma_0^2} \left[ \frac{1}{\Gamma_0^2 a^2} \left( K_i(\Gamma_0 a) - \frac{K_0(\Gamma_0 b)}{I_0(\Gamma_0 b)} I_i(\Gamma_0 a) \right) \right] 4 I_i(\Gamma_0 a) +
\]

\[
\left( K_i(\Gamma_0 a) + \frac{K_0(\Gamma_0 b)}{I_0(\Gamma_0 b)} I_i(\Gamma_0 a) \right)^2 \left( I_0^2(\Gamma_0 a) + I_i^2(\Gamma_0 a) \right)
\]

\[
\equiv -i \frac{Z_0}{2 \gamma^2 \beta} g(a, b, \Gamma_0) \equiv -i \chi_0 g(a, b, \Gamma_0)
\]

where \( Z_0 = \frac{1}{\varepsilon_0 c} \) is the vacuum impedance, \( \chi_0 = \frac{Z_0}{2 \gamma^2 \beta} \) and \( g(a, b, \Gamma_0) \) is a generalized geometry factor defined as follows,

\[
g(a, b, \Gamma_0) = \frac{4 \omega_p^2}{\Gamma_0^2 a^2} \left[ 1 - 2 \left( K_i(\Gamma_0 a) + \frac{K_0(\Gamma_0 b)}{I_0(\Gamma_0 b)} I_i(\Gamma_0 a) \right) \right] +
\]

\[
\frac{4 \omega_p^2}{c^2 \Gamma_0^2} \frac{1}{\Gamma_0^2 a^2} \left( K_i(\Gamma_0 a) - \frac{K_0(\Gamma_0 b)}{I_0(\Gamma_0 b)} I_i(\Gamma_0 a) \right) \frac{4 I_i(\Gamma_0 a)}{\Gamma_0^2 a^2} +
\]

\[
\left( K_i(\Gamma_0 a) + \frac{K_0(\Gamma_0 b)}{I_0(\Gamma_0 b)} I_i(\Gamma_0 a) \right)^2 \left( I_0^2(\Gamma_0 a) + I_i^2(\Gamma_0 a) \right)
\]

Equation (18) gives the modified geometry factor of the longitudinal impedance in the presence of the additional coupling between the background particles and the excited longitudinal electric field in the beam-pipe. The residual contribution to the longitudinal impedance is the difference between equations (17) and (16).
To visualize the effect of the presence of the uniform background on the space charge impedance, the rest of this section is devoted to the numerical analysis of the analytical expression of eq. (17). As representative cases, we follow (Al-khateeb et al. [25]) and we choose the beam energies $\gamma = 1.1$ and $\gamma = 2$. Other beam-pipe parameters are the ring circumference $L = 216$ m, beam-pipe radius $b = 0.1$ m, and beam radius $a = 0.5b$. Fig. 1 and Fig. 2 show plots of eq. (17) for the positive imaginary part of the impedance $Z_i/n$ vs. harmonic number $n = k_z R$, for different background densities, for $\gamma = 1.1$ and $\gamma = 2.0$ respectively. Fig. 3 shows the plot of the same equation (17) for the positive imaginary part of the impedance $Z_i/n$ vs. $\omega_p/\omega$ for a fixed harmonic number $n = 10$ for the two values $\gamma = 1.1$ and $\gamma = 2.0$.

**Discussion and Conclusions**

The contribution of a uniformly distributed background of charged particles to the space charge impedance has been investigated analytically. For a particle beam moving in a perfectly conducting beam-pipe, closed form expression for the longitudinal space-charge impedance has been derived. Residual or background impedance can be defined as the difference between the impedance in the presence of the background ($\omega_p \neq 0$) and that in its absence ($\omega_p = 0$), i.e., the difference between equations (17) and (16).

![Figure 1](image)

**Fig. 1:** The positive imaginary part of the impedance $Z_i/n$ of equation (17) vs. harmonic number $n = k_z R$ for different background densities and for the parameters $L = 216$ m, $b = 0.1$ m, $a = 0.5b$, and $\gamma = 1.1$
Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles

Fig. 2: The positive imaginary part of the impedance $Z/n$ of equation (17) vs. harmonic number $n = k_z R$ for different background densities and for the parameters $L = 216$ m, $b = 0.1$ m, $a = 0.5b$, and $\gamma = 2.0$

From the curves of Fig. 1 and Fig. 2, the positive imaginary part of the impedance $Z/n$ decreases systematically with the harmonic number $n$. All curves for the representative energies $\gamma = 1.1$ and $\gamma = 2.0$ tend toward an asymptotic value as the harmonic number $n$ increases, namely, toward the value of $Z/n$ for $\omega_p = 0$. Fig. 3 shows that the impedance increases for about two orders of magnitudes as the ratio $\omega_p/\omega$ is increased; for $\gamma = 1.1$ as well as for $\gamma = 2.0$.

Fig. 3: The positive imaginary part of the impedance $Z/n$ of equation (17) vs. $\omega_p/\omega$ for the harmonic number $n = 10$ and for the parameters $L = 216$ m, $b = 0.1$ m, $a = 0.5b$, and $\gamma = 1.1$ (upper curve) and $\gamma = 2.0$ lower curve.
The observed increase and modification in the impedance curves introduced by the presence of the background particles contribution can be of importance for modeling the longitudinal dynamics of particle beams and for the instability analysis. In addition to the coupling between the beam electromagnetic fields and the beam-pipe eigenmodes, the presence of the charged background introduces an additional coupling between the beam and its environment, which is responsible for the observed increase and modifications.

The illustrative choice of the parameters is somewhat arbitrary and requires a much more detailed investigation in the future. In particular, a deeper look on this problem requires taking into account the perturbation of the background charge density instead of solving the problem by only accounting for the perturbed current resulting from the quiver motion of the background in the field of the beam.

Acknowledgments

The author would like to thank Dr. A. Al-khateeb for reading the manuscript, his suggestions and comments.

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ımızate الشحنة القيزمية لذرة أسطواني غير مقاوم وجود خلفية منتظم من الجسيمات المشحونة

حصل محمد الرشيدات

ملخص

تم في هذه الدراسة تقسيم مماثلة شحنة الفراغ الطولية في أنبوب ماسارع أسطواني موص بالمنظم بوجود خلفية ذات توزيع منتظم من الجسيمات المشحونة، وإيجاد التعبير الرياضي لهذه المحاولة عند أي نقطة من محو الحزمة المسارع عند سطحها. تدخل الخلفية المكونة من الجسيمات المشحونة تزاوجاً عنيفاً بين الحزمة ومحيطها ووجدنا أن هذه الحالة تزيد من شحنة الفراغ الطولية لترددات التدفق المنخفضة المعتدلة. في حين أن أطوال الموجة القصيرة لا تتأثر بهذه الخلفية.

وتظهر تغيرات المماثلة مع تردد البلازما للخلفية زيادة عظمى قصيرة يحتوي محاولة من ضعف مقارنة مع هذه المماثلة بغياب الخلفية. وقد أوردنا في هذه الدراسة أمثلة رقمية لتوضيح النتائج السابقة وذلك بأخذ حزمة مسرعة، طاقتها معرفة بـ $\gamma = 1.1$ و $\gamma = 2.0$ في مسار دائرى نصف قطره 216 m وانبوب $a = 0.5 b$ ونسبة قطره $b = 0.1 m$ لحزمة نصف قطرها $a = 0.5 b$.

كلمات ذات دلاله: كينماتكا الحزم، شحنة الفراغ الطولية، المماثلة، تردد البلازما.
Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles

References


Determination of Uranium in Phosphate Rocks by Fusion Glass Method for X-Ray Fluorescence

Ali Khuder* and Mohamad Marouf**

Abstract

A flux of lithium metaborate (2.20 g) and lithium tetraborate (1.20 g) was used to fuse oxides and salts in phosphate rocks. NaNO₃, 0.50 g, was added as an oxidizing agent, while, SiO₂, 0.1 g, was added for glassing at 700 °C for 10 min. Uranium in glass samples was determined by ED-XRF technique. The calibration curve was linear in a concentration range of 12 ppm - 827 ppm with a correlation coefficient, R², of 0.9980. The RSD (n=3) for uranium determined in S17 standard reference material was of a value of ±1.0 % at 370 ppm. The glass samples were used for the determination of U in phosphate rocks. The results of uranium determined by fusion glass method were in good agreement with those obtained by SQ-XRF, fluorometry and γ-ray methods.

Ca, Sr and Fe elements were also determined with the developed fusion glass method. The results of these elements were comparable to those obtained by AAS.

Keywords: XRF, fusion glass, lithium metaborate, lithium tetraborate, calibration curve

Introduction

Generally, x-ray fluorescence analysis deals with solid and homogeneous samples. Particle size of the sample affects x-ray incident with wavelength > 3 Å. Fusion glass technique is the approach, which is mostly used for solving a homogeneity problem and matrix effect.

Fusion glass procedure includes heating the sample, which is mixed with a suitable flux, at a relatively high temperature for a limited period of time. The heavy absorber may be proposed for decreasing the matrix effect. The prepared glass samples are usually used as standard reference samples, due to their stability throughout the time of multiplication and analysis. Unfortunately, the fusion glass approach is time-consuming and a sample is subjected for dilution.

Different reagents are recommended for the use as suitable fluxes for different matrices [1-4]. The flux is chosen according to the composition and physical and chemical properties of the sample. For example, potassium pyrosulphate is used for the...
fusion of samples at low temperature [5]. A lithium meta- and tetra- borate or a sodium tetraborate are often used as fluxes [6, 7]. Fusion with lithium borate salts is usually preferred due to the relatively low viscosity of the melt; consequently low tendency of sticking with the crucible [8-10]. Many workers use the ratio of flux-to-sample in the range of 1:1-10:1 [11]. In addition, lithium metaborate is widely used due to its ability to dissolve many matrices with no acquirements for a large number of dilutions of the sample [8]. Although the use of mathematical approach solves the enter-element effect, which is raised from preparing glass samples with a small ratio of flux-to-sample [12], the practical approach is still in use for the analysis of different matrices. However, borate salts are usually employed for fusion of silicates, alloys, plant materials, metals and soils [1-4, 13, 14]. Studies on lithium borate fluxes have not dealt yet with the determination of uranium in phosphate rocks using fusion method for XRF.

This work focuses on: (i) the determination of uranium in phosphate rocks using a mixture of lithium meta- and tetra- borate with a pre-oxidation of the sample by sodium nitrate; (ii) determination of some other elements, e.g. Ca, Sr and Fe in the same samples; (iii) evaluation of the precision and accuracy of the developed fusion glass method for XRF analysis.

Experimental

a. Apparatus and instrumental conditions

X-ray fluorescence (XRF) determinations were performed using a Si(Li) detector with an active area of 30 mm², FWHM – 180 eV at 5.9 keV and a PCAII multi-channel analyzer. X-ray tube with a secondary target of Mo was used with operation conditions of 50 mA and 45 kV. Net intensity was measured using the AXIL program, which was developed in the IAEA laboratories [15]. γ-ray spectrometer equipped with a HPGe detector (eff. 12.5 %, FWHM = 0.998 keV at 122 keV and 1.88 keV at 1332 keV) and a fluorometer (GMBH-G-M fluorometer, Jerrell-Ash-27000) were also used for the determination of uranium in phosphate rocks. Ca, Sr and Fe elements were determined by a Perkin-Elmer 2380 atomic absorption spectrophotometer.

All reagents used in this study were of analytical-reagent grade.

b. Preparation of glass samples

Glass samples were prepared as mentioned elsewhere [8]. 22 and 12 parts of lithium metaborate and lithium tetraborate (weight of the mixture was 3.40 g), respectively, were mixed thoroughly in a crucible made of Pt 95 % - Au 5 %. The mixture was heated at 280 °C for two hours. An amount of 0.33 g of a sample was added to the dry flux. Preoxidation of the sample was attended using 0.5 g of NaNO₃. A small amount (0.1 g) of NH₄I was added as a releasing agent; 0.27 g of SiO₂ was added for a glassing.

The mixture was then heated in electrical furnace at 700 °C for 10 min; after which fusion of the sample was carried out at 1000 °C for 10 min. The melt was subjected to a rapid cooling in a Pt 95 % - Au 5 % dish. Finally, the sample was kept in desiccators for further XRF measurements.
Determination of Uranium in Phosphate Rocks by Fusion Glass Method for X-Ray Fluorescence

However, the preparation of glass samples was consisted of the following steps:

1. Pre-oxidation of the samples with NaNO₃ at 700 °C for 10 min.
2. Addition of a releasing agent, i.e. NH₄I, to prevent sticking of the melt in the bottom of the crucible and SiO₂ to prepare glass samples free of cracking.
3. Fusion of the samples at 1000 °C for 10 min.
4. Rapid cooling of the melts at ambient temperature.
5. Keeping the glass samples in desiccators for further work.

c. Calibration curve

The calibration curve, representing the relation between the intensity (cps) of XRF and the concentration of U (ppm), was constructed using a series of synthetic glass samples. The concentrations of U in synthetic samples, 12-827 ppm, covered the range of this element in phosphate rocks. Other compounds, e.g. F₂O₃, CaO, Al₂O₃, NaF, Na₂O, MgO, KH₂PO₄, SrO, ZrO₂, Y₂O₃, were added to the synthetic samples to match the content of elements in the unknown ones.

d. Phosphate soils analysis

Four phosphate soil samples were collected from the Sharkeih and Khneifes phosphate mines, which are located in eastern side of Palmyra in the middle of Syria. The samples were ground to fine particles and homogenized for further analyses. The samples were fused in a similar way described for the standard samples. The samples were analyzed by fusion glass technique for XRF using the previously mentioned calibration curve method. The results were compared with those obtained using γ-ray, fluorometry, and simple quantitative and fundamental parameter methods for XRF.

Results and discussion

The experiment showed that pre-heating of the 22:12 mixture at 280 °C for 2 hours is preferable to avoid the swelling of flux granules. The free from crack and homogeneous synthetic glass samples were subjected for analysis by XRF technique. The net intensity (count per seconds=cps) of U (Lα= 13.6 keV) in these samples was determined using AXIL program. Figure 1 shows a linear relationship between the net intensity, Iₚ, and the concentration of U (C_u). The computed concentration of uranium was calculated using the following equation: I_u = f (C_u). Linearity of the calibration curve was obtained by plotting computed U concentration against used U concentration (Figure 2). The later Figure shows a good linearity represented by a correlation coefficient (R²) of 0.9980.
The lowest limit of uranium concentration (LLC) was calculated using the following equation: LLC = \((2/m)(I_b/T_b)^{1/2}\) \(11\); where: \(m\) is the sensitivity given as cps/ppm; \(I_b\) is the intensity of the background (cps); \(T_b\) is time of measurement. By applying the previously mentioned equation, the LLC of uranium was found to be 11 ppm, taking into account that \(m\), 0.1343 cps/ppm, was obtained from the slope of the calibration curve (Fig. 1) and \(I_b\), 0.546 cps, from measuring the counts at \(\text{La} = 13.6\ \text{keV}\) for \(U\) in synthetic blank sample.

Fig. 1. Calibration curve of uranium

![Calibration curve of uranium](image1)

Fig. 2. The relationship between the computed and chemical concentrations of \(U\) in synthetic fusion glass samples

![Relationship between computed and chemical concentrations](image2)
The calibration curve method was applied for the determination of uranium in the phosphate uranium ore IAEA/S-17 standard reference material, which contains 370 ppm of uranium. The obtained mean value was 367.5 ppm with standard deviation (SD) of ±3.7 ppm. This indicates precision of 1.0 % for U determination using a fusion glass sample for XRF analysis; taking into account, the precision is represented by a standard relative error ((SRD=(SD/C_U)x100, %) at a probability level of 95 % and a number of measurements (n) equal to 3. The method was associated with an accuracy value of –0.70 %.

The determination of uranium concentration in phosphate rock samples, collected from Sharkeih and Khneifes phosphate mines was carried out using the developed fusion glass sample for XRF. The results of later method were compared to those obtained by γ-ray spectrometry, fluorometry, and simple quantitative and fundamental parameter for XRF (Table 1). The results in this work were calculated using SD = ±1σ and n=3.

Precision value of uranium determination by the developed fusion glass method for XRF, ≤±4.5 %, was comparable to those resulted using standard methods, simple quantitative for XRF, ≤±4.8 %, γ-ray spectrometry, ≤±4.3 %, and fluorometry, ≤±6.0 % (Table 1). The precision obtained via fundamental parameter method for XRF was not of a good satisfaction, ≤±14.4 %.

In terms of accuracy, there was an agreement between the values of uranium determined by fusion glass method for XRF and those obtained by γ-ray, fluorometry and simple quantitative for XRF in order of values < 7.9 % for 11 cases out from 12, suggesting the goodness of the proposed fusion glass method. The large variation occurred between fundamental parameter method for XRF and other methods were obtained, reflecting the presence of systematic error in the determination of uranium using fundamental parameter method for XRF.

Table 1. Uranium determination in phosphate rocks using different methods.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Uranium concentration, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17 γ-SM (n=3)</td>
</tr>
<tr>
<td>K</td>
<td>96.4 ± 3.3</td>
</tr>
<tr>
<td>A.Tina-3</td>
<td>68.7 ± 2.2</td>
</tr>
<tr>
<td>A.Tina-5</td>
<td>63.4 ± 2.0</td>
</tr>
<tr>
<td>Sch-21</td>
<td>41.5 ± 1.8</td>
</tr>
</tbody>
</table>

Where: 17 γ-ray spectroscopy method, 9FM is the fluorometry method, 9SQM, 9FPM, 9FGM are the simple quantitative, fundamental parameter and fusion glass methods for XRF, respectively.

It could be deduced that fusion glass method for XRF over performed other methods for the determination of uranium in phosphate rocks, as no correction factors were involved neither complicated mathematical approaches. In addition, the developed
Khuder and Marouf

fusion glass method showed the ability for multi-element determinations. Table 2 displays the results of the determination of Fe, Sr and Ca elements in the glass-prepared samples. Similar calibration curves were constructed to those obtained for uranium determination.

Table 2. Comparison between fusion glass method for XRF (FGM-XRF) and atomic absorption spectrophotometric (AAS) method for Fe, Sr and Ca determination in phosphate rocks.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ca (%)</th>
<th>Sr (ppm)</th>
<th>Fe (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AAS</td>
<td>FGM</td>
<td>AAS</td>
</tr>
<tr>
<td>K</td>
<td>33.9±0.9</td>
<td>34.9±0.4</td>
<td>1591±40</td>
</tr>
<tr>
<td>A.Tina-3</td>
<td>35.9±1.2</td>
<td>37.0±0.2</td>
<td>1127±90</td>
</tr>
<tr>
<td>A.Tina-5</td>
<td>36.2±1.6</td>
<td>37.3±0.9</td>
<td>1417±132</td>
</tr>
<tr>
<td>Sch-21</td>
<td>29.6±0.8</td>
<td>29.8±0.5</td>
<td>1307±150</td>
</tr>
</tbody>
</table>

Conclusions

The results show the useful application of the 22:12 mixture flux of lithium meta-tetra borate for the fusion of phosphate rocks. The prepared synthetic samples were used for U determination with a satisfied precision and accuracy. The application of FGM was extended to determine Fe, Sr and Ca in the phosphate samples, recommending however the method for the multi-element determination using the calibration curve as a simple approach for analysis.

Acknowledgements

The authors thank Prof. I. OTHMAN Director General of AECS for his encouragement and keen interest in this work. Thanks also due Prof. G. ZEISAFOON and Prof. H. KALLAWI for their valuable advices. Finally, thanks also due Ms. D. HALLOOM to her assistance in the preparation of fusion glass samples and providing analysis by XRF.
Determination of Uranium in Phosphate Rocks by Fusion Glass Method for X-Ray Fluorescence

علي حضر و محمد معروف

ملخص

استخدم مصهر مكون من ليثيوم مينا البورات (2.20 g) في صور الفوسفات بطريقة الزجاج المنصر

الاكتسيود وأملاح في الصخور الفسفاطية. أضيف 5 g من NaNO3 كعامل أكسدة، بينما، أضيف 0.1 g من SiO2 من أجل التزجيج بالدرجة 700 °C و لمدة 10 دقائق. عين البورات في العينات الراجية

بتقنية التخطيط بالأشعة السينية باستخدام نرم (ED-XRF)، كان منحنى المعايرة خطياً في مجال من 257 ppm إلى 12 ppm التراكيز من 827 ppm بمعامل تصحيح R² قدره 0.9980. كان الخطأ المعياري النسيب

مقابل كتركية قياس 3 RSD مساوية 1.0 % مقابل n=3 عينة الوراثي في العينة المعيارية سوية 17

التركيز 370 ppm. استخدمت العينات الراجية لتعيين البورات في الصخور الفسفاطية. كانت نتائج

تعيين البورات بطريقة الزجاج المنصر على توافق جيد مع تلك النتائج، التي تم الحصول عليها بطرق

التحليل البسيط بالأشعة السينية (SQ-XRF) و الفلوروميتر و أشعه غاما. عينت أيضاً العناصر Fe و Sr و Ca بطريقة الزجاج المنصر المنصهر المطورة و كانت النتائج مقارنة لتلك

References

Influence of Nd-YAG Laser Pulses on Aluminum Alloys. Study of Chemical Distribution of Elements

Layla Baziz*, Abdul-Kader Nouiri* and Yaser A. Yousef**

Received on Oct. 6, 2005 Accepted for publication on Feb. 26, 2006

Abstract

Several studies have been made on laser-matter interaction during the last years. The irradiation of a metallic target by a high energy pulsed laser can produce several changes in physical and chemical properties of material [1-2]. This work is realized on local (Algerian) aluminum alloys which has been recycled and found to contain some foreign elements (Zn, Si, Cu, Mg, O, ...). The irradiation source used in this work is Nd-YAG pulsed laser with a 15nsec of pulse duration, 532 nm wavelength and 3 mW of power. In this paper, we present the distribution of foreign elements obtained by Energy-Dispersive X-ray mapping (EDX) using Scanning Electronic Microscope(SEM) at irradiated surface.

Keywords: irradiation, aluminum alloys, laser, distribution.

Introduction

Laser technology covers a wide range of applications. Industrial production processes make a number of critical demands on fine welding, fine cutting and micro drilling solutions. The laser meets many of these demands almost perfectly[1]. Nanosecond laser pulses may produce both thermal melting (as femtosecond and picosecond pulses) and ultra fast non-thermal melting depending on the pulse fluency. This was demonstrated experimentally by Sokolowski-Tinten et al. [2] who found that the transformation of GaAs into its liquid state occurs within several tens of Picoseconds at fluencies close to the melt threshold due to thermal melting under highly superheated conditions [2] or within several hundreds of femtoseconds via carrier excitation [2,3] for very high fluencies. The processes occurring under high energetic femtosecond pulse irradiation may be described more precisely with the help of the theoretical work of Stampfl and Bennemann [4]. The major material processing routines that are either routinely used in the industry are reviewed [5]. The joining of small metallic work pieces (10-200 mm) causes problems that often cannot be solved by conventional methods. In this case, soft soldering by means of laser radiation is sufficient. During soldering, laser light is used to melt an additional material with a considerably lower melting temperature than that of the material of the component to be joined. In order to
understand these phenomena (soldering, melting, ….), a metallic alloys (Al, Cu, Zn, ….) is irradiated by Nd:Yag pulsed laser. The irradiated area is studied by Scanning Electron Microscope (SEM) and X-ray mapping. The Oxygen distribution is also studied as a function of distance from the center of the laser irradiated spot in order to estimate the temperature distribution.

**Experimental**

The samples studied are produced from a recuperated (recycled) aluminum alloy. They were polished mechanically and cleaned. The chemical composition of material is obtained by X-ray analysis. The chemical composition of the recycled aluminum alloy is Al(72.02 Wt%), Si(13.05 Wt%), Zn(6.34 Wt%), O(4.28 Wt%), Mg(2.08 Wt%), Cu(1.75 Wt%) and Ni(0.48 Wt%). A nanosecond pulsed laser (Nd:YAG) is used to irradiate the sample of that alloy. The instrument used in this experiment was Spectrum Laser System. The pulse duration, wavelength and pulse energy are 15 nsec, 532 nm and 50mJ, respectively. All irradiation experiments were performed in air at room temperature. The analysis of irradiated area is realized by Energy-Depressive X-ray mapping(EDX) using the Scanning Electron Microscope(SEM).

**Results and discussion**

The SEM microstructure of the original sample of the recycled aluminum alloy before laser irradiation (un-irradiated zone) shows rough contrast area, and other impurities are segregated at grain boundaries Fig.1. The analysis by EDX-point measurements of un-irradiated zone shows that the rough contrast area is SiO₂, and the majority of area is Al₂O₃ with some composites like ZnO are distributed in the matrix and segregated in grain boundaries Fig.1. Concerning the irradiated area, the observations by SEM show three zones Fig.2:

![Figure 1: SEM image of the investigated alloy, Irradiated zone (right) and un-irradiated zone (left).](image-url)
Influence of Nd-YAG Laser Pulses on Aluminum Alloys. Study of Chemical Distribution of Elements

Figure 2: Magnified image of laser irradiation spot

- First zone is a small hole, its depth depends on laser energy and the number of pulses. This hole is due to evaporation or ablation phenomena.
- Second zone is melted area.
- Third zone is annealed area.

The physical and chemical properties of all three zones may be modified because the grains and grain boundaries disappeared inside both first and second zones. The grains of third zone are modified according to the distance from the center.

Distribution of Oxygen

The EDX mapping of Oxygen is presented in Fig. 3 which represents the qualitative distribution of Oxygen at the irradiated area (90 pulses). It is clear that the concentration of Oxygen is very low within the first zone (the Oxygen is evaporated), but we observe an increasing of Oxygen in second and third zone. This high influence of laser beam on Oxygen distribution is probably due to the atomic weight of Oxygen. This phenomenon may be used to estimate the temperature distribution at the irradiated area [6]. That is to say; the temperature is very high at the first zone, so it decreases with increasing of distance from centre of the hole. The quantitative distribution of temperature is a problem because we cannot make an experimental measure of the temperature at nanosecond scale. In future, the temperature distribution can be evaluated by combination of Oxygen distribution and computer simulation.
Fig. 3: Quantitative (b) and spatial (a) distribution of Oxygen after laser irradiation.
White circle shows the irradiated zone.
Distribution of other elements

Concerning the other elements, like Mg, Cu and Si, the EDX analysis shows that the distribution of each element is not very modified after the laser irradiation. Concentrations of some elements like Cu and Si are equal to those obtained before the irradiation ([Cu]=1.75 Wt% and [Si]=13.05 Wt%). Fig.4. shows the distribution of magnesium at the irradiated area. Fig.5 shows the distribution of Cu and Si at the irradiation area, there is no high influence of laser beam on distribution of these elements. Figure 6 shows the X-Ray images for the same irradiated area scattered by different elements. The hole appears to be much smaller for the aluminum(a) and magnesium (b) than that for oxygen (c). The figure gives a conclusive evidence for the effect of laser pulse on the concentration of the different elements.

![Graph](image)

**Fig. 4:** Quantitative(right) and spatial (left) distribution of Magnesium after laser irradiation. White circle shows the irradiated zone.
Fig. 5: Distribution of Cupper (right) and Silicon (left) after laser irradiation. White circle shows the irradiated zone.
Conclusion

The Nd:Yag pulsed laser irradiation can influence the chemical composition of Aluminum alloys, that depends on laser energy and pulses number. The distribution of Oxygen is modified much more than other elements like Cu, Mg or Si.

Acknowledgment

This work is supported by the Center for Theoretical and Applied Physics (CTAP), Yarmouk University, Irbid, Jordan. The authors acknowledge the director of CTAP, Prof. Nabil Al Laham for his continuous support and collaboration.

The authors are thankful to Mr. Wajih Yousef, Department of Earth and Environmental Sciences, Yarmouk University, for the SEM data.
تأثير نبضات من ليزر النيوديميوم على توزيع العناصر الشائعة في سبانك الأنفيوم

ليلي باعزيز، عبدالقادر النويري، ياسر يوسف

ملخص
تأثر نبضات الليزر عالية الطاقة و متتالية القصر في العمر الزمني على سطوح المواد كان محط اهتمام العديد من الباحثين خلال السنوات الماضية. تهدف الدراسة الحالية إلى تحديد تأثير نبضات من أشعة الليزر على توزيع العناصر الشائعة في سبانك من الأنفيوم المستخرج المستخدمة في الجزائر. أظهرت نتائج التحاليل باستخدام المجهر الإلكتروني الماسح وجود عنصر مثل الزنك والسيليكون والنحاس والأكسجين في المغناضوم في تركيب السبانك. تم استخدام ليزر نبضي نوع (Nd-YAG) بطول موجي 532 نانومتر وعمر نبضي قدره 15 نانوثانية في دراسة توزيع العناصر على سطوح تلك السبانك.

References
Performance Evaluation of AES/Triple-DES/Blowfish Ciphers under W2K and Linux Operating System Platforms

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Received on July 31, 2005 Accepted for publication on April 2, 2006

Abstract

In this paper, the results obtained from Java implementation of three cryptographic algorithms on two operating system platforms, namely: Windows 2000 Professional (W2K) and Linux are presented. These algorithms are: Advanced Encryption Standard (AES), Triple Data Encryption Standard (T-DES) and Blowfish. The selected algorithms are all symmetric block ciphers. The performance of the three algorithms is compared based on the CPU execution time as well as the real (elapsed) time. The CPU execution time is broken further into user time and kernel (system) time. The evaluation of the performance of the three cryptography algorithms is done for secret key generation, encryption and decryption operations. Java and JCA (Java Cryptography Architecture) are used to implement the three ciphers. The results show that the Blowfish algorithm is the fastest, followed by the AES algorithm then the Triple-DES algorithm. The results of this work will support the selection of the best encryption algorithm in terms of speed and will help in capacity planning of the overall system. From the results obtained, we propose to either embed a security module within the processor to provide ultimate speeds for cryptography operations or to dedicate a special server, which is responsible for providing cryptographic services for highly secured environments.

Keywords: AES, Blowfish, Cryptography, JCA, Operating system, Performance evaluation, Symmetric ciphers, Triple-DES.

Introduction

In the past, securing sensitive information using encryption was only restricted to key governmental agencies and diplomats. These days, secure encryption on the Internet is the key to confidence for people wanting to protect their sensitive data/information, or doing E-Commerce or doing business online.

Ensuring the safety of data/information using encryption has been used in several important newly emerging applications including: E-Commerce, secure messaging, virtual private networks ...etc. Several medium size and large companies that have...
proprietary or sensitive information are required to encrypt their entire data/information fearing that in the wrong hands this information could cause millions of dollars in damage.

Efficient implementation of cryptography algorithms plays an important role in the new era of information technology (IT). This is mainly due to the growing need for high-speed and highly secured communication channels [1]. Also, modern applied cryptography in the field of wireless communication networks demands high processing rate to fully utilize the available network bandwidth. In addition, it is important that any implementation should follow the variety and advancements in algorithms and standards.

Cryptography provides the mechanisms necessary to provide the following data/information security concerns:

- **Authentication**: the knowledge of who sent a message and to determine whether a user’s identity is authentic.
- **Confidentiality**: ensuring that information is accessible only to those authorized to have access.
- **Integrity**: safeguarding the accuracy and completeness of information and processing methods.
- **Non-repudiation**: the sender cannot deny sending the message if there is a specimen signature.
- **Availability**: ensuring that authorized users have access to data/information and associated assets when required.

There are two general types of key-based encryption/decryption algorithms (also known as ciphers): asymmetric (or public-key) and symmetric (conventional or private key).

Asymmetric ciphers are designed to allow for encrypting data using one key and decrypting it using another key. Public-key algorithms are much slower than Symmetric algorithms.

Symmetric algorithms, on the other hand are designed in a way such that the same key is used to encrypt and decrypt the message. Hence, any two parties interested in encrypting/decrypting data have to use the same (secret) key generated for both encryption and decryption. Symmetric encryption was the only available option prior to the advent of Public Key encryption in 1976.

Symmetric algorithms can further be divided into two main categories: block ciphers and stream ciphers [1, 2]. Block ciphers are based on the principles of Feistel ciphers and operate on data in groups or blocks where the message is broken into blocks of bits, each of which is encrypted separately. Stream ciphers; on the other hand only operate on a single bit (i.e., a block of one bit size) at a time, which makes them more suitable for real time applications such as multimedia. Block ciphers seem to be
applicable to a broader range of applications than stream ciphers. It is easy to see that a
block cipher can be used in a way to make it operate as a stream cipher.

A symmetric encryption scheme has five major components as follows [1, 2, 3]:

- **Plaintext** - this is the text to which the encryption algorithm is applied.
- **Encryption Algorithm** – the algorithm that is applied to the plaintext to perform
  mathematical operations to conduct substitutions and transformations to the
  plaintext.
- **Secret Key** - This is the input for the algorithm as the key dictates the encrypted
  outcome.
- **Ciphertext** - This is the encrypted or scrambled text generated by applying the
  algorithm to the plaintext message using the secret key.
- **Decryption Algorithm** - This is the encryption algorithm in reverse. It uses the
  ciphertext, and the secret key to derive the plaintext message.

When using this form of encryption, it is essential that the sender and receiver have
a way to exchange secret keys in a secure manner. Knowing the secret key one can
figure out the algorithm, hence communications will be insecure.

Therefore, there is always a need for a strong encryption algorithm, so that if
someone were to have a ciphertext and a corresponding plaintext message, they would
be unable to determine the encryption algorithm.

In general, there are two methods of attacking conventional encryption - brute force
and cryptanalysis:

- **Brute force technique**: Using a method (computer) to find all possible combinations
  and eventually determine the plaintext message.
- **Cryptanalysis technique**: It is an attack on the characteristics of the algorithm to
deduce a specific plaintext or the key used. One would then be able to figure out the
plaintext for all text that continues to use this compromised setup.

Table 1 shows the average time required for exhaustive key search (brute force
technique) for some key lengths

<table>
<thead>
<tr>
<th>Key Size (Bits)</th>
<th>Number of Alternative Keys</th>
<th>Time required at 10^6 Decryption/µs</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>$2^{56} \approx 7.2 \times 10^{16}$</td>
<td>20 hours</td>
</tr>
<tr>
<td>112</td>
<td>$2^{112} \approx 5.192 \times 10^{33}$</td>
<td>$1.6 \times 10^{13}$ years</td>
</tr>
<tr>
<td>128</td>
<td>$2^{128} \approx 3.4 \times 10^{38}$</td>
<td>$5.4 \times 10^{15}$ years</td>
</tr>
<tr>
<td>168</td>
<td>$2^{168} \approx 3.7 \times 10^{49}$</td>
<td>$5.9 \times 10^{16}$ years</td>
</tr>
</tbody>
</table>
From Table 1, the AES-128 algorithm gives about $3.4 \times 10^{38}$ possible 128-bit AES keys compared with $7.2 \times 10^{16}$ possible 56-bit Blowfish keys. This makes AES more immune to “brute-force” exhaustive attacks as compared to the Blowfish algorithm, but less than the TDES algorithm.

There are several factors behind the selection of a particular encryption/decryption algorithm such as its strength and immunity. The running time of the algorithm is also another important factor that should be considered as well. Other factors include: flexibility, memory requirement and software & hardware suitability. Encryption algorithms may consume a huge amount of system resources for generating the secret key and for the actual work needed for encrypting or decrypting the data. If the running time of the algorithm is neglected then this might lead to jeopardizing the overall performance of the operating system. Because of this reason, the primary objective of this paper is to evaluate the selected encryption algorithms based on their running time including both execution time as well as the total real time.

Three symmetric block ciphers have been selected for our study, namely, the Advanced Encryption Standard (AES), the Blowfish, and Triple Data Encryption Standard (Triple-DES or TDES or 3DES) [1, 4, 5, 6, 7]. These three block ciphers have been chosen because AES is now replacing the outdated Data Encryption Standard (DES), which has been a worldwide standard for more than 25 years. TDES resolves the flaws in DES which was the de facto standard. The Blowfish is a fast cipher with a different structure and functionality.

The selected three block ciphers were implemented using Java and Java Cryptography Architecture (JCA). Java will enable the implemented program to be portable across platforms. Java was used by other researchers including [8] to implement other algorithms. Other encryption/decryption algorithms have been incorporated into several Java technology offerings.

A comparison of the processing times needed for both the kernel (system) and the user to generate the secret key, to encrypt and to decrypt the data will be recorded. Also, the real time, which includes in addition to the kernel and user times the I/O times, is recorded as well.

Evaluating the performance of ciphers becomes of interest to many researchers [9, 10]. AES origin, description, evaluation, implementation, attacks, software implementation, hardware implementation and performance evaluation are discussed in [4, 11-16]. The blowfish structure and characteristics is discussed in [4, 17, 18, 19], and finally, the TDES is well addressed in [4, 7].

Several authors were involved in research to achieve the maximum performance of operating systems [3]. The research includes benchmarks and a comparison to other famous benchmarks [3, 20, 21]. Other researches focused on the kernel’s point of view and have been categorized into different areas. Performance evaluation of kernels has been explored in [22, 23]. Several performance analysis tools [24] and measurement techniques [25] have been discussed in the literature. Some of these measurement techniques were interested in measuring the hardware performance based on specific
kernels such as [26]. Other studies targeted the best application optimization reachable by measuring the application performance [27] or by optimizing the application [28].

Research efforts have also been accomplished in the area of operating system architecture and design [3, 29, 30] or concentrated on the overall system performance [31]. This type of research might be accomplished using an operating system simulator [32] or by using a normal PC operating system [33, 34]. The outcomes of these studies have helped enormously in both fine-tuning the operating systems and the hardware needed [35, 36].

The importance, necessity and future of security in the web and e-commerce were best studied in [37]. Cryptography and its implementations in applied fields are exposed and explored in [33, 38].

Section 2 introduces the three ciphers under consideration. An overview of JCA and the Java implementation of the three ciphers is discussed in section 3. In section 4, the implementation section, we describe the experiment setup and the implemented program using JCA and Java. Section 5 introduces the testing methodology and presents the results obtained from the implementation. Finally, section 6 concludes the study and points to the future work.

**The Three Ciphers**

Cryptography is widely applied to protect digital data. Nowadays, there are many kinds of cryptography and most of them require a secret key to encode digital data. In this section we briefly describe the structure of the three selected ciphers: the (AES) [4, 5], Blowfish [4, 6, 7, 8] and TDES [4, 7] that have been selected for Java and JCA implementation.

In 1997, the National Institute of Standards and Technology (NIST) issued a call for proposals for an encryption standard “the DES of the 21st century”, as a new official standard. The new standard is called the advanced encryption standard (AES). NIST required that AES should have security strength equal to or better than the TDES and significantly improved efficiency [1]. AES was approved by NIST in September 2000, and became effective on May 26, 2002 as a replacement for the out-of-date DES. It consists of four easily reversible different stages that make up a standard round [1]. The stages are iterated 10 times for a 128-bit key, 12 times for a 192-bit key, and 14 times for a 256-bit key. The four stages are as follows:

- **Substitute bytes**: A non-linear byte substitution that uses an S-box to perform a byte-by-byte substitution of the data block.
- **Shift rows**: A simple transformation that uses permutation that cyclically shifts (permutes) the bytes within the block.
- **Mix columns**: A transformation using substitution that makes use of arithmetic over GF (2^8). It groups 4-bytes together forming 4-term polynomials and multiplies the polynomials with a fixed polynomial mod (x^4+1).
• Add round key: Bitwise XOR of the current block with a portion of the expanded key. This is the only stage that uses the key.

The final round of both encryption and decryption consists only of three stages (i.e., no mix columns stage). The main steps involved in the encryption process in the AES are illustrated in Figure 1.

![Diagram](image)

**Figure 1.** The main steps involved in the encryption process in the AES.

AES is a symmetric block cipher that supports combinations of key lengths of 128, 192, or 256 bits and block sizes of 128, 192, or 256 bits. With three different key sizes defined by the AES standard, the corresponding algorithms are named AES-128, AES-192, and AES-256.

On October 2, 2000, NIST announced that Rijndael has been accepted as the proposed algorithm for AES. Rijndael is a substitution-linear transformation network with 10, 12, or 14 rounds, depending on the key size. A data block to be processed using Rijndael is partitioned into an array of bytes, and each of the cipher operations is byte-oriented [5].

The Blowfish algorithm was designed by Bruce Schneier in 1993 to be simple, fast, compact and variably secure. It is a cipher with a different structure and functionality.
than the other two ciphers. It is a symmetric block cipher with a block size of 64 bits. The plaintext is divided into two 32-bit halves called, the left half ($LE_0$) and the right half ($RE_0$). $LE_i$ means the left and right half of the data after round $i$ has completed. Blowfish is a variable-length key of at most 448 bits and has a fair amount of acceptance in a number of applications. The secret key of Blowfish algorithm ranges from 32 bits to 448 bits. With 448 bits key, the Blowfish algorithm requires $2^{448}$ combinations to examine all keys. The Blowfish algorithm consists of two parts: a key-expansion part and a data-encryption part. Key expansion converts the key into several sub key arrays totaling 4168 bytes. Data encryption occurs via a 16-round Feistel network. Each round consists of a key-dependent permutation, and a key- and data-dependent substitution. All operations are XORs and additions on 32-bit words. The only additional operations are four indexed array data lookups per round. No attacks are known against the 448-bits Blowfish algorithm. The Blowfish algorithm has many advantages. It is suitable and efficient for hardware implementation. Besides, it is unpatented and no license is required [19]. A complete definition of Blowfish algorithm is found in [1]. Figure 2 shows a block diagram of the blowfish algorithm.

![Blowfish algorithm block diagram](image)

Figure 2. Blowfish algorithm block diagram.
TDES simply extends the key size of DES by applying the algorithm three times in succession with three different keys as shown in Figure 3.

\[ C = EK_3[DK_2[EK_1[P]]] \]

Where,

- \( P \) is the plain text,
- \( EK_i \) means apply the encryption algorithm using Key(i), and
- \( DK_i \) means decrypt using Key(i),
The Triple data encryption algorithm (TDEA or 3DEA) and AES will coexist in FIPS approved algorithms.

**Java Cryptography Architecture**

This section gives an overview of Java Cryptography Architecture (JCA) used in our implementation. JCA is a core Application Programming Interface (API) of the Java programming language and is designed to allow developers to incorporate both low-level and high-level security functionality into their programs [40, 41, 42, 43]. It encompasses the parts of the Java 2 SDK Security API related to cryptography, as well as a set of conventions and specifications. It also includes a "provider" architecture that allows for multiple and interoperable cryptography implementations. The JCA was designed around two principles, namely: Implementation independence & interoperability; and algorithm independence & extensibility [42, 43].

Implementation independence and algorithm independence means that cryptographic services can be used without worrying about the implementation details or even the algorithms. When complete algorithm-independence is not possible, the JCA provides standardized, algorithm-specific APIs. When implementation-independence is not desirable, the JCA lets developers indicate a specific implementation.

Due to its implementation interoperability feature, JCA allows various implementations to work with each other, use each other's keys, or verify each other's signatures. This would mean, for example, that for the same algorithms, a key generated by one provider would be usable by another. Algorithm extensibility means that new algorithms that fit in one of the supported engine classes can be added easily. The Java Cryptography Extension (JCE) extends the JCA API to provide a framework and implementations for encryption, key generation and key agreement, and Message Authentication Code (MAC) algorithms [42].

Starting with Java 2 Software Development Kit (SDK), Standard Edition (J2SE) Version 1.4.2, the Java Cryptography Extension (JCE) was integrated with the SDK and the Java Runtime Environment (JRE). Therefore, it is no longer necessary to install the JCE optional package, as support for cryptography is now available as part of J2SE.

**Implementation**

In this section, we give a general overview of the experimental set up and how the selected ciphers are implemented using JCA and Java programming language.

**Experiment Setup**

The three ciphers were run on Pentium III processor with a CPU speed of 800 MHz and a total of 256 MB RAM. The algorithms were tested on two different operating system platforms. The first test was conducted under Windows 2000 Professional operating system and the second test was conducted under Mandrake/Linux 8.2 Kernel version 2.4.18.

The three encryption/decryption algorithms are performed on the same file of size 10 MB. Java version 1.4.2 has been used for implementing the three ciphers. The
algorithms were tested using key sizes of 128 bits for the AES, 56 bits for Blowfish, and 112 bits for the TDES algorithm.

The experiment was repeated ten times for each algorithm and for each of the three operations, the secret key generation, the encryption operation and decryption operation. The average of the ten runs for each operation was recorded in the corresponding table.

**The Implemented Program**

A program was developed to implement the three ciphers using Java and JCA. The program is constructed into 3 modules. The first module is responsible for generating secret keys to be used for encrypting and decrypting messages. A secret key has to be generated for each cipher. The second module is the encryption module that takes a secret key generated for the same cipher algorithm and uses this key to encrypt a message (e.g. an AES secret key to encrypt an AES message, a blowfish secret key to encrypt a blowfish message, etc). The decryption module is the third module that takes a secret key and decrypts a message. The message will be decrypted successfully only if the key used for decryption is the same key used for encrypting the message initially.

Using this methodology in the design of the encryption/decryption program, allows for timing each operation (key generation, encryption and decryption) separately. The program also does not interact with the user while it is running (prompting where to save the secret key or the name of the file to encrypt), instead it expects all of the required parameters to be supplied when invoking the application. This is necessary to obtain accurate measurements of the time spent for each operation without being influenced by the time it took the user to interact with the program. The following packages and classes are used in the implementation:

```java
javax.crypto.Cipher;
javax.crypto.KeyGenerator;
javax.crypto.CipherInputStream;
javax.crypto.SecretKey;
javax.crypto.spec.SecretKeySpec;
java.security.Key;
java.security.AlgorithmParameters;
java.security.SecureRandom;
java.security.NoSuchAlgorithmException;
java.io.*;
```

A brief description of the three main modules using Java and JCA follows.
Secret Key Generation

Package: javax.crypto

Class: KeyGenerator

Create a secret key to be used for encryption and decryption by using the KeyGenerator class and supplying it with a string to select the algorithm (e.g. blowfish) as in the following code snippet:

```java
KeyGenerator KG = KeyGenerator.getInstance(algorithm);
Key key = KG.generateKey();
```

Encryption Module

```java
// initialize the Cipher with the secret key
Cipher cipher = Cipher.getInstance(algorithm);
cipher.init(Cipher.ENCRYPT_MODE, key);

// creating the encrypted cipher stream
File fileIn = new File(fileName);
FileInputStream fis = new FileInputStream(fileIn);
cipherInputStream = new CipherInputStream(fis, cipher);

byte[] b = new byte[1024];

// writing the encrypted data to the output file
File fileOut = new File(fileOut);
FileOutputStream fos = new FileOutputStream(fileOut);
int i = cipherInputStream.read(b);
fos.write(b, 0, i);
```
4.2.3 Decryption Module

// initialize the Cipher with the secret key
cipher = Cipher.getInstance(algorithm);
cipher.init(Cipher.DECRYPT_MODE, key);

// creating the decrypted cipher stream
File fileIn = new File(fileName);
FileInputStream fis = new FileInputStream(fileIn);
cipherInputStream = new CipherInputStream(fis, cipher);

byte[] b = new byte[1024];

// writing the decrypted data to the output file
file = new File(fileOut);
FileOutputStream fos = new FileOutputStream(file);
int i = cipherInputStream.read(b);
fos.write(b, 0, i);

Testing Methodology and Experimental Results

In the experiment, both the elapsed time (real time or wall-clock time) and the CPU time are measured. The elapsed time takes into account everything such as disk or memory access, idle time, I/O, operating system overheads, etc. This gives a useful number but not for the comparison purpose we intend. The CPU executing time (or the CPU time) is the time the CPU spends computing a task and doesn’t consider the time spent waiting for I/O or running other programs. The CPU time is further broken down to system (kernel) time and user time. The system time is the time spent executing instructions in the kernel (kernel mode) on behalf of the user program. The user time is the time spent executing instructions in the user program (user mode). For programs running on dedicated systems and spending most of their time doing computation, the elapsed time and CPU time should be approximately equal. Discrepancies between the CPU time and elapsed time will usually occur in cases where a program is paging (or swapping) due to insufficient memory on the system.
The *time* Linux utility was used to measure the elapsed time, system time and user time of the implemented program running on the Linux platform. The results obtained are shown in Table 2.

### Table 2. Algorithms Processing Time in Seconds on Linux

<table>
<thead>
<tr>
<th></th>
<th>AES</th>
<th>Triple-DES</th>
<th>Blowfish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User</td>
<td>Kernel</td>
<td>Real</td>
</tr>
<tr>
<td>Key Generation</td>
<td>0.86</td>
<td>0.026</td>
<td>1.301</td>
</tr>
<tr>
<td>Encryption</td>
<td>2.493</td>
<td>0.43</td>
<td>4.928</td>
</tr>
<tr>
<td>Decryption</td>
<td>2.406</td>
<td>0.461</td>
<td>4.158</td>
</tr>
</tbody>
</table>

Figure 4 illustrates these results (the user time, kernel time and real time) for the three algorithms under Linux environment.

![Mandrake/Linux 8.2](image)

**Figure 4.** Linux User, kernel and real times in seconds for the three algorithms

To perform the measurements under Windows platform, a small program was written to record the user, kernel, and the total (real) time, which is the summation of the user time, kernel time, and I/O time. The program was written in C# language and it uses the `System.Diagnostics.Process` class included within the .Net Framework. The results obtained for the three algorithms are shown in Table 3.

### Table 3. Algorithms Processing Time in Seconds under Windows 2000 Pro.

<table>
<thead>
<tr>
<th></th>
<th>AES</th>
<th>Triple-DES</th>
<th>Blowfish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>User</td>
<td>Kernel</td>
<td>Real</td>
</tr>
<tr>
<td>Key Generation</td>
<td>1</td>
<td>1.01</td>
<td>2.59</td>
</tr>
<tr>
<td>Encryption</td>
<td>2.06</td>
<td>2.20</td>
<td>6.47</td>
</tr>
<tr>
<td>Decryption</td>
<td>2.08</td>
<td>2.06</td>
<td>6.27</td>
</tr>
</tbody>
</table>
Figure 5 illustrates these results (the user time, kernel time and real time) for the three algorithms under Windows 2000 Professional environment.

![Windows 2000 Professional](image)

**Figure 5.** User, kernel and real times in seconds for the three algorithms under Windows 2000

Both hardware and software implementation of encryption/decryption algorithms are available [1, 4, 5, 8, 13, 44]. However, implementing encryption algorithms in software have a tremendous impact on the processor resulting in degrading its overall performance.

Table 4 shows the CPU execution time obtained from the implemented program when run under Linux environment.

**Table 4. CPU Execution Time in Seconds (Linux)**

<table>
<thead>
<tr>
<th></th>
<th>AES</th>
<th>Triple-DES</th>
<th>Blowfish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Generation</td>
<td>0.886</td>
<td>0.851</td>
<td>0.831</td>
</tr>
<tr>
<td>Encryption</td>
<td>2.923</td>
<td>10.223</td>
<td>2.682</td>
</tr>
<tr>
<td>Decryption</td>
<td>2.867</td>
<td>12.078</td>
<td>2.695</td>
</tr>
</tbody>
</table>

Figure 6 illustrates the CPU execution time, which includes both the system time and user time for the three algorithms under Linux environment.
Performance Evaluation of AES/Triple-DES/Blowfish Ciphers under W2K and Linux
Operating System Platforms

The CPU execution time which includes both, system and user time for the three algorithms under Windows 2000 Professional is shown in Table 5 and illustrated in Figure 7.

Table 5. CPU Execution Time in Seconds (Windows 2000 Pro.)

<table>
<thead>
<tr>
<th></th>
<th>AES</th>
<th>Triple-DES</th>
<th>Blowfish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Generation</td>
<td>2.01</td>
<td>2.18</td>
<td>1.34</td>
</tr>
<tr>
<td>Encryption</td>
<td>4.26</td>
<td>12.16</td>
<td>3.5</td>
</tr>
<tr>
<td>Decryption</td>
<td>4.14</td>
<td>12.20</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Figure 6. CPU executing time in seconds (Linux)

Figure 7. CPU executing time in seconds (W2K Professional)
From Figures 6 & 7, it is clear that the key generation operation for all algorithms is almost identical. The major difference between these algorithms is the CPU time spent while performing the encryption and decryption operations.

It is clear also from Figures 4 and 5 that the AES algorithm has the shortest total (real) time followed by the Blowfish algorithm and then the TDES algorithm under both Linux and Windows platforms. However, regarding the CPU time, it is clear from Figures 6 & 7 that the Blowfish algorithm is the fastest followed by the AES algorithm and then the TDES algorithm. One reason that the Blowfish algorithm is the fastest is due to the mechanism it follows for ciphering data. It is obvious that because of the increased complexity incorporated within the TDES, which is needed to address the security issues that exist in the DES algorithm, is degrading the performance in terms of the CPU time.

Regarding the CPU time under Linux operating system platform, the results indicate that the Blowfish algorithm is faster than the AES algorithm by 10% for encryption and 6.4% for decryption. However, the blowfish algorithm is faster than the TDES by 281% for encryption and 348% for decryption.

For the CPU time under Windows 2000 platform, the Blowfish algorithm is faster than the AES algorithm by 21.7% for encryption and 18.3% for decryption. However, the blowfish algorithm is faster than the TDES by 247% for encryption and 248.5% for decryption.

In order to increase the speed of these algorithms we propose to have a built in cipher module within the processor. This will eliminate any overheads introduced when implementing encryption algorithms in software. Another proposal is to have a dedicated server responsible for secret key generation and distribution, encryption, decryption, authentication … etc. This approach is very useful for highly secured environments (e.g. the military).

Conclusions and Future Work

In this study we presented an implementation of three symmetric block encryption algorithms using Java and JCA. The main objective was to evaluate the performance of these algorithms in terms of CPU execution time and total run time. The measurements were performed on two operating system platforms, namely Windows 2000 Professional and Linux. The analyzed time was the CPU execution time for generating the secret key, encryption and decryption on a 10MB file. The results showed that the AES algorithm was the fastest followed by the blowfish algorithm then the TDES algorithm. The TDES algorithm was slow in its performance due to the added complexity and security it has over the DES algorithm.

The results obtained play a major role on selecting the appropriate encryption algorithm to use for software implementations. The author supports the idea of using a built in module within the processor dedicated for security considerations. This will have the advantage of relieving the processor from the overhead associated with implementing encryption algorithms in software. Having a built in module within the
processor will provide speed for encryption algorithms used in e-commerce and m-commerce which will be heavily demanded in the near future. Using a dedicated server is another possible proposal. This server will have the responsibility of controlling and performing all security tasks such as key generation and distribution, encryption and decryption. This server will prove beneficial in highly secured environments.

Other implementations of the three algorithms undertaken in this study are a future research interest of the author. It is important to compare different implementations with the JCE and Java implementation. We are planning to use both “C” as a high level programming language and Assembly as a low level machine language, which will enable us to optimize computation intensive parts of the ciphers. The implementation could also include dedicated types of hardware that will provide at the hardware level random number generator and built-in co-processors.

Also, as a future work, we propose two interesting ciphers to be investigated further. The first cipher belong to the Crossing Over Systems (COS) cipher family. COS ciphers are block ciphers, built only from stream ciphers primitives (nonlinear feedback shift registers and Boolean functions). These ciphers have been especially designed to yield a very high encryption security and a very high encryption speed with an internal secret 256-bit key [45].

The second cipher is the elliptic curves cryptography [46]. Elliptic Curve Cryptosystem (ECC), which was originally proposed by Niel Koblitz and Victor Miller in 1985, is seen as a serious alternative to RSA with a much shorter world length. ECC with a key size of 128-256 bits is shown to offer equal security to that of RSA with key size of 1-2Kbits. To date, no significant breakthroughs have been made in determining weaknesses in the ECC algorithm, which is based on the discrete logarithm problem over points on an elliptic curve.

Advanced Encryption Standard
Triple Data Encryption Standard (T-DES)
Blowfish

نجيب عبدالكريم الكوفي

ملخص

ي análisis: este estudio se enfoca en la evaluación del desempeño de tres cifrados: Advanced Encryption Standard (AES), Triple Data Encryption Standard (T-DES) y Blowfish, evaluando tanto bajo el sistema operativo Windows 2000 como Linux. Se propone la implementación de una entorno dedicado para realizar tareas de seguridad, como la generación y distribución de claves, cifrado y descifrado. Se planea utilizar diferentes implementaciones, como el C y la lenguaje de ensamblaje, para optimizar tareas computacionalmente intensivas. Además, se propone investigar dos cifrados adicionales: el sistema de cifrado a través de sistemas (COS) y la criptografía de curvas elípticas. Los cifrados de COS son bloques cuya implementación se fundamenta en funciones de flujo y funciones booleanas, y se diseñan para ofrecer alta seguridad y velocidad de cifrado. La criptografía de curvas elípticas (ECC) se presenta como una posible alternativa a RSA, aunque aún se necesitan avances significativos para determinar si son seguros.

281
Advanced Encryption Standard (AES)

Advanced Encryption Standard (AES) is a symmetric encryption algorithm that can be used for data encryption. It is a widely adopted standard for securing data in various applications.

Triple Data Encryption Standard (T-DES)

T-DES (Triple Data Encryption Standard) is a symmetric encryption algorithm that encrypts data three times using a key. It is an enhancement of the DES algorithm.

Blowfish

Blowfish is a symmetric encryption algorithm designed by Bruce Schneier. It is known for its speed and security.

Key Generation

The process of generating keys is crucial in encryption. Key generation often involves complex algorithms to ensure the security and randomness of the generated keys.

Encryption

Encryption is the process of converting plaintext into ciphertext using an encryption algorithm and a key.

Decryption

Decryption is the reverse process of encryption, where ciphertext is converted back into plaintext using a decryption algorithm and the corresponding key.

References


Performance Evaluation of AES/Triple-DES/Blowfish Ciphers under W2K and Linux Operating System Platforms


[16] [http://www.secinf.net/uplarticle/2/aes-performance.pdf]


284
Performance Evaluation of AES/Triple-DES/Blowfish Ciphers under W2K and Linux Operating System Platforms


Two Enhanced Fuzzy Similarity Approaches for Arabic Web Pages Classification

Ahmad T. Al-Taani* and Noor Aldeen K. Al-Awad *

Received on March 8, 2006 Accepted for publication on July 17, 2006

Abstract

In this study, two novel approaches for web page classification are presented. These approaches use fuzzy term-category relation by manipulating the maximum value of membership degree for the training data and the degree value for a test web page. Different measures methods are used in this study and compared with the proposed methods. Experimental results showed that the proposed methods "Maximum Average" and "Average Sum" had achieved good performance compared with other methods. A detailed discussion of these two methods is presented in this study.

Key words: Text classification, Machine learning, Fuzzy logic, Arabic Web Pages.

Introduction

Due to the rapid growth of the World Wide Web (WWW), there is an increasing need to automated Web page classification methods to assist Web users in organizing the large amount of information returned by search engines. These methods are also needed in constructing catalogues that organize web documents into hierarchical collections [1]. Classification is expected to play an important role in future search services. According to Chen et al. [2] "users prefer navigating through catalogues of pre-classified content".

Web page classification is a complex process and is harder than text classification because it contains noisy information such as sounds, images, navigation bars, and page formatting. So we need to make these data useful for end user who needs to manage his work depending on an accurate and efficient classification methods. It is an important to focus on the main subjects and significant content. The critical task to deal with ambiguous web pages and their embedded structure is to use some classification methods such as fuzzy set theory, or machine learning [3].

The efficiency of any approach depends on the training set and the test set and it is better to be greater than some optimistic measure or threshold value. The choice of the language may affect the classification process because of its complexity for dealing with
words and phrases, which occurs frequently in the Arabic language. Arabic language has a little volume of spreading among the web in comparison to the other languages.

In this study, two novel approaches for Arabic web page classification that were used as weighted sums are presented. These proposed approaches are called the Maximum Average (MA) and the Average Sum (AS) operators. In the Maximum Average method, the similarity between a test web page and a category is measured through calculating the maximum value of the membership degree and the relative frequency (degree value) for every term in the test document. The averages between these two values are calculated for the terms, after that the maximum value of these averages is used to classify the test web page in the accompanying category. In the Average Sum method, the averages are summed up for each category and the maximum value of these averages is selected to be the proposed category that best classifies the test web page.

Related Work

Recently much work has been done on Web-page classification. Shen et al. [1] presented a Web-page classification algorithm based on Web summarization. The authors first gave empirical evidence that ideal Web-page summaries generated by human editors can improve the performance of Web-page classification algorithms. They then proposed a Web summarization-based classification algorithm and evaluate it along with several other text summarization algorithms on the Web directory.

Dwi et al. [4] presented a fuzzy similarity approach to solve a text categorization problem. The effectiveness of various fuzzy conjunction and disjunction operators used in fuzzy similarity formula and several document representations were evaluated using test sets from three text document collections. Based on empirical results obtained from using these collections, a special case of the fuzzy similarity formula performed very well.

Al-Taani et al. [5] have presented a fuzzy similarity approach for Arabic web pages classification. The approach uses a fuzzy term-category relation by manipulating membership degree for the training data and the degree value for a test web page. Six measures are used and compared in this study. These measures include: Einstein, Algebraic, Hamacher, MinMax, Special case fuzzy and Bounded Difference approaches. These measures are applied and compared using many different Arabic web pages. Einstein measure was gave best performance among the other measures.

Yang et al. [6] proposed a method using natural language parsing, web page classification and clustering to find reliable list answers. The authors also studied the effectiveness of web page classification on both the recall and uniqueness of answers for web-based list question answering (QA).

Stephanie et al. [7] proposed an integrated classification system for Web pages and links which are based on a content analysis of 75 source pages, the almost 1,500 links they contained, and the target pages to which the links led.
Michelangelo et al. [8] described a new method for the classification of a HTML document into a hierarchy of categories. The hierarchy of categories is involved in all phases of automated document classification, namely feature extraction, learning, and classification of a new document. The authors introduced a new measure for the evaluation of system performances.

Rongbo et al. [9] proposed a Web filtering system that uses text classification approach to classify Web pages into desirable and undesirable ones. Automated text classification is done using supervised neural networks.

Lawrence et al. [10] presented in their paper new features and algorithms for automating Web-page classification tasks. The authors showed that the automated classification of Web pages can be much improved if, instead of looking at their textual content, they consider each link's URL and the visual placement of those links on a referring page. They also developed a model and algorithm for machine learning using such tree-structured features. They applied their methods in automated tools for recognizing and blocking Web advertisements and for recommending “interesting” news stories to a reader.

Eric et al. [11] analyzed the relative utility of document text, and the text in citing documents near the citation, for classification and description. The authors concluded that The combination of evidence from a document and citing documents can improve on either information source alone. And, by ranking words and phrases in the citing documents according to expected entropy loss, we are able to accurately name clusters of web pages, even with very few positive examples.

Gongde et al [12] proposed a new classifier called the kNN model-based classifier by unifying the strengths of k-NN and Rocchio classifier and adapting to characteristics of text categorization problem.

Anders et al. [13] described in their paper their approach to integrate a manually selected, catalogued and quality assessed collection of WWW-resources with a much larger robot-generated subject index via cross browsing and cross searching. They aimed at exploring different methods of automatic classification on a robot-generated subject index in order to improve resource discovery for Internet resources.

Aijun et al. [14] presented a feature reduction method based on the rough set theory and investigate the effectiveness of the rough set feature selection method on web page classification. Their experiments indicated that rough set feature selection could improve the predictive performance when the original feature set for representing web pages is large.

Hans et al. [15] proposed an iterative approach for developing fuzzy classifiers. In their approach, they used fuzzy rule-based classification systems based on labeled data. The initial model is derived from the data and subsequently, feature selection and rule base simplification are applied to reduce the model, and a genetic algorithm is used for model tuning. The authors are demonstrated their approach on the Wine data classification problem is.
Heiner et al. [16] proposed an approach for the automatic acquisition of classification rules using techniques from inductive logic programming and describe experiments in applying the approach to an existing web-based information system. The approach can be used to enhance web-based information systems with content-related metadata in terms of an assignment of pages to certain topics.

Sarah et al. [17] described a method for improving the classification of short text strings using a combination of labeled training data plus a secondary corpus of unlabeled but related longer documents. They have showed that such unlabeled background knowledge can greatly decrease error rates, particularly if the number of examples or the size of the strings in the training set is small.

Materials and Methods

Overview of the proposed approaches

The work presented in this paper consists of two main stages: Preprocessing stage (Training, Noise Elimination, and Learning), and Classification stage (Figure 1). The preprocessing stage was a goal of a previous research done by us [5]. The main objective of the research done in this work was to propose new weighted sum measures to be used in the classification process. Then the proposed approaches were tested and compared with existing weighted sum measures.

![Figure 1: The architecture of the classification flow for the enhanced approaches.](image-url)
The First Proposed Approach: Maximum-Average (MA) Approach

Starting from the test web page to decrease the possibilities of computation, the degree \( \text{Deg} (p) \) of a test page is neither calculated from the maximum-relative computation nor from the Boolean vector point of view. The relative frequency of each individual term is calculated using a novel formula 1:

\[
\text{NewDeg}(t_i) = \frac{f(t_i)}{\sum_{t \in p} f(t_j)}
\]

(1)

Where the numerator denotes the occurrence frequency of the term \((t_i)\) in the test web page, and the dominator denotes the total number of words found in the test web page. Now, for each term we need to find the maximum value of its membership value \(M(t_i,c_j)\) from formula 2:

\[
\text{NewMember} (t_i, c_j) = \text{MAX} (M(t_1,c_1), M(t_2,c_2), ... , M(t_n,c_n))
\]

(2)

After calculating NewDeg and NewMember, we calculate the average of these values to ensure that not only the highest frequency of the terms in the test document will classify the document but also the membership value will participate in the process. Now we calculate the similarity by formula 3:

\[
\text{Sim}(t_i, c_j) = \frac{\text{NewDeg}(t_i) + \text{NewMember}(t_i, c_j)}{2}
\]

(3)

Now, the category of the web page will be the one with the highest similarity value, formula 4:

\[
\text{Cat}(p) = \text{MAX} \{\text{sim}(t_1,c_1), \text{sim}(t_2,c_2), ... , \text{sim}(t_n,c_n)\}
\]

(4)

The following pseudo code describes how the Maximum-Average approach works:

// we assume that all of the terms either in the training data or in the test data are normalized
// and reduced into distinct terms, and their frequencies are already computed.

For I = 1 to X do // Calculate the membership value for each term.
    // X is the number of distinct terms in the training data.

\[
M(t_i, c_j) = \frac{f(t_i)_{in\ c_j}}{\sum_{j=1}^{M} f(t_i)_{in\ c_j}}
\]

// \( M \) is the number of categories, and \( f(t_i) \) is the frequency of the term \( t_i \) in category \( c_j \).
Repeat

For \( K = 1 \) to \( N \) do          // \( N \) is the number of distinct terms in a test web page.
    Get \( f(t_k) \)                  // \( f(t_k) \) is the frequency of the term \( k \) in the test web page.

\[
\text{NewDeg}(t_k) = \frac{f(t_k)}{\sum_{i=1}^{N} f(t_i)}
\]

\( \text{Max1} \) = \( \text{Max2} \) = 0

For \( P = 1 \) to \( M \) do
    \( \text{NewMember}(t_k, c_p) = \text{MAX}(M(t_k, c_p)) \)
    \( \text{Max1} = \text{NewMember}(t_k, c_p) \)
    // Find the maximum of the membership value for term \( t_k \)
    // \text{MAX} is a function that returns the maximum value.

Repeat

\( \text{Sim}(t_k, \text{Cat}_p) = (\text{NewDeg}(t_k) + \text{Max1})/2 \)     // Normalize the results.

\( \text{Max2} = \text{MAX} (\text{Sim}(t_k, \text{Cat}_p)) \)

Repeat

Return (\( \text{Max2} \), catp)

**The Second Proposed Approach: The Sum-Average (SA) Approach**

The degree \( \text{Deg}(p) \) of a test page is calculated as the relative frequency of each individual term through the use of equation 1. The **maximum** membership value for each term in the test document is calculated using equation 2. Then, the average is computed for each term in the test document using equation 3. The grand total for each group of terms that belongs to the same category in \( \text{Sim}(t_i, c_j) \) is calculated using the following formula 5:

\[
\sum_{t \in \rho} \text{Sim}(t, c) = \sum_{t \in \rho} \text{Sim}(t_1, c_1) + \text{Sim}(t_2, c_2) + \ldots + \text{Sim}(t_M, c_M) \tag{5}
\]

One result among these results that best classify the test web page in the correct category is selected as the best category. The maximum value of the calculated similarities is selected using Formula 6.

\[
\text{Cat}(p) = \text{MAX} \left( \text{Sim}(t_1, c_1), \text{Sim}(t_2, c_2), \ldots, \text{Sim}(t_M, c_M) \right) \tag{6}
\]
The following is pseudo code for the Average-Sum approach:

For I = 1 to X do  // Calculate the membership value for each term.
    // X is the number of distinct terms in the training data.
    \[ M(t_i, c_j) = \frac{\sum_{j=1}^{M} f(t_i) \in c_j}{\sum_{j=1}^{M} f(t_i) \in c_j} \]
    // M is the number of categories, and \( f(t_i) \) is the frequency of the term \( i \) in category \( c_j \)

Repeat

For K = 1 to N do  // N is the number of distinct terms in a test web page.
    Get \( f(t_k) \)  // \( f(t_k) \) is the frequency of the term \( k \) in the test web page.

\[ \text{NewDeg}(t_k) = \frac{f(t_k)}{\sum_{i=1}^{N} f(t_i)} \]

Max1 = 0

For P = 1 to M do
    NewMember(t_k, cat_p) = MAX(M(t_k, cat_p))
    Max1 = NewMember(t_k, cat_p)  // Find the maximum of the membership value for term \( t_k \)
    // MAXIMUM is a function that returns the maximum value.

Repeat

Sim(t_k, Cat_p) = (NewDeg(t_k) + Max1)/2  // Normalize the results.

Repeat

For R = 1 to M do
    Sum(R) = 0
    For S = 1 to N do
        Sum(R) = Sum(R) + Sim(t_s, Cat_r)

Repeat

Repeat

Max2=0

For T = 1 to M do
    If (Sum(t) > Max2) Then Max2 = Sum(t)

Repeat

Return (Max2, cat_p)
The Classification Task

We used the two proposed approaches to classifying Arabic web pages depending on the value of the similarity measures $\text{Sim}(w,c_j)$. The similarity measures were calculated for each category with the same test web page. Then the classifier chooses among these known categories the one that represents best the category of document, i.e. it can be taken from category whose membership value is the highest, which is expressed in the following equation, $\text{Cat}(p) = \max(\text{Sim}(w,c_1), \text{Sim}(w,c_2), \ldots \text{Sim}(w,c_n))$.

Experimental Results

The training data is first collected from different sources, and then normalized using the noise elimination modules, which contains the HTML stripping, stop word removing, and stemming routines. Then, the learning process begins by representing the terms as numbers to reduce their representation. In the final step, the two new proposed measures and the six other measures are applied to the web pages and compared and analyzed.

Tables 1 (A-J) show the experimental results obtained by using the 50 test web pages (5 web pages / category) collected from different web sites. The (√) mark means that the file is classified correctly by that measure; otherwise the number represents the category that classified using that measure. These categories are: 1: Autobiography (Auto), 2: Children’s Stories (Child), 3: Economics (Eco), 4: Health and Medicine (Hlth), 5: Interviews (Intrv), 6: Religion (Rlg), 7: Science (Scnc), 8: Short Stories (Short), 9: Sociology (Socio), and 10: Tourist and Travel (Trst).

<table>
<thead>
<tr>
<th>E H B A M S MA AS</th>
<th>E H B A M S MA AS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auto1</strong></td>
<td>√</td>
</tr>
<tr>
<td><strong>Auto2</strong></td>
<td>√</td>
</tr>
<tr>
<td><strong>Auto3</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>Auto4</strong></td>
<td>√</td>
</tr>
<tr>
<td><strong>Auto5</strong></td>
<td>√</td>
</tr>
<tr>
<td><strong>Child1</strong></td>
<td>√</td>
</tr>
<tr>
<td><strong>Child2</strong></td>
<td>7</td>
</tr>
<tr>
<td><strong>Child3</strong></td>
<td>√</td>
</tr>
<tr>
<td><strong>Child4</strong></td>
<td>9</td>
</tr>
<tr>
<td><strong>Child5</strong></td>
<td>√</td>
</tr>
</tbody>
</table>

(A) Autobiography (Auto) category. (B) Children’s Stories (Child) category.
Two Enhanced Fuzzy Similarity Approaches for Arabic Web Pages Classification

<table>
<thead>
<tr>
<th>E</th>
<th>H</th>
<th>B</th>
<th>A</th>
<th>M</th>
<th>S</th>
<th>MA</th>
<th>AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco1</td>
<td>√</td>
<td>5</td>
<td>√</td>
<td>10</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Eco2</td>
<td>√</td>
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(E) Interviews (Intrv) category.

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(F) Religion (Rlg) category.

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(G) Sociology (Socio) category

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(H). Science (Scnc) category.

295
Table 1(A) - (J): Experimental Results Obtained using 50 Web Pages of 10 categories.

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(I) Short Stories (Short) category.  (J) Tourist and Travel (Trst) category.

Figures 2 and 3 show the analysis and the accuracy of the two proposed approaches together with the six existing approaches. Examining these results it can be seen that the methods performed differently for all categories depending on their precision, the category itself, or the whole test set. Table 2 presents the performance of each method. We can see from this Table that the first novel approach (MA) is the most efficient approach and gave a classification rate of about 80%. The second novel approach (AS) also gave promising result, a classification rate of about 72% and came after Einstein and Bounded approaches. This means that it is more efficient than the other four approaches.

10 categories

Figure 2: Analyzing results
Two Enhanced Fuzzy Similarity Approaches for Arabic Web Pages Classification

![Algorithms accuracy graph](image)

**Figure 3:** Algorithms Accuracy

<table>
<thead>
<tr>
<th>Method</th>
<th># of pages classified Correctly out of 50</th>
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<td>Einstein</td>
<td>39</td>
<td>78%</td>
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<td>Bounded</td>
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<td>AS</td>
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<td>72%</td>
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<td>Algebraic</td>
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<td>ScFuzzy</td>
<td>29</td>
<td>58%</td>
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<td>Hamacher</td>
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<td>22%</td>
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<tr>
<td>MinMax</td>
<td>7</td>
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**Table 2:** Approaches Percentage

Since the performance of the proposed approaches are almost same as the Einstein method in terms of number of categories classified correctly, we found that the CPU time analysis is required to investigate the effectiveness of the proposed approaches. Figures 4 and 5 show the CPU time analysis for the test set. Comparing the CPU time of the two proposed approaches (MA and AS) and the Einstein approach, it can be seen that the two proposed approaches yield better results for all categories in the test set. Also we can conclude that the MA approach is more efficient that the Einstein approach and the second proposed (AS) approach.
Figure 4: The Bar Chart of the Average CPU Time per Category

Figure 5: The Line Chart of the Average CPU Time per Category
Conclusions and Future Work

The primary contribution of this work was to investigate the use of different approaches for automatically classifying web pages and to apply them to Arabic web pages then to propose new approaches. As a result, two novel approaches (MA and AS) were proposed in this study. Six measures were used in this study and compared with the proposed approaches. These measures use fuzzy term-category relation by manipulating membership degree for the training data and the degree value for a test web page.

Experimental results demonstrated the effectiveness of the proposed approaches in classifying 80% and 72%, respectively, of the 50 Arabic web pages. The CPU time analysis also proved that the proposed approaches represent an improvement over the work of earlier researchers, since the two proposed approaches gave better CPU time for all categories in the test set.

The proposed method MA is manipulated by taking the average of the maximum membership degree for the training data and the degree value for the test data, and the best category is the one with the largest average. On the other hand the AS approach is performed better than four of the conjunction/disjunction-based measures. The two novel approaches compute the classification formula from the test web page terms degrees and their related membership values.

In this research, a web page is considered as a separate document. Future work will consider increasing the efficiency of the second proposed approach AS and to classify Arabic web pages depending on their hyperlinks, in which each web page is categorized based on the group of web pages that it refers to, and recursively get the category label with the most proposed one.
طارقتيان محسن: طرق التشابه الضبابية لتصنيف صفحات الويب العربية

أحمد توفيق الطهاني و نور الدين كامل العوض

ملخص

لقد تم في هذه الدراسة عرض طريقتين جديدين لتصنيف صفحات الإنترنت. الطريقتان تستخدمان العلاقة بين المصطلحات وفته من خلال معالجة أعلى قيمه لدرجة العضوية للبيانات المدرجة وقيمة الدرجة لصفحة الإنترنت الخاصة بالاختبار. لقد تم في هذه الدراسة مقارنة الطرق المقترحة بستة مقياس من القيم المختلفة: تشمل: أينشتاين (Einstein)، المقياس الجبري (Algebraic)، المقياس الجبري (Hamacher)، عظم الأصغر (Sc fuzzy)، حالة الخاصة من الطريقة الغامضة (MinMax)، والفرق المحدود (Bounded Difference).

لقد تم تطبيق الطرق المقترحة ومقدرتها على 50 صفحة إنترنت عربية أخذت من مواقع عربية معيارية ومؤرخة لتمثل 10 أصناف مختلفة. بواقع 5 مواقع لكل صنف. في الأصناف تشمل: السيرة الذاتية، قصص الأطفال، الاقتصاد، الصحة، والطب، مقابلات، كتب، علم النفس، قصص قصيرة، علم الاجتماع، والسياحة والسفر. النتائج تظهر أن الطرق المقترحة هي أعلى معدل مع معدل “Average Sum” و مجموع المعدلات "Maximum Average".

الكلمات ذات الصلة: تصنيف النص، تعلم الآلة، نطاق الطرق الضبابية، المهمة، صفحات الإنترنت العربية، نظارات التشابه الضبابية لتصنيف صفحات الويب العربي.

References


Two Enhanced Fuzzy Similarity Approaches for Arabic Web Pages Classification


Improving the Effectiveness of Web Caching at the Client’s Site

Samia Abul-Rub* and Sami Serhan**

Received on April 14, 2003 Accepted for publication on Aug. 28, 2005

Abstract

In this paper, the performance is analyzed and evaluated in terms of hit ratio, wasted bandwidth, network traffic, and user latency under various situations, levels and architectures.

We propose configuration of a WWW caching system that would give an optimal performance of 84% hit ratio, 4.7E+9 bytes of wasted bandwidth, 6.8E+9 bytes of network traffic and 7 seconds of user latency. This configuration suggests the suitability of fully associative mapping cache memory organization at both the client’s and the proxy’s sites, least recently used replacement policy at the client’s site and least frequently used policy at the proxy’s cache.

Key words: Web caching, World Wide Web, cache memory organization, cache fetch policy, cache replacement policy, proxy servers, clients, hit ratio, wasted bandwidth, network traffic, user latency.

Introduction

Recent years have witnessed an extensive use of the World Wide Web WWW. On the Internet, traffic jams and bottlenecks have become daily occurrences. The increasing popularity of the WWW led to huge amounts of traffic traveling through the Internet and therefore, an increase in latency. Some popular Web documents may become unobtainable at peak times.

For this reason, latency reduction has been among the primary concerns of the Internet research and development community and has opened a huge area of research [1-2],[4-10].

Caching was a vital solution that could not be overlooked. The term ‘Web caching’ refers to the incorporation of caches in several sites on the Internet [21]. These sites are typically at the clients and at the proxy servers. The major problem being addressed is managing the various caching policies, strategies and organizations involved in a Web caching system in a way that leads to better performance [15,18]. Various environments...
are considered under which Web caching is implemented. The effects of different structures on the overall performance of the system are studied.

**Background And Previous Work**

Considerable work has been done on caching Web objects. In [3], [23], a LRU extension is proposed, in which Web objects are greedily removed from the cache in the order of recency of last access until enough space is created for the incoming object. Their proposal aimed at providing a model to deal with the heterogeneity of sizes for Web objects.

The work in [14] has investigated Web pre-fetching from the proxy to the browsers by taking advantage of the idle time between user Web requests and using prediction algorithms to predict the next request submitted by users. They have shown that proxy-side pre-fetching is a promising technique that can reduce user observed latency by over 20%.

In the author’s work among the Swiss Federal Institute of Technology (SFIT) [19], the advantages and drawbacks of active caching (pre-fetching) of Web content are discussed. He made his recommendations that active caching functionality must be employed in every WWW caching proxy. He has shown that up to 29.4% of the cached objects will be invalid if the cache proxy does not use active caching. Among them, 27.3% of the objects will not exist any more and 2.2% will have an updated copy on the corresponding WWW servers. His results showed that proxy caching without active caching saves only 6.3% more from original users’ traffic than proxy caching with active caching functionality.

The work in [11] showed that (30%-50%) of cache hits constitute freshness misses. He proposed Web caching refreshment policies that extend freshness lifetime by selectively validating cache objects upon their expiration. By increasing cache freshness, requested objects are more likely to be fresh and thereby are serviced faster. They demonstrated that 25% of freshness misses can be eliminated by applying a good refreshment policy.

The study in [12] has shown that there is an opportunity to improve user response time from cache by improving the cache consistency mechanism and that when a validation is returned form cache directly, it is returned approximately an order of magnitude faster than an object that requires a consistency check.

The work in [20] proposed an intelligent dynamic caching technique to model document life histories. Their simulation results showed that the frequency of requests for a document, rather than object size, is more relevant to the management of Web caches.

The authors in [24] studied partitioning dynamic pages into classes based on URL patterns and proposed a scheme allowing an application to specify page identification, cacheability, and data dependence. Their experimental results show 20% improvement in cache hit-ratios.
On the other hand, the authors in [13] examined the different approaches to Web cache consistency. They have shown that no certain mechanism prevails but that it is dependant on the highest priority performance aspect in the system, and that a weak cache consistency protocol reduces network bandwidth consumption and server load more than either time-to-live or an invalidation protocol and can be tuned to return stale data less than 5% of the time.

**The Proposed Model**

The assumptions and strategies used in our model can be summarized as follows:

- Maximum proxy cache size is 10 GB
- Maximum client cache size is 2.3 GB
- A time-out occurs at a user-latency greater than 45 seconds. Time-out is defined as the stage when no more delay is accepted and the request has to be re-issued.
- For the cache memory organization and mapping strategy, we considered Fully Associative Mapping (FAM), Direct Mapping (DM), and Set Associative Mapping (SAM).
- The following cache fetching policies were considered:
  - On demand (OD)
  - Pre-fetching based on the links in the Web object (if available) (PL). It is assumed that only 30% of the links are pre-fetched and are selected randomly.
  - Pre-fetching based on the contents of the Web object (PO). It is assumed that 40% of matching Web objects are pre-fetched and are selected randomly.
- In both pre-fetching policies, pre-fetching on miss was applied.
- Several policies have been proposed in the literature for cache replacement policies, but not all have been implemented in this study. In all replacement policies, it is assumed that all removals from the cache are done only upon need and not based on any other time-dependent criterion [23].
- The policies studied are First In First Out (FIFO), Least Recently Used (LRU), Least Frequently Used (LFU), and Random Replacement.
- Wasted bandwidth is defined as the total size of Web objects, which have been fetched at the proxy’s cache but not used by more than 10% of the clients, or the total size of Web objects, which have been fetched at the client’s cache but not used more than once.
- The Time-to-live (TTL) coherence protocol was applied. In TTL protocol, expired objects remain cached at the proxy cache. When a request is made to an expired Web object, an ‘if-modified-since’ inquiry is sent to the Web server, so that a new copy is retrieved only if the object has actually been modified (the copy currently at
the proxy cache is stale). The TTL coherence protocol has been chosen, for its implementation simplicity.

**Workloads**

The workloads used in this study are classified as follows: Artificial workloads and Real-system workloads

**Artificial workloads**

The reason behind using artificial workloads is to generate representative access patterns that are possible and significant but are not easily found in real-systems’ traces.

In this work, the following patterns were considered:

- **Varying the degree of temporal locality**

  Temporal locality can be generalized by assuming that when a certain Web object, WO, is referenced at time T and followed by a request sequence RS, it is likely when WO is referenced at time T+t, that RS will also follow. Artificial workloads were used to vary the degree of the causes of temporal locality and study the effects of these variations on the performance of Web caching.

- **Varying the degree of spatial locality**

  The general description of spatial locality can be stated as follows:

  If an access is made to a Web object, WO, and that object was found in location L, then the next R references are likely to be found in the same location L. L could be a client cache, a proxy cache, a peer cache or a Web server.

**Real-system workloads**

Real-system workloads are essential in order to reflect the reality involved in a Web caching system. The workloads used in this study were collected at different organizations. Access traces were collected from four proxy servers at four different sites (named JU, PU, AS, and ASG) distributed throughout the Internet.

Table 1 summarizes the traces. All traces were taken from one proxy server per system.

Three sites used MS Proxy Server version 2.0 while the fourth used Netscape Proxy Server version 3.5. In all the traces, the initial misses have been included.

The choice of sites was based on providing two separate environments and studying the effects of such environments on the performance of the system. Environments cover requests in a particular field and requests that represent public Internet access in which varying interests (access to different unrelated Web objects) resemble the users of the system.
The Neutral Environment

We have conducted a total of 16 experiments. All experiments have been built and designed based on one ‘neutral environment’. This environment defines the set of Web caching parameter values that are considered neutral so that when studying a certain factor in any experiment, the study assumes that other factors have their values assigned by that neutral environment. Table 2 defines the neutral environment.

Table 1: real-system workloads

<table>
<thead>
<tr>
<th>Site</th>
<th>Collection Period</th>
<th>No. of Clients</th>
<th>Requests (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JU</td>
<td>Sep 1999 – Apr 2001</td>
<td>150</td>
<td>11.5</td>
</tr>
<tr>
<td>PU</td>
<td>Apr 2000 – Jun 2001</td>
<td>35</td>
<td>9.4</td>
</tr>
<tr>
<td>AS</td>
<td>Dec 2000 – Jun 2001</td>
<td>60</td>
<td>7</td>
</tr>
<tr>
<td>ASG</td>
<td>Nov 1999 – Jul 2001</td>
<td>46</td>
<td>21.4</td>
</tr>
</tbody>
</table>

Table 2: definition of the ‘neutral environment’

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Proxy</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory Organization</td>
<td>FAM</td>
<td>FAM</td>
</tr>
<tr>
<td>Fetch Policy</td>
<td>OD</td>
<td>OD</td>
</tr>
<tr>
<td>Replacement Policy</td>
<td>LFU</td>
<td>LRU</td>
</tr>
<tr>
<td>Cache Size</td>
<td>6 GB</td>
<td>800 MB</td>
</tr>
</tbody>
</table>

Results and Analysis

We now present the results obtained from our experiments. Some experiments operated on artificial, others on real-system workloads. We classify the results as follows:

- The influence of Temporal and Spatial Localities

As shown in Figure 1, the hit ratio increases with increasing temporal locality. This is a logical consequence, as more clients require the same Web objects, which are present in the cache.

Spatial locality does not acquire the same gradual increasing behavior as temporal locality. At some stages, decreases in hit ratios followed by increments as spatial locality increases are noted. This irregular behavior is directly related to the nature of location L. Whenever L is a cache, the hit ratio increases, otherwise, it decreases.

For the same reasons addressed in hit ratio, as temporal locality increases, wasted bandwidth, network traffic and user latency all decrease as shown in Figures. 2 to 4.
- The influence of Proxy Cache Size

Figures 5 to 8 show the results on proxy cache size. The four real-systems at hand are examined the following results and analysis are concluded:

- All four systems tend to stabilize at cache size equal to 9 GB, with minor jumps in hit ratios.
- The consequence of increasing the cache size is more noticeable when traces were taken from sites where the degree of ‘similarity in interests’ is high.
- When the system’s environment itself forces a high degree of variations in interests, even when a document is in cache, it will only be referenced by very few clients if not only by the requesting client. In such environments, the proxy cache size has a slow effect.

Figure 6 examines the effects of proxy cache size on wasted bandwidth.

![Figure1: The influence of temporal and spatial localities on hit ratio.](image1)

![Figure2: The influence of temporal and spatial localities on wasted bandwidth.](image2)

![Figure3: The influence of temporal and spatial localities on network traffic.](image3)

![Figure4: The influence of temporal and spatial localities on user latency.](image4)
In Figure 7, traffic is studied over proxy cache size. It is concluded that the ‘similarity of interests’ issue is a major environmental factor influencing the amount of traffic.

The influence of proxy cache size on user latency is illustrated in Figure 8.

- The influence of optimizing the Proxy Cache Size

The purpose of this experiment was to study how dominating the stabilizing proxy cache size is. By examining Figures 5 to 8 and analyzing the results, this experiment has taken 8 GB as a stabilizing cache size starting point. The size is forced on 50% of the system’s proxy caches. Figures 9 to 12 demonstrate the results of the experiments. The word ‘average’ is added to describe the y-axes as in this case 50% proxy caches of 8 GB have been taken as a basis and varied the rest of the proxy caches in several cases and taken the average of all. The following is concluded:

- A very high increase in hit ratios reaching almost 50% is noted. This implies the strong effectiveness of proxy cache sizes on a Web caching system having an incremental relationship with hit ratio as shown in Figure 9.

- Only a slight reduction (compared to what was obtained on hit ratio) was observed on wasted bandwidth. Going back to the definition of wasted bandwidth - total size of fetched Web objects not used by more than 10% of clients, it is analyzed that the results of Figure 10 are not surprising. Having more Web documents at the proxy cache (with a larger cache size) does not necessitate having those documents requested by more than 10% of clients and, therefore, in this case, the ‘similarity of interests’ factor dominates as well. The same applies to network traffic.

- Figure 11 shows considerable reduction in traffic over the network happening. With larger proxy servers’ caches, the amount of traffic traveling between proxies and Web servers is reduced.

- The influence of different Memory Organizations at the Proxy and the Client sites

The order in which the rest of the experiments, addressed next, were conducted was different. Under a certain test parameter (memory organization, fetch policy, and replacement policy), the experiments study all different possible value assignments for that parameter on all evaluation criteria (hit ratio, wasted bandwidth, network traffic and user latency). The purpose of following this mechanism is our belief that it would help analyze influences on the tested evaluation criterion in more depth.

The word ‘average’ was added to all y-axes of the results of these experiments to reflect the fact that, in each case, the average of the four real-systems have been taken. Moreover, in all these systems, whenever a client is marked by value X, it is meant 70% of the clients, the other clients varied and the average of all cases was taken. In addition, whenever a proxy is marked by value Y, it means 100% of proxies, i.e. homogeneous proxies. In this analysis, each criterion is considered separately.

Figure 13 shows the effects of varying the clients’ cache memory organization over different proxies’ cache memory organizations on hit ratio. Regardless of the proxies’
memory organization, it is noted that FAM performs better than either DM or SAM. However, the best hit ratio was obtained when proxies also have a FAM organization, giving a hit ratio as high as 87%. SAM then followed and last was DM giving the lowest hit ratio in all cases. This is again due to the flexibility of FAM over the other memory organizations. It is also concluded that proxies with DM caches will considerably degrade the performance, offering a maximum average hit ratio of only 48%.

The results on wasted bandwidth are shown in Figure 14. And those on network traffic in Figure 15. By observing these results, it is concluded that flexibility is the dominating factor concerning memory organization. The same applies for user latency as shown in Figure 16. The results obtained strongly reject using DM at the proxy’s site.

- **The influence of different Fetch Policies at the Proxy and Client sites**

  Figure 17 shows the influence on hit ratio. It is noted that an OD proxy cache has the worst
Improving the Effectiveness of Web Caching at the Client’s Site

performance. This can be explained by stating that proxies serve requests to a considerable number of clients, and those clients do have a minimum degree of temporal locality between them. The use of OD results in many Web objects being removed from cache while still needed and as a side effect, a reduced hit ratio. On the other hand, pre-fetching at the proxy site with both its types perform better. A PO proxy however, gives the best results.

Pre-fetching 40% of matching Web objects helps in obtaining high degrees of hit ratio, as these objects will be available to all clients, and it is likely for the clients to access different pre-fetched objects. Again, it appears that a matching contents criterion is better compared to available attached links.

At the client’s site, it is observed that clients are at their best performance, when the documents are fetched only upon need, i.e. when using OD. It is concluded that when PL and PO are used, hit ratio is reduced since pre-fetching removes needed documents from the clients’ caches. In addition, very low percentage of the links and matching pre-fetched objects is used, as they are not needed. OD is sufficient with a pre-fetching
proxy, as different clients are able to find their requested objects in a nearby proxy upon their need.

Figure 18 shows the influence of fetching policies on wasted bandwidth. It is noted that an OD proxy continues to give the worst performance by wasting high percentage of bandwidth. This is because, when a proxy demands a Web object, that demand is a subsequent to a client’s request. Other clients are likely to request matching or linked objects but not exactly the same copy present in the cache, which leads to a high degree of wasted bandwidth. Therefore, pre-fetching outweighs OD in its benefits. For the same reasons mentioned when discussing hit ratio, PL then follows providing lower wasted bandwidth and PO gives the lowest. At the client’s side, OD is best in reducing wasted bandwidth, followed by PL and then PO.
The influence of different fetch policies on network traffic is shown in Figure 19. With OD clients, traffic was high in both an OD and a PL proxy. The purpose of pre-fetching is to reduce traffic on the long run, so traffic is reduced whenever pre-fetching is applied. However, it is noted that OD clients gave the lowest network traffic. This is because a PO proxy was used and a high number of clients found their requests in the proxies’ caches and kept a copy in theirs, so at some stage, traffic was limited to only that required by the coherence protocol. In general a PO proxy gave the lowest network traffic. It is noted however, that heterogeneity in the clients and proxies pre-fetching policies leads to high network traffic as the amount of bytes traveling is maximized due to first pre-fetching links at the proxy’s cache and then matching Web objects at the client’s cache or vise versa.
In this experiment, the effects of different replacement policies are examined. By observing the hit ratio shown in Figure 21, it is concluded that the best performance is obtained when using LFU on the proxy side and LRU at the client’s side. Random replacements had extremely low hit ratios. FIFO on the other hand had a somewhat similar effect as that of LRU but at a lower scale. At the proxy’s side, frequency has proved to be a better replacement policy than recency.

Recency, on the other hand, was a better policy at the client’s site. Since proxies serve requests to multiple clients, the least recently used Web documents are not actually the least wanted documents, but least frequently used documents are. At the client’s site, the least recently used documents are those less likely to be referenced in the near future. The results strongly reject random replacement at the proxy side. Moreover, FIFO replacement has not proved to be a performing policy as with increasing locality and some special circumstances, the first Web objects entering the cache are highly requested.

The results obtained on wasted bandwidth and network traffic are shown in Figure 22 and Figure 23 respectively.

The more complex a replacement policy is, the more latency is expected at the clients’ side. However, the results obtained on user latency and those shown in Figure 24 suggest that a good replacement policy at the proxy’s and clients’ sides prove to offer lower user latency on the long run.

**- The influence of Homogenous and Heterogeneous Proxies**

In all previous experiments, only homogenous proxies were studied at a time. Alternatively, heterogeneous proxies can be used. It is important to examine the effects of incorporating heterogeneous proxies. Heterogeneity can be at various levels including memory organization, fetch policy, replacement policy and prediction strategy. In this experiment, heterogeneity was varied at one level at a time and the average of all has been taken. A strong recommendation of homogeneous proxies is concluded.

The further complexity that heterogeneity creates, results in more wasted bandwidth, traffic and latency reaching to almost one minute as shown in Table 3, which has a direct effect on reducing the hit ratio.
Improving the Effectiveness of Web Caching at the Client’s Site

7. Summary and Conclusion

Having conducted the previously mentioned experiments, analyzed and made conclusions from the obtained results, implications and recommendations for a Web caching system design are now drawn:

- All factors considered in the evaluation criteria have an important participation in the performance of a Web caching system. The degrees of this participation are shown in Table 4. It is noted that there is no dominating criterion; all have a considerable influence on the performance of a Web caching system.

- The following configurations are recommended:
  - Client cache size: Minimum client cache size of 2 GB.
  - Proxy cache size: Minimum client cache size of 8 GB.
- **Cache memory organization**: FAM for both the client’s cache and the proxy’s cache.

- **Cache fetch policy**: On-demand client cache and pre-fetching at the proxy cache based on matching Web contents are recommended.

- **Cache replacement policy**: LRU client cache replacement policy and LFU for proxy caches.

- The use of homogeneous proxies.

The previous recommendations lead to an optimal system performance of 84% hit ratio, 4.7E+9 bytes wasted bandwidth, 6.8E+9 bytes network traffic and 7 seconds user latency.

**Table 3**: The Average Influence of Homogeneous and Heterogeneous Proxies

<table>
<thead>
<tr>
<th>Factor</th>
<th>Homogeneous</th>
<th>Heterogeneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hit ratio</td>
<td>70</td>
<td>24</td>
</tr>
<tr>
<td>Wasted bandwidth*</td>
<td>6.83</td>
<td>16.7</td>
</tr>
<tr>
<td>Network traffic*</td>
<td>8.83</td>
<td>18.5</td>
</tr>
<tr>
<td>User Latency</td>
<td>24</td>
<td>29</td>
</tr>
</tbody>
</table>

* Measured in e+9 units

**Table 4**: Percentage Average of the Influence of Each Evaluation Criterion

<table>
<thead>
<tr>
<th>Evaluation Criterion</th>
<th>Memory Organization</th>
<th>Fetch Policy</th>
<th>Replacement Policy</th>
<th>Prediction Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hit ratio</td>
<td>23</td>
<td>31</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>Wasted bandwidth</td>
<td>22</td>
<td>32</td>
<td>28</td>
<td>18</td>
</tr>
<tr>
<td>Network traffic</td>
<td>23</td>
<td>27</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>User latency</td>
<td>21</td>
<td>28</td>
<td>29</td>
<td>22</td>
</tr>
</tbody>
</table>
Improving the Effectiveness of Web Caching at the Client’s Site

تحسين كفاءة الكاش في الويب عند طرف المتصفح

سامي سرحان و سامي أبو الورث

ملخص

يتم في هذا البحث تحليل وتقسيم الأداء من حيث نسبة الإصابة. عرض النطاق الترددي الضائع، حركة مورشة الشبكة، وتأخير المستخدم، في حالات ومستويات وهمي متناقشة. نظر في هذا البحث شكل لانظام ذاكرة كاش خاص بشبكة الويب العالمية بحيث أداء مثالي تصل فيه نسبة الإصابة إلى 84% وعرض نطاق تردد ضائع تردد ضائع (4.7E+9 bytes) وحركة مورشة على الشبكة (6.8E+9 bytes) و7 ثوان تأخير للمستخدم. يفترض هذا الشكل ملاءمة تنظيم ذاكرة كاش ذات التخطيط كامل الربط في كل من موقع الوكيل والموقع. يقترح هذا الشكل ملاءمة طريقة الأقل استنديلاً الاستبدال عند موقع الوكيل وطريقة الأقل تواتر استخدام عند موقع الوكيل.

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Mathematical Model of Real Physical Processes in Control Systems

Mamoun S. Al Rababaa *

Received on March 31, 2005 Accepted for publication on April 10, 2006

Abstract

This work is devoted to the creation of the mathematical model of electromechanical state of power supply node of the control system of actuating induction motors with squirrel-cage rotors and massive hollow ferromagnetic and non-magnetic rotors. The method of analysis is based on combining the methods of nonlinear electromagnetic circuits and electromagnetic field in nonlinear continuous movable medium. The created algorithms and computer programs of transient processes calculation account uneven changes of commutation currents in the magnetization windings. The matter is that the transient process calculation is not available without accounting such phenomenon shown. The results of computation of transient electromechanical process of power supply node of four actuating induction motors supplied by common transformer given.

Key words: control system, actuating induction motor, transformer, power supply node, electromagnetic field, transient processes.

General characteristic

The problem urgency. The recent events of mathematical modelling achievements have great opportunities for investigations of real physical processes in control systems and their elements in all their complication. It became possible to own successful combining achievements of computer mathematics and quick effective electronic-computing machines. [1,7].

The experience shows that it is possible to give the most detailed description of electromagnetic processes, which take place in the whole control system and in its elements separately, in general case on the basis of combining the electromagnetic field equations and the equations of electromagnetic circuits.[5].

It is recommended that all possible actuating electromagnetical devices, the actuating induction motors play special part among them, should be regarded as the most important control system elements.
Adopted mathematical models of the motors themselves as well as transformers exist at present. However, availability of motors of diverse types as well as transformers in control system, unlike their individual work, are qualitatively different concepts. In the system, they form the common oscillatory system because its interchange of electromagnetic energy is typical. Such oscillating system as a rule, is formed by power supply nodes of induction motors from the common transformer. Of mathematical modeling and computer simulation the power supply nodes of this kind are worth being considered as multi-functional elements of the system.

The work investigates commutation and transient processes of supply power nodes of actuating induction motors as a control system element.[9].

There are three main constructions of actuating induction motors: with a short circuit squirrel-cage rotor, with a massive ferromagnetic rotor and with a massive nonmagnetic rotor.[3]. Mathematical models of motor with short circuit rotor are constructed on basis of non-linear electromagnetic circuit theory, and those ones with massive ferro- and nonmagnetic rotors are constructed on mutual combining of the electromagnetic circuit theory, and the electromagnetic field theory.[2,6]

Typical group power supply node of induction motors through the transformer from the source of total power is considered as a control system element. It is natural that all possible control influences, feedbacks etc. are fed to the motors of such node. But as in thesis the processes are considered within time range, account of all these factors is not difficult. It is sufficient here to introduce this or other functional dependence into the equations of certain motor winding. These problems being solved for this or for another specific case, the author of thesis concentrated on the construction of united equation system of electromechanical state of supply power node of motors.

Analysis of transient processes of control system based on differential equations of state assumes assignment of initial conditions - the unknown values at the moment $t = +0$. The initial conditions depend on both the previous circuit state and its state at $t > 0$.

Power supply node belongs to $D$-degenerated ones, that is why uneven changes of currents in the electrical windings are possible in commutation condition. As the investigation shows calculation of the subsequent process is not practically available without accounting of this phenomenon. A very significant place in thesis is devoted to the solution of this complicated problem.

The next very significant problems for theory and practice have been solved in the work:

- method of differential equation construction of electromechanic state of power supply node of actuating induction motors with short circuit and massive ferro-and nonmagnetic rotors as a control system element has been suggested;[10,11].
- method of account of uneven changes of currents in induction windings of the node elements, conditioned by electrical commutations has been worked out;
Mathematical Model of Real Physical Processes in Control Systems

- algorithm of simultaneous integration of mixed non-linear differential equations with ordinary and partial derivatives of electromechanical state of the node of actuating induction motors, which foresees all possible commutation changes, has been elaborated;

- computer program of transient electromechanical processes calculation of power supply node of control system with actuating induction motors with short circuit, ferro- and nonmagnetic rotors has been developed.[9].

Objective and investigation problems. This work develops the methods of transient electromechanical processes analysis of power supply node of actuating induction motors with short circuit and massive hollow ferro- and nonmagnetic rotors as an element of control system, with account of instantaneous commutation distribution of currents in the magnetization windings.

To achieve this aim it was necessary to solve the following main problems:

- to construct differential equations of electromechanical state of actuating elements of the system on basis of the methods known in published research works;

- to construct differential equations of electromechanical state of power supply node of actuating induction motors in the node coordinate basis;

- to adapt general commutation rules to the equations of power supply node of induction motors in the node coordinate basis.

Scientific innovation of the obtained results:

- method of construction of mixed non-linear differential equations of electromechanical state of power supply node of actuating induction motors as an element of control system was worked out;

- method of account instantaneous distribution of commutation currents in magnetization windings of power supply node elements of actuating induction motors was worked out;

- algorithm and computer program of calculation of transient electromechanical processes of power supply node of actuating induction motors with short circuit and massive ferro- and nonmagnetic rotors which foresees uneven changes of commutation currents in electrical windings were constructed.[9,10]

Investigation methods. Theoretical investigations are grounded on nonlinear differential equations of circuits in ordinary derivatives, on the method of node voltages in ordinary derivatives, on the method of node voltages in time range for circuits, on nonlinear differential equations in partial derivatives of quasi-stationary electromagnetic field, on nonlinear differential equations of motion in ordinary derivatives, on methods of numerical solving of non-linear differential equations, on methods of solving of non-linear algebraic equations, on the algorithmic language PC.
**Practical significance of the obtained results.** Computer calculation programs of electromechanical transient processes of power supply node of actuating induction motors with short circuit and massive ferro- and nonmagnetic rotors from the source of total power can be used for analysing the existing control system and elaborating the stage of new systems design.[8,9].

**General contents of work**

It contains grounded urgency, scientific novelty and practical value of the work, formulated objective of investigations and main statements which are submitted to defence.

Main theoretical statements of work on basis of which there are constructed mathematical models of element of control system, methods of formation of differential equations of electrical and electromagnetic circuits, methods of initial conditions calculation at uneven changes of commutation currents.[4,9]

**Electric circuit.** The subcolumns of current path set branches of electrical circuit is given as follows

\[
\frac{dI}{dt} = M_r U_r + N_r; \quad \frac{dI}{dt} = M_s U_s + N_s, \quad \text{.............................................................. (1)}
\]

where \(U_r, U_s, I_r, I_s\) are correspondingly the subcolumns of voltages and currents of edges and chords of graph, the matrixes \(M\) and the subcolumns \(N\) including the differentiation symbol by time.[3].

The equation of circuit given by the method of node voltages is

\[
AU = X; \quad U = F U, \quad \text{.............................................................. (2)}
\]

where

\[
A = M + F M F^T, X = -N - F N, \quad \text{.............................................................. (3)}
\]

\(F^T\) is the topological matrix;

\(F^T\) is the transpose matrix \(F\).

**Electromagnetic circuit.** Differential equations of pathes which belong to edges and chords of graph, magnetic subcircuit are given as analogue of (1)

\[
\frac{dV_p}{dt} = S_p - P_p \frac{d\Phi_p}{dt}; \quad \frac{dV_s}{dt} = S_s - P_s \frac{d\Phi_s}{dt}, \quad \text{.............................................................. (4)}
\]

where

\(V_p, V_s, \Phi_p, \Phi_s\) are correspondingly the voltage and magnet fluxes subcolumns of edges and chords of graphs;
Mathematical Model of Real Physical Processes in Control Systems

$S, S'$ are the subcolumns of input signals;
$P, P'$ are diagonal matrixes of differential magnetic resistances.

The structural equations of magnetic subcircuit are given as

$$\frac{d\Phi_t}{dt} + F \frac{d\Phi_s}{dt} = 0; -F \frac{dV_p}{dt} + \frac{dV_x}{dt} = 0. \quad \cdots (5)$$

The expressions (4), (5) form the full system of non-linear differential equations of electromagnetic circuit.

Methods of time sampling of ordinary non-linear differential equations on explicit and implicit principles are introduced later.

The theories of transformer and actuating induction motors with short circuit and massive ferro- and nonmagnetic rotors with three-phase as well as with two-phase stators are considered.

The differential equations of three-phase transformer are constructed according to winding currents and phase fluxes are as follows

$$\frac{dI_j}{dt} = S_j U_j + T_j U_s + E_j, \quad j = 1, 2, \quad \frac{d\Phi}{dt} = W(t), \quad \cdots (6)$$

The coefficient matrixes are

$S_1 = A_1; \quad S_2 = A_2; \quad T_1 = A_2; \quad T_2 = A_1;
E_1 = -A_1 R_1 I_1 - A_2 R_2 I_2; \quad E_2 = -A_3 R_1 I_1 - A_4 R_2 I_2,$

$$A_i = \alpha_1 (1 - \omega_1 D_1); \quad A_2 = \beta_2 \omega_2 D_2; \quad A_3 = \beta_3 D_3; \quad A_4 = \alpha_2 (1 - \omega_2 D_2); \quad D_1 = \beta_1 \omega_1 G; \quad D_2 = \alpha_2 \omega_2 G; \quad \cdots (7)$$

$$G = \frac{1}{\lambda_A \lambda_B + (\lambda_A + \lambda_B) \lambda_C} \begin{vmatrix} 2\lambda_B + \lambda_C & \lambda_B - \lambda_C \\ \lambda_A - \lambda_C & 2\lambda_A + \lambda_C \end{vmatrix},$$

$$\lambda_i (i = A, B, C) = 1/\rho_i'' + \alpha_1 + \alpha_2,$$

where

$w_i$ is the number of turns of transformer windings;
$\alpha_i$ are the reverse inductances of winding dissipation;
$\lambda_i$ are the magnetic conductances;
$\rho''(\Phi)$ are the differential magnetic resistances of cores of transformer phases;
$R_i$ are the resistances.
The equation of the single-phase transformer is a special case among the considered ones.

Actuating induction motor can also operate both in three-phase regime and in power supply regime from two independent sources namely, excitation and control.[9].

The differential equations of three-phase motor with short circuit rotor assume the form.

\[ \frac{d i_j}{dt} = S_j u_j + T_j u_s + E_j, \quad j = S, R, \]

where the indexes S and R indicate correspondingly the relation to stator and rotor, while

\[ S_j = A_j; \quad T_j = A_{jk}; \]

Elements of the submatrixes and subcolumns (8), (9) for the case of three-phase stator is found as

\[ E_j = -A_j R_j + A_{jk} (\Omega_k \Psi_k - R_k j_k); \quad j, k = S, R, \]

\[ A_S = \alpha_S(1 - \alpha_S G), \quad A_R = \alpha_R(1 - \alpha_R G), \quad A_{SR} = -\alpha_S \alpha_R G, \]

\[ G = \begin{bmatrix} T + b_A l_A & b_B l_A \\ b_A l_B & T + b_B l_B \end{bmatrix}, \quad \Omega_n = \frac{\omega}{\sqrt{3}} \begin{bmatrix} -2 & -1 \\ 1 & 2 \end{bmatrix}, \]

\[ b = \frac{(R - T)}{i_m^2}; \quad b_A = \frac{2}{3} b \cdot (2i_A + i_B); \quad b_B = \frac{2}{3} b \cdot (i_A + 2i_B), \]

\[ i_A = i_{SA} + i_{RA}; \quad i_B = i_{SB} + i_{RB}; \quad i_m = \sqrt{i_A^2 + i_B^2 - i_A l_B}, \]

\[ \Psi_{jk}(j = S, R; k = A, B) = \frac{i_k}{\tau} \cdot \frac{j_k}{\alpha_j}; \]

\[ T = \frac{1}{\tau + \alpha_S + \alpha_R}; \quad R = \frac{1}{\rho + \alpha_S + \alpha_R} \]

where

\( \omega \) is the angular rotational velocity of rotor;
\( \Psi_S, \Psi_R \) are full magnetic flux linkages of stator and rotor;
\( \alpha_S, \alpha_R \) are the reverse leakage inductances of stator and rotor windings;
\( \rho = \rho(i_m) \) is the reverse differential inductance of the machine; \( \tau = \tau (i_m) \) is the reverse static inductance of the machine.

The angular rotational velocity is determined from the equation of motion
\[
\frac{d\omega}{dt} = \frac{\rho_0}{J} \left( \sqrt{3} \rho_0 (\Psi_{SA} i_{SB} - \Psi_{SB} i_{SA}) - M_m \right), \hspace{1cm} \text{(11)}
\]

where

- \(\rho_0\) is a number of magnetic poles;
- \(M_m\) is the moment of resistance;
- \(J\) is the summarized inertia moment.

Corresponding equations of motor with two-phase stator are given in work.

In massive rotor body of actuating induction motor with massive rotor intensive eddy currents are induced, for their accounting one should use combining methods both of the theory of electromagnetic circuits and the theory of electromagnetic field.[5,12].

At present, the equation of motor with ferromagnetic rotor with double-phase stator is considered in contrast with the previous case. The equation of stator circuit is in the form of

\[
\frac{di_s}{dt} = S \mu_s + E_s, \hspace{3cm} \text{..........................................................(12)}
\]

where

\[
S_j = \begin{bmatrix} \alpha_{SA} & \alpha_{SB} \\ \alpha_{SB} & \alpha_{SA} \end{bmatrix} Q_s; \hspace{0.5cm} T_j = 0; \hspace{0.5cm} E_j = -\alpha_s (R_s i_s + Q_s).
\]

\[
Q_s = \frac{1}{R} \left( c_p \int_{-\pi/2}^{\pi/2} \frac{\partial E(R,\alpha)}{\partial \alpha} \cos(\alpha + \gamma) d\alpha; c_v \int_{-\pi/2}^{\pi/2} \frac{\partial E(R,\alpha)}{\partial \alpha} \sin(\alpha + \gamma) d\alpha \right), \hspace{1cm} \text{.....(13)}
\]

where \(i_s\) is the column of excitation and controls the currents of stator winding;
- \(R_s, \alpha_s\) are the active resistance and the reverse dissipation inductance of stator winding;
- \(E(R,\alpha)\) is the value of electrical field intensity on rotor surface as the function of angular coordinate \(\alpha\);
- \(c_p, c_v\) - are the constant coefficients.
Computation of $E(R, \alpha)$ is connected with integration the equations of quasi-stationary electromagnetic field in rotor body.

The equation of electromagnetic field in rotor massive is constructed according to vector potential of electromagnetic field in cylindrical coordinate system

$$\frac{\partial A}{\partial t} = \frac{1}{\gamma} \left( \frac{\partial^2 A}{\partial r^2} + \frac{\gamma}{r^2} \frac{\partial^2 A}{\partial \alpha^2} + \left( \frac{\gamma}{r} + \frac{\partial}{\partial r} \right) \frac{\partial A}{\partial r} + \frac{1}{r^2} \frac{\partial}{\partial \alpha} \frac{\partial A}{\partial \alpha} \right) - \omega \frac{\partial A}{\partial \alpha}, \quad \ldots \ldots \ldots (14)$$

where

- $A$ is the axial component of vector potential;
- $\omega$ is the angular velocity;
- $\gamma$ is the electrical conductivity;
- $\nu = H(B)/B = \nu(B)$ is the static reluctivity of medium;
- $r, \alpha$ are the spatial coordinates.

The borders of integration (14) is located within $R_1 \leq r \leq R, -\pi/2 \leq \alpha \leq \pi/2$, where $R_1, R$ are the internal and the external radius of rotor body.[9].

Modulus and radial and angular components of magnetic induction vector and axial component of vector of electrical field intensity of vector in the lateral section of rotor is computed in the form of

$$B = \sqrt{B_r^2 + B_\alpha^2}; \quad B_r = \frac{1}{r} \frac{\partial A}{\partial \alpha}; \quad B_\alpha = -\frac{\partial A}{\partial r}; \quad E = \frac{\partial A}{\partial t}, \quad \ldots \ldots \ldots (15)$$

where $B_r, B_\alpha$ are the radial and the angular components of vector of magnetic induction.

Boundary conditions on the external ($r = R$) and internal ($r = R_1$) rotor surfaces and lengthwise the radiuses of integration limits are in the form of

$$\left. \frac{\partial A}{\partial r} \right|_{r=R} = -B_\alpha (R, \alpha), \quad \left. \frac{\partial A}{\partial \alpha} \right|_{r=R_1} = 0 \quad A(r, \pi) = -A(r, 0), \quad \ldots \ldots \ldots (16)$$

at this:

$$\nu_a (R, \alpha) B_a (R, \alpha) = \frac{\sqrt{3}}{R} \left[ \frac{\rho_m \Psi_A}{\pi \rho_o^2} \left( \frac{2w}{\pi \rho_o^2} \right) \cos(\alpha + \gamma) \right]$$

$$326$$
where $\rho_m$ is the static magnetic resistance of stator and spatial interval.

The differential equations of electromagnetic state (12), (14) are supplemented by the differential equation of motion.

Corresponding equations of electromechanical state of motor with aluminium rotor, and the equations of both motors with three-phase stator have been obtained in paper.

Mathematical models of transformers and actuating induction motors used as supplements of their supply power nodes from energy sources.

In Fig. 1 there are shown calculation curves of angular speed of actuating induction motors with ferromagnetic rotor (1) and with nonmagnetic rotor (2) in the restart regime.

![Fig. 1. Calculation curves of angular velocity of actuating induction motor with ferromagnetic rotor (1) and with nonmagnetic rotor (2) in restart regime.](image)

In Fig. 2 there is shown distribution of vector potential in cross-section of massive rotor of actuating induction motor in one of transient processes at the fixed time.
Fig. 2. Vector potential distribution in cross-section of massive rotor actuating induction motor in one of transient processes at the fixed time

Mathematical models of power supply nodes of actuating induction motors are constructed.

In Fig. 3 there is shown the diagram of control system that contains two power supply nodes (two transformers 1 and 4, three actuating induction motors 3, 5, 6, the filter 2 and the resistive load 7). The equation (2) of such complicated electromechanical system, providing the transformer 4 is related to the graph tree, are in the form of

\[
\begin{bmatrix}
S_{41} + S_{52} + S_2 + S_{33} \\
T_{41} \\
T_{42} \\
S_{42} + S_{55} + S_{56} + g \frac{d}{dt}
\end{bmatrix}
\begin{bmatrix}
U_{41} \\
U_{42}
\end{bmatrix}
= \begin{bmatrix}
E_{41} - E_{42} - T_{42} U_{41} + E_2 + E_{53} \\
E_{42} - E_{55} - E_{56}
\end{bmatrix}
\]

Having solved at every time step and integration (18) according to node voltages (they are voltages of the transformer 4 simultaneously), the full system of electromechanical state equations disintegrates into the equations of isolated elements (6), (8), (11), (12), (14).

Transient regimes in electrical circuits of power supply nodes of actuating induction motors are often accompanied by uneven changes of currents in windings of electrical
machines and transformers, this is conditioned by necessity to keep up Kirchhoff’s law at the moment of time \( t = +0 \). Accounting of this phenomenon is accomplished on the grounds of construction of the equivalent inductance circuits. They are obtained from the output diagram of connections of shorting out all the elements except of inductions coils. The diagram, which conforms to the diagram in Fig. 3, is shown in Fig. 4.

\[ I_p(+0) + FI_x(+0) = 0; \]
\[ -F\Psi_p(+0) + \Psi_y(+0) = \Psi(-0), \]
\[ \Psi_p, \Psi_x \text{ are the matrixes-columns of full magnetic-flux linkages of the elements that belong to edges and chords;} \]
\[ \Psi(-0) \text{ is the matrix-column that is determined by magnetic flux linkages, preceding commutation.} \]

The structural equation (19) are completed by the equations of edgs and chords
\[ I_e = G\Psi + F\xi, I_x = G_x\Psi_x + F_x, \]
\[ \text{Equations (19) - (20) are given in the node coordinates} \]
\[ A^\Psi_r (+0) = X(-0); \]
\[ \Delta^\Psi \xi = F_\xi \Delta^\Psi_r, \]
\[ \text{Expressions (19) - (20) are given in the node coordinates} \]
where the matrix $A$ and column $X$ are found from the equations

$$
A = G_\theta + FG_\alpha F^*_\alpha, \quad X(-0) = I_d(-0) - FI_x(-0).
$$

Fig. 4 Calculation subdiagram which corresponds to the commutation system on figure 2 at random break in the secondary transformer circuit (1).

The right side of the second equation (22) is the equation, written on the first Kirchhoff's law at the moment $t = -0$.

Accordingly if the first Kirchhoff's law is followed in calculation diagram at $t = -0$, the uneven changes of magnetic-flux linkages and currents will not take place.

The equation described transformation from increment of magnetic-flux linkages to current increments have been given in work.

The results of calculations of commutation currents in supply power node of four induction motors, while switching on one of them are given in the table 1.

Table 1.

<table>
<thead>
<tr>
<th>Phase A</th>
<th>Phase B</th>
<th>Prim. winding</th>
<th>Second. winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_{1A}$</td>
<td>$i_{2A}$</td>
<td>$i_{3A}$</td>
<td>$i_{4A}$</td>
</tr>
<tr>
<td>-3.61</td>
<td>-1.71</td>
<td>-3.54</td>
<td>-4.70</td>
</tr>
</tbody>
</table>

After commutation

<table>
<thead>
<tr>
<th>Phase A</th>
<th>Phase B</th>
<th>Prim. winding</th>
<th>Second. winding</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_{1A}$</td>
<td>$i_{2A}$</td>
<td>$i_{3A}$</td>
<td>$i_{4A}$</td>
</tr>
<tr>
<td>-4.06</td>
<td>-1.97</td>
<td>-4.10</td>
<td>0.0</td>
</tr>
</tbody>
</table>

In admissibility of analysis without accounting this phenomenon is illustrated by the curves in Fig. 5 and Fig. 6. Availability of direct current source caused by balanced currents in the node at the moment of $t = +0$ is observed on the first one. This source creates the effect of dynamic motor braking that does not correspond to experimental data.
Mathematical Model of Real Physical Processes in Control Systems

Fig. 5. Phase current of the phase A of secondary transformer winding in the starting regime of four motors with further turning off one of them without calculation initial conditions at the moment of commutation.

Fig. 6. The same process as on Fig. 5, but with calculation of the initial conditions at the moment of commutation.

Conclusions

1. This Work proved that regular mathematical methods of commutation and transient processes calculation of power supply node of actuating induction motors with short circuit and massive rotors as element of control system are not created at present. The suggested method do not have analogues.

2. The proposed differential equations of transformers and actuating induction motors with short circuit and massive rotors are unified for their usage as the equations of element basis of control systems. As in the case of motors with massive rotors it has been done for the first time.

3. Accounting structural properties of control system circuits of actuating induction motors with short circuit and massive rotors which consist of availability of a great number of loops and a limited number of nodes, it is necessary to construct the system state equation by means of method of node voltages in time interval.

4. As a matter of fact, that circuits of control system of actuating induction motors with short circuit and massive rotors are $D$-degenerated, commutation regimes are accompanied by uneven changes of currents in electrical windings of elements of control system. It was proved that transient process calculation is impossible without accounting this phenomenon.

5. Accounting structural features of power supply node of control system of actuating induction motors with short circuit and massive rotors, it is necessary to form an account of uneven changes of currents in element winding in node coordinates on basis of calculation inductivities schemes.
6. It has been proved that differential equations of electromechanical state of power supply node of control system of actuating inductions motors with short circuit and massive rotors are not stiff, that is why it is advisable to realize the algorithms of their integration by explicit method.

7. The results of computer simulation of transient processes of power supply node of actuating induction motors with short circuit and massive rotors illustrate progressing of electromechanical processes in time and uneven change of currents in the magnetization windings. They also illustrate the fact that neglecting general commutation laws results in the wrong results.

8. The proposed mathematical theory being grounded on nonlinear differential equations in ordinary and partial derivatives in time interval, the mapping of all possible effects and feedback makes no problem. They can be introduced, if needed, into the total equation system individually.

9. The suggested method of calculation of transient and commutation processes of power supply node of actuating induction motors with short circuit and massive rotors as the element of control system first makes possible to accomplish analysis and synthesis on the defined mathematical ground, using numerical methods and computer simulation without resorting to expensive and not always accomplished in practice natural experiments.
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A Generic XML-(Relational : Object) Mapping Scheme (GXROMS)

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Received on Aug.10, 2005 Accepted for publication on Dec. 21, 2005

Abstract

XML (eXtensible Markup Language) has been playing a major role in Data Exchange through the Internet, due to its high ability of organizing, describing, and structuring data. Thus, XML has been widely used for exchanging Relational Database Management Systems (RDBMSs) and Object Oriented Database Management Systems (OODBMSs) contents. This paper introduces a scheme that can be used for systematic XML-RDBMS transformations as well as XML-OODBMS transformations. The proposed scheme (GXROMS) contains three components: a generic front-end (Scans XML constructs), a Common Intermediate XML Interface and a generic back-end (produces DBMS constructs). Our choice of implementation of the generic front-end and generic back-end interfaces called JAVA Document Object Model (JDOM). JDOM represents a hybrid of the two famous schemes Document Object Model (DOM) and Simple API for XML parsing (SAX), maximizing the benefits of both and minimizing their drawbacks. The main advantage in the proposed scheme is that it is a generic transformation scheme rather than application specific transformations provided by the majority of already existing XML-RDBMS or XML-OODBMS mapping schemes. In addition GXROMS strengthen its mapping schemes as it is capable of dealing with XML schemas well as XML semi or non structured documents.

Keywords: XML, XML schema mapping, XML transformation, XML-Relational mapping, XML-Object-Oriented mapping

Introduction

DBMSs have become the basic building blocks for any successful, well-established business. A wide variety of DBMSs have been developed since the 60’s of the last century [1,2]. Staring from Network and Hierarchical Database architecture, and followed by the evolution of Relational and Enhanced Relational Databases systems which were built on the sound basis of set theory. The DBMSs continued to deploying Object-Oriented concepts into the world of Databases which resulted in the state-of –art DBMSs that are OODBMSs.
Another area that has been witnessing an increased development through the last two decades is communication and networking technologies. The establishment of a reliable, fast and secure network infrastructure, including access to the Internet, has become a vital pre-request for any successful system.

The evolution of DBMS and the Internet has resulted in a still-hot challenge, data exchange through the Internet. Network clients all over the globe are always willing to be able to directly exchange files containing a mixture of texts, images, audio and video, regardless of heterogeneity of their underlying systems including DBMSs [3-6]. This challenge has resulted in the development of many languages that aimed at simplifying data exchange between online resources. Among these is XML (eXtensible Markup Language) [7-9] which is one of the most widely used data exchange language. The XML language has been created in 1998 and became a standard format for various data transfers [10-15]. The advantage of using such kind of transfer media brings some new features. Deploying XML for data exchange is a direct consequence of its flexibility and capability of representing different data formats, either structured or semi-structured [1,12,16,17].

Many DBMS specific solutions have been developed so far [10,11,13,14], in order to allow data to be exchanged via the web. However, these solutions lack generality in the sense that they are applicable for the specific DBMS for which they were originally developed. Thus, their reusability is definitely limited. Moreover, mapping schemes made to allow data exchanges among heterogeneous DBMSs do still need extensive elaboration.

This paper proposes a generic scheme for allowing data exchange among heterogeneous as well as homogeneous DBMSs(RDBMSs and OODBMSs). The proposed scheme is more generic than the model described in [4] in the sense that its applicable for any RDBMSs or OODBMSs syntax. Thus, it is not an application specific solution.

Section 2 highlights related work briefly. A detailed description of the proposed scheme is depicted in Section 3. In addition it provides comparative analysis of the proposed scheme against some of the already existing solutions. Section 4 concludes the work done in this paper.

Literature Overview

Several schemes that aim at achieving data exchange among homogeneous as well as heterogeneous environments have been developed so far. Some of these schemes are Automatic XML Interchange System (AXIS) [17] and Load/Extract Utility System (LEUS) [4]. AXIS is a data exchange architecture used to allow data interchange among heterogenous enterprises using XML, whereas, LEUS system is limited to relational database transformation.

AXIS utilizes XML Document Type Definitions (XML DTDs) since XML has become a de facto standard data format. AXIS maps XML DTDs structures into database structures. These database structures are stored in AXIS Meta model. The Meta model is
consulted whenever XML document generating the data given in the database and vice versa. The architecture of AXIS is depicted in [17].

AXIS consists of three components:
1. Relational Database meta data model.
2. XML meta data model.
3. Correspondence model.

Data exchange schemes between relational Databases using XML has been extensively investigated. For instance, in [16] it has been found that some researchers focus on offline data transfers. They also assume the existence of an XML interface as a part of the designated RDBMS. The mapping schemes provided in their work depend on the mapping described in [3]. They also concentrate on data validation for data incoming from XML documents into the RDBMS. Other mapping schemes focus on specific DB products such as Oracle and Sybase [1,6] mappings into XML and vice versa.

A well composed DTD-RDBMS mapping scheme is depicted in [3] by Bourret. He discusses table-based mapping as well as object-relational mapping among heterogeneous data sources. In Bourret work an extensive XML mapping into either RDBMS or OODBMS is described including: mapping DTDs to object schemes, mapping object schemes to database schemes, and mapping complex data models.

The mapping scheme proposed by Bourret considers mapping choices, repeated children, optional children, subgroups, and mixed content. Moreover, attribute mappings are highlighted as well as alternate mapping.

Bourret work also considers mapping W3C schemes to object schemes. However, he concluded that mapping XML schemes to object schemes is not a good idea if it can be avoided. This is due to the fact that mapping XML scheme to an object scheme might oblige applications to use data specific objects in order to process the data in the XML document transferred via the proposed scheme.

Three semantic based transformation algorithms are proposed by Dongwon Lee in [11] in order to convert XML documents to relational formats and vice versa. This scheme consists of:

1. **CPI: Constraint Processing Inline algorithm.** It converts XML scheme to a relational scheme while preserving semantic constraints of the original XML scheme.

2. **NeT: Nested Translation algorithm.** It derives a nested structure from a flat relational scheme by applying the net operator on the XML schema to make that schema Hierarchical.

3. **CoT: Constraint based Translation algorithm.** It concludes dependences among input tables and generates an equivalent XML schema.
A storage technique and mapping schema for XML is described by Sihem in [18]. This work develops a new mapping scheme that identifies orthogonal aspects of mapping XML into relations. This work focuses on the support of storage techniques for mixed contents.

**Generic XML-(RDBMS : OODBMS) Mapping Scheme(GXROMS)**

**Generic Mapping Scheme Design Goals**

The design of mapping schemes is a difficult task, as it requires both general knowledge about database systems and detailed mapping schemes, and specific knowledge about customization process of the selected mapping schemes. Such types of knowledge require discussion of a mapping scenario.

In a heterogeneous environment, heterogeneous DBMSs cannot communicate directly via the web through schema integration process [19]. Thus, DBMS record fragments of existing data types (e.g. text, images, video, audio, … etc) then these data types are classified and transferred into XML documents that can be either structured or semi-structured. At the recipient side these XML tags are transformed back into DBMS fragments. In order to rebuild the DBMS record fragments using received XML tags, many schemes have been developed so far. However, the majority of these mapping schemes are DBMS specific. That means that they are applicable for transformations among specific DMBSs like Oracle for instance [6]. This implies their limited reusability. The XML-(RDBMS : OODBMS) proposed mapping scheme overcomes their shortcoming by providing a generic mapping scheme that generates a generic RDBMS or OODBMS constructs as appropriate which can be easily converted into a specific RDBMS or OODBMS syntax.

Figure 3.1 depicts the architecture of GXROMS scheme. The figure describes the stages through which a given XML schema/document is transferred into the corresponding DBMS generic SQL constructs.

![Figure 3.1 The architecture of GXROMS system](image)

In current research, we have used XML schema style to define the allowable structure of elements for XML document rather than direct DTD, because XML schema is richer; provide an improved data typing system and having more advanced internal
structures than declarations in DTDs. Therefore, the above front-end interface through Pre-CIXMLI processing supports conversion of DTDs to XML schemas, a more the W3C’s recommended XML data modeling language. Converting DTDs to XML schema provides numerous powerful benefits, including:

- Support for primitive (built-in) data types (e.g., xsd:integer, xsd:string, xsd:date, and so on), which facilitates using XML in conjunction with other typed-data, including relational data.

- The ability to define custom data types, using object-oriented data modeling principles: encapsulation, inheritance, and substitution.

The largest addition XML schemas provide to the functionality of the descriptions is a vastly improved data typing system. XML schemas provide data-oriented data types in addition to the more document-oriented data types XML 1.0 DTDs support, making XML more suitable for data interchange applications. Built-in data types include strings, booleans, and time values, and the XML schemas draft provides a mechanism for generating additional data types. Using this pre-processing, the draft provides support for all of the XML 1.0 data types (NMTOKENS, IDREFS, etc.) as well as data-specific types like decimal, integer, date, and time. Using XML schemas, developers can build their own libraries of easily interchanged data types and use them inside schemas or across multiple schemas.

The first, and probably most significant, difference between XML schemas and XML DTDs is that XML schemas use XML document syntax. While transforming the syntax to XML doesn’t automatically improve the quality of the description, it does make those descriptions far more extensible than they were in the original DTD syntax. Declarations can have richer and more complex internal structures than declarations in DTDs, and schema designers can take advantage of XML’s containment hierarchies to add extra information where appropriate – even sophisticated information like documentation. There are a few other benefits from this approach. XML schemas can be stored along with other XML documents in XML-oriented data stores, referenced, and even styled, using commercial tools.

The stages through which XML schemas/documents are transferred into (RDBMS : OODBMS) require processing XML schemas/documents by CIXMLI (Common Intermediate XML Interface). This generates the CIXML(Common Intermediate XML) file which is then examined against the syntax directed translation processor resulting in a file that consists of generic SQL constructs that allow XML data fragments to be stored consistently in any given RDBMS or OODBMS provided that a proper converter has produced the specific DDL and DML statements corresponding to the designated DBMS.

Typical XML documents can be classified into either DTD (Document Type Definition)-based and non-DTD based documents. XML-DTD documents are highly, regularly structured documents that adhere to certain structure described in the beginning of the XML file. All subsequent tags in that file convey to the DTD rules. On the other hand, non DTD-based XML documents have tags that do not obey some specific tag
structure. Consequently, these documents are not highly structured as opposed to the DTD-based ones. The preprocessing carried out by pre-CIXMLI (Common Intermediate XML Interface) aims at extracting the DTD rules from DTD-based as well as non DTD-based documents. If the processed file is already a DTD-based document, then the DTD in the file can be extracted forwardly. However, non DTD-based XML files need careful consideration and heavy pre-processing in order to extract the DTD tags implied in them. This has been accomplished by introducing a new syntax and semantic transformation grammar which extract accumulative knowledge based on graph algorithms and intelligent DTD-XML knowledge extraction.

In this case, we have classified the transformations into two categories: structure-mapping approach and model-mapping approach [16]. In the former, the design of database schema is based on the understanding of DTD (Document Type Descriptor) that describes the structure of XML documents. In the latter a fixed database schema is used to store any XML documents without assistance of DTD. We have concluded that a combination of graph algorithms and model-mapping approach can solve many problems associated with non DTD based XML constructs. The major product of this work we called intelligent DTD-XML knowledge extractor. It has been found comparable to other approaches in terms of its capability in supporting DTD and non-DTD transformation as well as its capability of supporting any sophisticated XML applications that are considered either as static or dynamic. For space limitation and simplicity, detailed description of this approach will be the subject of another paper.

**Implementation Decision of the XML Parser**

For parsing XML files, two dominant models exist: DOM (Document Object Model) and SAX (Simple API for XML parsing) [20,21]. SAX is an event driven API that calls event methods whilst parsing the document, i.e. it provides methods that can react to data in an XML document at the time that data being read. This is simple and obvious in three cases: if we’re only interested in a few parts of processed document; if we know how to locate those parts within the stream of SAX events or if the sequence of data is important. DOM on the other hand, parses the entire document and creates a corresponding Document object that can be browsed using appropriate method calls. Since DOM creates the object from the XML file, it requires enough memory to hold the file. This may be a disadvantage if the file is very large and available memory is very small. In effect, DOM provides programmatic access to the entire document, in a non-linear order. Though the DOM model is easier to use, but the SAX model allows faster parsing and requires less memory.

Our choice of implementation is a modified form of DOM called JDOM. JDOM was selected because it attempts to provide a seamless XML parser and builder as API. It is a hybrid of SAX and DOM, maximizing the benefits of both and minimizing their drawbacks. Therefore, JDOM model allows faster parsing and requires less memory than DOM in addition it is easier to use than SAX because it provides programmatic access to the entire document, in a non-linear order.
Mapping Model Components of Common Intermediate XML Interface (CIXMLI)

Tags can be used freely in an XML document or can be used in accordance with the document type definitions (DTDs) or XML Schema which define the types for a class of documents. An XML document that conforms to a DTD or XML Schema is called a valid XML document. A DTD or XML Schema is used to define the allowable structure of elements in a valid XML document. A DTD can include four kinds of declarations: element type, attribute-list, notation and entity. An element type declaration is analogous to a data type definition; it names an element and defines the allowable content and structure. An element may contain only other elements (called element content) or may contain any mix of other elements and text, which is represented as PCDATA (called mixed content). An EMPTY element type declaration is used to name an element type without content. Finally an element type can be declared with content ANY meaning the type of the element is arbitrary. Attribute-list declarations define the attributes of an element type. The declaration includes attribute names, default values and types.

XML Schema, which is also used to define the allowable structure of elements for a given application or application domain in a valid XML document uses XML document syntax. Declarations in XML Schema can have richer and more complex internal structures than declarations in DTDs. Schema designers can take advantage of XML’s containment hierarchies to add extra information where appropriate. XML Schemas also provide an improved data typing system. They provide data-oriented data types in addition to the more document-oriented data types that XML 1.0 DTDs support, making XML more suitable for data interchange applications. Built-in data types include strings, booleans, and time values. The XML Schema draft provides a mechanism for generating additional data types. Besides, XML Schema supports namespaces and the notion of keys to uniquely identify elements in an XML document.

Several mapping rules injected in CIXMLI mapping model to perform various XML mapping concepts. There is an obvious mapping between some XML elements and their correspondence data modeling concepts of RDBMS. But in case of XML-OODBMS mapping, it needs extra attention because of advanced concepts such as class hierarchy, association, aggregation, etc…[1,2]. Therefore, in this section we will concentrate on some OO mapping scheme.

In general our system can handle transformations shown in table 1.

**Table 1. XML concepts mapping**

<table>
<thead>
<tr>
<th>XML concept</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mapping – XML elements</td>
<td>Complex and Simple</td>
</tr>
<tr>
<td>Mapping – XML attributes</td>
<td>All</td>
</tr>
<tr>
<td>Mapping – Relationships</td>
<td>Association (1:1 , 1:n )</td>
</tr>
<tr>
<td></td>
<td>Aggregation</td>
</tr>
<tr>
<td>Mapping – XML data</td>
<td>All</td>
</tr>
</tbody>
</table>
XML elements shown in Table 2 can be complex or simple elements. Complex element can have children elements, while simple elements have no children elements. If XML element is a complex element, then the element is mapped to new class, if it has a parent element, then it is mapped to a reference attribute (pointer to object) for the current class in the parent class. If the XML element is simple then it will be directly mapped to attribute in the parent element (class).

The following table shows some important elements used to define XML schema.

<table>
<thead>
<tr>
<th>Element</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>annotation</td>
<td>Specifies the top-level element for schema comments</td>
</tr>
<tr>
<td>attribute</td>
<td>Defines an attribute</td>
</tr>
<tr>
<td>complex type</td>
<td>Defines a complex type element</td>
</tr>
<tr>
<td>documentation</td>
<td>Defines text comments in a schema (must go inside annotation)</td>
</tr>
<tr>
<td>element</td>
<td>Defines an element</td>
</tr>
<tr>
<td>notation</td>
<td>Describes the format of non-XML data within an XML document</td>
</tr>
<tr>
<td>schema</td>
<td>Defines the root element of a schema</td>
</tr>
<tr>
<td>sequence</td>
<td>Specifies that the child elements must appear in a sequence. Each child element can occur from 0 to any number of times</td>
</tr>
</tbody>
</table>

For simplicity, the following algorithm shows abstract mapping of (XML schema elements to OO data modeling concepts):

Algorithm MapTree_Class_Hierarchy
Input: XML Root_Class_Hierarchy element

1. While <> end of Root_Class_Hierarchy children
2. Begin
3. Element e = Root_Class_Hierarchy child
4. If Root_Class_Hierarchy child is complex Element then
5. Map e to class e
6. Map e.AttributeChildren to Attributes in class e with same type
7. If e.Parent is element then
8. Map Parent as attribute in class e with reference type to parent
9. End if
10. List Elements d = e.getChildren()
11. i = 1
12. While <> end of d elements
13. Begin
14. If element d[i] is simple element then
15. Map element d[i] as Attribute in class e with same type
16. Else if element d[i] is complex Element then
17. If d[i].getAttribute(maxOccurs) = unbounded then
18. Association type = One to Many
19. Map d[i] to attribute in class e with type as list of reference to d[i] object
20. Else if d[i].getAttribute(maxOccurs) = 1 then
21. Association type = One to One
22. End if
A Generic XML-(Relational : Object) Mapping Scheme (GXROMS)

23. Map d[i] to attribute in class e with type as reference to d[i] object
24. End if
25. End if
26. End if
27. MapTree_CLASS_Hierarchy(d[i])
28. End if
29. End if
30. End while
31. Else
32. Error Message
33. End if
34. End While

Syntax and Semantic Based Mapping

Each of the elements or attributes being processed will be associated with two attributes: type_t and null_t. type_t can have the value of: SIMPLE, COMPLEX or ATTRIB. ATTRIB stands for XML defined attributes, whereas SIMPLE stands for atomic XML elements, and COMPLEX stands for elements that consist of other elements (i.e. nested elements). This classification will play a vital role in the subsequent mapping. The second attribute nullable_t is a Boolean attribute which can be either true or false. If the existence of the element is necessary (i.e non nullable) then the value will be false, whereas if the existence of the element is unnecessary, then the value of nullable_t will be true. Another attributes associated with each elements are declare and sequencer which are going to be utilized by the syntax directed translation scheme.

The next step is the CIXMLI processing. In this step the extracted DTD and data tags from the previous step are examined in order to:

1. Eliminate wildcards like:*,+,?, ..etc and replace them with sound interpreting XML tags. In addition to setting the value of the nullable_t for every element by either true, false or empty. Entities that are found to be attributes (t_type = ATTRIB) will have their nullable attribute to be false if the Keyword #REQUIRED appears in their definition and will have it true otherwise.
2. Secondly, classify all of the DTD parsed elements into either simple or complex, by specifying the value of type_t attribute for each.

Tags declaring elements with wild cards can not be directly mapped into any SQL statement. Therefore, they need intermediate processing and transformation. The following set of examples describes how these wild cards can be omitted.

Example 1:

```xml
<!ELEMENT chapter(title, section+)>  
+ wildcard  means that the associated  element can appear once or more times in any subsequent chapter tag. Such an element definition will be replaced with the following definition:

<!ELEMENT chapter(title, section_1, section_2,...,section_n)>  
```

343
The value of \((n)\) can be determined from the currently parsed XML document, by counting the maximum number of sections in all chapter data tags. The first section (i.e., section_1) will have its nullable_t true, whereas the remaining sections will have it false. The title element will have its nullable_t true. The nullable_t value for chapter will be empty if chapter is not appearing as a component within another element in that XML document.

**Example 2:**

```xml
<!ELEMENT chapter(title, section*)>
```

* wildcard means that the associated element can appear zero or more times in any subsequent chapter tag. Such an element definition will be replaced with the following definition:

```xml
<!ELEMENT chapter(title, section_1, section_2,…,section_n)>  
```

de the value of \((n)\) will be determined as in Example 1. the assignment of the values of the nullable_t attribute is also as in Example 1 with one exception: section_1.nullable_t will be false.

**Example 3:**

```xml
<!ELEMENT chapter(title, section?)>
```

? wildcard means that the associated element can appear zero or once in any subsequent chapter tag. Such an element definition will be replaced with the following definition:

```xml
<!ELEMENT chapter(title, section_1)>  
```

here it's clear that title.nullable_t will be false, whereas section_1.nullable_t will be true. The value of chapter.nullable_t will be determined as depicted in Example 1.

Another symbol that needs being eliminated is |: or connector.

**Example 4:**

```xml
<!ELEMENT chapter(title|section)>  
```

| operator means that in any chapter tag, either one section component or one title component will appear and not both. Such an element definition will be replaced with the following two definitions:

```xml
<!ELEMENT chapter(title)>  
<!ELEMENT chapter(section)>  
```

here it's clear that title.nullable_t will be false, as well as section.nullable_t which will be also false. The value of chapter.nullable_t will be determined as depicted in Example 1.

However, in many cases the structure of declared elements is not as easy as depicted in the above examples. It usually consists of a mixture of the different elements.
A Generic XML-(Relational : Object) Mapping Scheme (GXROMS)

operators. Thus, the following syntax directed grammar describes the generation of all possible valid element definitions using the operators ")", ",", "+", "+", "|", "*", "?", "|".

1. \( E::= (E) \) \( E_.copies = E_.copies \)
2. \( E::= E, E \) \( E_.copies = 1, E_.copies = 1 \)
3. \( E::= E1+ | E1* \) \( E_.copies = n \)
4. \( E::= E1? \) \( E_.copies = 1 \)
5. \( E::= E1|E \) \( E \) is either \( E \) or \( E1 \) \( E_.copies = \) split the definition into two definitions on using \( E \) and the other using \( E1 \). Moreover, let \( E1.copies = E.copies \) and \( E1.copies = E.copies \)
6. \( E1::= E \) \( E_.copies = E_.copies \)
7. \( E1::= id \) \( id.copies = E1.copies \)
8. \( id ::= \) the set of elements names deduced by the pre-CIXML generic front end.

After applying the above rules to any element definition, the final result will be associating each id in that definition, and newly generated ones if any, with a proper number of copies. The value of \( n \) will determined as previously discussed. Then, that id will be replaced in the definition in which it appears by the designated number of replicas. For instance, if the element \( A \), which appeared in the definition of some element \( B \) had the number of copies 4, then the occurrence of \( A \) will be replaced with: \( A_1, A_2, A_3, A_4 \).

The second task accomplished by CIXML interface is classifying each of the elements deduced from pre-CIXML front end into either: SIMPLE, COMPLEX, or ATTRIB. In order to do so, the CIXML interface parses the XML document received, checking each of the entities found in the lists deduced by the front end preprocessor. If a given entity, call it \( T \), appears in an attribute tag, then \( T\. type_t = ATTRIB \), whereas if it never appears within the definition of any other element, then \( T\. type_t = COMPLEX \). Remaining elements will be assigned type \( t \) to be SIMPLE.

The processing done to the XML file by CIXML interface results in what we will call CIXML document. This document will be passed to the next stage of processing, the syntax directed translation processing shown in figure 3.1. This stage aims at generating corresponding generic DDL and DML from the designated CIXML document. The following set of syntax directed translation rules with their associated actions are used to accomplish this task.

1. \( mode ::= \#REQUIRED | \#DEFAULT \)
2. \( type ::= \) a type defined in XML documents
3. \( ATT(A)::= <!ATTLIST A t type mode> \rightarrow Att(A).declare = t RDBMS.cast(type) \)
4. \( simple ::= <!ELEMENT s (type)> \rightarrow simple.declare = s RDBMS.cast(type) \)
5. \( \text{simple ::= <!ELEMENT \ s \ type> \ Att(s) } \rightarrow \text{simple.declare} = s \ \text{RDBMS.cast(type)} \ || \ "\" || \text{Att(s).declare} \)

6. \( \text{simple ::= <!ELEMENT \ s \ type> \ Att(s)\_1,Att(s)\_2,\ldots,Att(s)\_n } \rightarrow \text{simple.declare} = s \ \text{RDBMS\_cast(type)} \ || \ "\" || \text{Att(s)\_n.declare} \)

7. \( \text{complex ::= <!ELEMENT \ tb\_name(simple\_1,simple\_2,\ldots,simple\_n)> } \rightarrow \text{complex.declare} = \)

\[
\begin{align*}
&\text{create table tb\_name( simple\_1.declare || \"|| } \\
&\text{simple\_2.declare || \ldots|| simple\_n.declare ||\"|| } \\
&\text{primary key tb\_namae.sequencer ||\"|| } \\
&\text{foreign key null )} \\
&\text{complex.ref = tb\_name.sequencer} \\
&\text{append complex.declare to generic RDBMS file}
\end{align*}
\]

9. \( \text{complex ::= <!ELEMENT \ tb\_name (simple\_1, \ldots,simple\_m, complex\_1,\ldots,complex\_n)> } \rightarrow \text{complex.declare} = \)

\[
\begin{align*}
&\text{create table tb\_name( simple\_1.declare || \"|| } \\
&\ldots|| \text{simple\_n.declare ||\"|| } \\
&\text{primary key tb\_namae.sequencer ||\"|| } \\
&\text{foreign key}_1 = \text{complex1. ref ||\"|| } \\
&\text{foreign key}_2 = \text{complex2.ref ||\"|| } \\
&\ldots
\end{align*}
\]

\[
\text{Foreign key}_n = \text{complexn.ref ||\"||}
\]

\[
\text{complex.ref = tb\_name.sequencer} \\
\text{append complex.declare to generic RDBMS file}
\]

10. \( \text{complex ::= <!ELEMENT \ tb\_name (complex\_1,\ldots,complex\_n)> } \rightarrow \text{complex.declare} = \)

\[
\begin{align*}
&\text{create table tb\_name(}
\end{align*}
\]
A Generic XML-(Relational : Object) Mapping Scheme (GXROMS)

\[
\begin{align*}
\text{primary key } & \text{tb\_name.sequencer } ||","|| \\
\text{foreign key}_1 = & \text{complex}_1.\text{ref } ||","|| \\
\text{foreign key}_2 = & \text{complex}_2.\text{ref } ||","|| \\
\vdots \quad \text{Foreign key}_{n} = & \text{complex}_{n}.\text{ref } ||","|| \\
\text{complex.\text{ref} } = & \text{tb\_name.sequencer} \\
\text{append } & \text{complex.declare to generic RDBMS file}
\end{align*}
\]

Comparison of GXROMS with Existing Mapping Schemes

This sections aims at comparing the GXROMS with already existing XML-DBMSs mapping schemes in terms of transformation accuracy, transformation quality, customization (i.e. generic mapping) and automation factors rather than time and space complexity factors. The mapping schemes proposed in [3-5,18] ignore the semantics of the scheme being mapped. This implies that XML-DBMS mappings will result in inaccurate interpretations due to the propagation of semantic ignorance between XML-RDBMS and RDBMS-OODBMS mappings.

Another problem associated with the schemes proposed by Bourret [3] is that they did not provide a systematic technique to resolve complex content models (i.e. XML tags with wildcards (+, ?, *, ...). These problems do not exist in GXROMS since it is dynamic grammar based mapping technique rather than a static mapping that is both syntactic and semantic driven.

The AXIS scheme proposed in [19] requires the association between the RDBMS model and the XML model to be manual rather than automatic. This implies that the quality of the mapping scenario will vary from a user to another. Moreover, such a mapping scheme imposes an additional overhead due to users’ necessary intervention. Such manual association is not required in GXROMS.

The mapping solution suggested in [6,14] is specific for some special RDBMS that provide support for parsing XML schemes and converting them to the corresponding DDLs and DMLs. This implies that the mappings in [14] lack generality, whereas GXROMS is generic and does not depend on any certain underlying DBMS. It also does not expect the existence of any parsing support for XML various documents.

The mapping technique suggested in [18] focused on mapping XML-RDBMS using grammar rules written in XML itself. However, some of the depicted mapper components rely on user provided data which might affect the quality of the mapping obtained from one user to another. Moreover, the mapping schemes considered XML schemes and DTDs, but no clear processing was provided for XML semi-structures or non-structured documents.
Conclusions

Several mapping schemes suggested in the literature for the XML-RDBMS transformations as well as XML-OOBDMS transformations. None of these schemes have tackled the problem of customization and generic mapping. Our research proposed design and development of a scheme that can be used for systematic XML-RDBMS transformations as well as XML-OOBDMS transformations. Main design goal of the system is to produce generic transformation scheme rather than application specific transformation provided by the majority of already existing XML-RDBMS or XML-OOBDMS mapping schemes. This has been achieved due to the powerful architectural design of the system (GXROMS) which has strengthened its functionality. At the heart of the system, several mapping rules injected in the Common Intermediate XML mapping model to perform various XML mapping concepts. It has been found that an obvious mapping between some XML elements and their correspondence data modeling concepts of relational database concepts. But in case of Object-Oriented concepts mapping, case based simulation modeling proposed to cope with some advanced concepts of Object-Oriented data modeling such as class hierarchy, association, and aggregation. In addition, many heuristic mapping rules combined within mapping algorithms developed on JAVA language using JAVA Document Object Model (JDOM) API to parse the XML schema. Our choice of implementation of the two interfaces (generic front-end and generic back-end interfaces) out-performed their counterparts SAX and DOM schemes by maximizing the benefits of both and minimizing their drawbacks. The proposed scheme have been tested successfully and proved to be highly customizable.
A Generic XML-(Relational : Object) Mapping Scheme (GXROMS)

References


Geology of the Dhaher (Bargish) Cave System, NW Jordan

Nizar Abu-Jaber *, Hakam Mustafa * and Deema Melhem *

Abstract

There has been much interest in the development of the Dhaher cave in the Koora district as a show cave. Because of this, a research program has been implemented in order to document the geology and nature of the cave, as well as the possibility for the development of the cave for tourism.

The research has led to the mapping the accessible parts of the cave, which is about 130 m long and contains three large chambers or halls. There are many interesting cave deposits inside, providing for the possibility of development as a show cave.

The cave formed due to the presence of two major fault systems within limestone in a rainy Mediterranean climate. The rate of limestone dissolution suggests the initiation of cave development in the Late Pleistocene. Isotopic data suggest that the development occurred under current climatic conditions.

Introduction

Karst geology and cave systems are some of the most fascinating and important geologic features in the public imagination. For this reason, many caves around the world have been developed as show caves, attracting tourists and generating revenue for local communities. The Carlsbad Caverns in New Mexico, USA and the Jeita Cave in Lebanon are well known, but there are numerous examples of smaller show caves around the world.

In recent years, there has been increased interest in the Dhaher, or Bargish, cave in the Koora district in northern Jordan. Press reports of the cave have whetted the appetite for the development of a new tourist destination in the area. While it is known that the cave exists, no detailed geological study or map of the cave is presently available.

The purpose of this report is to detail the geological and climatological context of this cave, to present a detailed map of the accessible portions of the cave for the first time, and to list the most important cave deposits (speleothems) present in the cave. The availability of this information is crucial in any future plans for the development of the cave as a show cave.

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**Geology and climate**

The Dhaher cave lies in the Bargish forests of the Koora district in northwestern Jordan (Figure 1). This area has a typical Mediterranean climate, with warm dry summers and cool rainy winters. Average rainfall in the area is about 600 mm/year (Meteorological Department Open Files). The area is covered by natural forests which themselves are unique in Jordan.

Geologically, the area consists of Upper Cretaceous limestones locally known as the Wadi Sir Formation [1], or the Massive Limestone Unit [2]. In the hydrogeological nomenclature used in Jordan, the name given to this formation is the A7 formation [3]. Despite the various terminology used, the limestone in question is a massive white microcrystalline limestone with occasional marly partings and dated to the Turonian Epoch of the Upper Cretaceous. It was deposited in a marginal marine environment during the transgression of the Tethys at that time.

The Wadi Sir Formation is characterized by being thickly bedded with thin marl partings, medium hard to very hard (most of the higher quality building stone quarried in Jordan is derived from this formation in Ajloun, to the south), with semi-conoidal to concoidal fracturing. In some areas, dolomitization has occurred. The formation is considered to be one of the most important aquifers in northern Jordan. This is because of the extensive fracturing and karst development which it underwent, allowing for the formation of the secondary porosity needed for such a formation to become an aquifer. It contrasts sharply with the marly nodular Shueib formation below it and the mainly marly Wadi Um Ghudran and the silicified Amman formation above. In northern Jordan, it is estimated that the Wadi Sir formation is around 60 m thick.

The structure of the area is dominated by the presence of the Jordan Valley rift to the west of the study area. This left lateral rift system defines the plate boundary between the Palestine crustal plate to the west and the Arabian crustal plate to the east. Movement along this rift system led to the evolution of the Ajloun dome, of which the study area is a part.

The Ajloun dome is actually a fold striking and plunging NNE [4]. Thus, within the study area beds dip towards the NW. Faulting in the area includes EW, NW, N and NE trending faults [5].

**Methodology**

The study involved surveying the cave interior as well as geochemical and isotopic study of some of the water and speleothems found in the cave as well as in a nearby spring (Ain Zubia). Due to the darkness in the cave, a portable electrical generator and cables were used to provide enough light to work inside.

Due to the rugged nature of the interior of the cave, the surveying process was difficult. It included the choice of a baseline, and measurement of the various extensions and rooms using a compass, tape measures and, where possible, total station surveying equipment.
Figure 1: Location map of the study area.
Water samples were collected in pre-cleaned polyethylene bottles and sealed tightly. Electrical conductivity and pH were measured using standard electrodes in the laboratory. The major cations (Ca$^{++}$, Mg$^{++}$, Na$^+$ and K$^+$) were analyzed using Atomic Absorption Spectroscopy. Chloride and bicarbonate were analyzed using standard titration techniques, and sulfate was measured using spectrophotometric techniques [6].

Isotopic analyses were conducted in the Water Authority of Jordan laboratories in Amman using a Finnigan Mat Delta E mass spectrometer. This was used for the determination of the stable isotopic composition of water (oxygen and deuterium isotopes) and speleothems (oxygen and carbon).

The isotopic ratio is expressed in standard $\delta$ (delta) notation as follows [7]:

$$\delta^{18}O_{\text{sample}} = \left[ \left( \frac{^{18}O}{^{16}O_{\text{sample}}} / \frac{^{18}O}{^{16}O_{\text{standard}}} \right) \right] - 1 \times 1000$$

$$\delta^{2H}_{\text{sample}} = \left[ \left( \frac{^{2H}}{^{1H}_{\text{sample}}} / \frac{^{2H}}{^{1H}_{\text{standard}}} \right) \right] - 1 \times 1000$$

$$\delta^{13}C_{\text{sample}} = \left[ \left( \frac{^{13}C}{^{12}C_{\text{sample}}} / \frac{^{13}C}{^{12}C_{\text{standard}}} \right) \right] - 1 \times 1000$$

The standards against which the isotopic ratios of oxygen and carbon are measured are Pee Dee Belemnite (PDB), and the isotopic ratios of hydrogen are referenced to Standard Mean Ocean Water (SMOW).

**Description of the cave**

**Physical nature**

The Dhaher cave has a total length of 130 meters. The entrance is a vertical 2 meter deep shaft with a diameter of 1 meter. The cave consists of the main cave passage which is typically 1-2 meters wide and 2-4 meters high. There are a number of large chambers and a few branches and passages. The largest chamber is about 50 square meters with a cave height of up to 11 meters. Figure 2 is a map of the cave, showing the upper and lower elevations at various locations as related to the base level at the entrance.

The entrance to the cave is rather long and narrow, with a semi circular cross section, with parts requiring crawling on the stomach to get in.

The Dhaher cave is a structural cave; it is mainly formed along two fault systems, one with a N70°W trend and a second with a N45°E trend. Each system consists of many parallel faults extending in the whole cave. In general the cave has linear extension along the faults.

Rain water infiltrates in the vadose zone which consists of jointed and faulted limestone rocks. The waters infiltrated through joints and faults and at flat ceilings parallel to bedding planes. Through passing the water through the faults and joints dissolution pores get larger and become more and more interconnected, so that the aggressive water advances more easily and deeper into the rocks interior; and the fissures become split.
Biological factors accelerate the carbonate rock dissolution. Plant roots allow transmission of water, which helps erosion and improves the water holding capacity of the rock. Respiration increases CO₂ content in the vadose zone, which also helps in the limestone dissolution. It has been observed that the stalactites in the cave form at the extensions of the joints, which typically include plant roots.

Water seeping along fractures, especially faults and major joints, dissolves the limestone and widens them and weakens the rocks along these fractures. This causes
the formation of stalactites as well as eventual failure of the ceiling. The weakest areas in the ceiling are the points of intersection of the two fault systems. Shafts along these points are formed. Later on some of these shafts are scoured by flowing sandy, pebbly water forming bell holes.

Within the cave, three significant halls are identified (Figure 2). At the end of the entrance to the cave, Bargash hall, 12 m long and 5 m wide is found. The maximum height of the ceiling is about 11 m, and the chamber seems to have formed as the result of a N50°E lineament. The hall contains some beautiful speleothems, including some striking stalactites and cascade deposits.

Irbid hall is 15 m long and up to 7 m wide, with a maximum height of about 10 m. A chimney which penetrates to the surface and the bottom of the room is covered with coarse gravel. The hall seems to have formed along an N20°W lineament.

The largest hall is the Yarmouk hall, which is about 20 m long, up to 8 m wide, and a maximum ceiling height of 11. The ceiling is cut by two lineament sets, at N70°W and N45°E. The floor of the hall is covered with rock material ranging in size from pebbles to boulders produced by the collapse of part of the ceiling at the lineament intersections.

Cave deposits observed

Stalactites and stalagmites: These are the most famous forms of speleothems (cave deposits). Stalactites hang downward from the ceiling and are formed as drop after drop of water slowly trickles through cracks in the cave roof. Stalagmites point upward and form as water drops to the floor, loses CO₂ and deposits calcite. Both stalactites and stalagmites grow in concentric layers and may reach lengths of several meters.

Soda straws: These are hollow on the inside and have water dripping through them. Over time the inside clogs with calcite, causing the stalactite to grow larger. These begin to form as drops of water hanging from the ceiling. As they lose carbon dioxide, they deposit a film of calcite. Successive drops add ring below ring, and the water dripping through the hollow center of the rings, until a pendant cylinder forms. Tubular or "soda straw" stalactites grow in this way; most are fragile and have the diameter of a drop of water, but some reach a length of perhaps a meter or more.

Flowstone. These are deposits of calcium carbonate, gypsum, and other mineral matter that has accumulated on the walls or floors of caves at places where water trickles or flows over the rock. In the case of the Dhaher cave, these consist exclusively of calcite. Layered deposits of calcium carbonate precipitated on rocks from water trickling over them. They are three meters long and two and a half meters wide.

Dripstone. This consists of calcium carbonate deposited from water dripping from the ceiling or wall of a cave or from the overhanging edge of a rock shelter; commonly refers to the rock in stalactites, stalagmites, and other similar speleothems. Sometimes the drip water flows down the walls and over the cave floor creating flowstone or rimstone deposits. Where drip water seeps from a joint and then drips over the edges of ledges, or seeps along cracks on sloping ceiling, draperies are formed. The color of
dripstones and flowstones caused by organic matter and/or iron and manganese oxide and hydroxides brought in as solutions from the surface, giving the speleothems an orange brown to deep brown or black color.

Cave popcorn: Small, knobby growths of calcite on the cave walls are called cave popcorn. Popcorn commonly forms in one of two ways in the cave: where water seeps uniformly out of the limestone wall and precipitates calcite; or, when water drips from the walls or ceilings of the cave and the water splashes on the floor or on ledges along the walls. This splashing action causes loss of carbon dioxide and the subsequent precipitation of calcite.

Cascade: Seeping of slowly water along the bedding plane causes the formation of what looks like a frozen waterfall. There is a beautiful example of this feature at the end of the entrance to the cave.

Curtain: A speleothem in the form of a wavy or folded sheet hanging from the roof or wall of a cave, often translucent and resonant. This occurs at fault planes where water seeps along a linear structure. Draperies or curtains develop where the feed water trickles down an inclined wall.

Bell hole: Downward wide and the top narrow, these result from strong water movement., resulting in angular gravel below the surface of the extensions of faults. These materials are a "soluble" residue of limestone and dolomite solution. On the cave walls thick zones of weathered limestone or dolomite remain when the solution process ends. This usually happens when there is no more inflow of aggressive water or when flowing water no longer transports the carbonate weathering products. Carbonate rocks do not dissolve immediately; and this signifies that they are not carried away completely from their primary place in ionic form, but that the disintegrated particles may remain on the cave passage walls. An incomplete dissolution may just prepare the carbonate rock for the mechanical transport of its particles by the flow of water. The weathered zone of limestone and dolomite is soft when it is wet and solid when dry.

Rimstone dams: these features build up in channels or on flow stones, the height range from millimeters to many meters; they may be single or interlocking to create a stair case of pools. Rims are straight, curved or crenulated [8]. We can see small rimstones in the cave.

**Evolution of the cave**

The rate at which caves form is related to the amount of rainfall in the area, the rate of recharge and the amount of CO₂ available [8]. Chemical and isotopic techniques were employed in order to gain an idea about the age of the Dhaher cave, if only in a preliminary value.

The hydrological cycle is basically a mass balance equation describing the amount of water entering or leaving a steady state system. In essence, it states that the input (rainfall and snow) is equal to output (runoff, evaporation and infiltration). In this case, we are interested in infiltration, as this is the amount of water which is actually working
to dissolve the limestone. In order to determine infiltration, it is necessary to understand the entire water cycle equation in the area.

The input function is easy to determine given the availability of precipitation data over several decades at nearby stations (Ras Muneef and Wadi El-Rayyan). Based on data from these stations, it is safe to assume the annual rainfall in the area to be on the order of 500mm/a. It is worth noting that through the Quaternary period, there have been several climatic changes which seem to reflect glacial-interglacial periods in Europe [9, 10]. Thus, the calculations herein represent denudation rates during the current dry, warm interglacial period, and thus probably represent an underestimate of what has occurred during the life of the cave.

Runoff is a function of the soil cover and slope of the area. In very general terms, and based on the geomorphology of the area, it is estimated that the runoff coefficient in this area is about 25% [11]. Evaporation is an important component which can be assessed by comparing the isotopic composition of the ground water with that of the local precipitation. Bajjali [12], who collected rainwater data from all over Jordan, has studied the stable isotopic composition of rainwater in the area. The nearest area reported by him was from water collected at the station at Ras Muneef. Ground water was also collected from the cave and from Ain Zoubia, and subsequently analyzed for its stable isotopic composition. Data used are presented in table 1.

### Table 1.: The isotopic results of the analysis of the water samples.

Ras Muneef data is the mean weighted average (n=15) from Bajjali (1990).

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\delta^{18}O$</th>
<th>$\delta^D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ras Muneef</td>
<td>-7.25</td>
<td>-33.19</td>
</tr>
<tr>
<td>Drip water</td>
<td>-6.11</td>
<td>-27.8</td>
</tr>
<tr>
<td>Cave spring</td>
<td>-6.10</td>
<td>-25.9</td>
</tr>
<tr>
<td>Ain Zoubia</td>
<td>-6.10</td>
<td>-27.3</td>
</tr>
</tbody>
</table>

Comparison between the rain and ground water was done using the well known phenomenon that as water evaporates, it becomes enriched in the heavier isotopes of oxygen and hydrogen. This roughly follows what is known as the Rayleigh distillation equation, as follows:

$$R = R_0 f^{(\alpha-1)}$$

$R_0$ is the initial isotope ratio in the water, $R$ is the ratio when only a fraction, “$f$”, remains, and $\alpha$ is the equilibrium fractionation factor during evaporation. This equation applies mostly to conditions of low humidity, and should be modified appropriately for the higher humidity seen in the area [13].

Thus, the purpose of the exercise is to determine $f$, or the fraction of water which infiltrates into the cave system. Based on the variations between the $\delta^D$ and the $\delta^{18}O$ of the samples, it is estimated that $f$ is about 0.95, given the very small enrichment seen in the ground water.
Thus, to calculate the amount of water moving through the karst system becomes a simple task. The catchments area of the cave area is about 100000m², which is five times the area of the cave. Assuming that 500mm/a fall onto the area, it is estimated that 50000 cubic meters of water fall in the immediate vicinity of the cave, of which 25% flows away as runoff, leaving 37500 cubic meters. Evaporation leads to the loss of about 5% of the remainder, leaving about 35600 cubic meters flowing through the limestone of the area.

Comparing the chemistry between input and output water allows determining the amount of carbonate dissolved by the water moving through the rock [14]. Table 2. gives the results of the chemical analyses performed on the rain water [12] and the ground water in the area.

Table 2.: The chemical results of the analysis of the water samples. Units are in mg/l

<table>
<thead>
<tr>
<th>Sample</th>
<th>TDS</th>
<th>pH</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>Na</th>
<th>HCO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>58.7</td>
<td>7.14</td>
<td>6.5</td>
<td>3.0</td>
<td>1.0</td>
<td>4.4</td>
<td>17.9</td>
</tr>
<tr>
<td>Drip water</td>
<td>503.0</td>
<td>9.5</td>
<td>95.8</td>
<td>26.46</td>
<td>0.30</td>
<td>16.6</td>
<td>460</td>
</tr>
<tr>
<td>Cave spring</td>
<td>610</td>
<td>7.1</td>
<td>57.4</td>
<td>25.5</td>
<td>0.41</td>
<td>16.8</td>
<td>310</td>
</tr>
<tr>
<td>Ain Zoubia</td>
<td>752</td>
<td>6.31</td>
<td>51.5</td>
<td>26.88</td>
<td>0.16</td>
<td>18.1</td>
<td>284</td>
</tr>
</tbody>
</table>

These results show significant removal of Ca²⁺, HCO₃⁻ and Mg²⁺ from the system through dissolution. It is noteworthy that the ratio of Mg²⁺ to Ca²⁺ is higher than would be expected from dissolution of limestone. Two reasons might account for this. The first is the presence of dolomite in the area. The second might be selective concentration of Mg²⁺ due to the dissolution of high-Mg calcite and the precipitation of low Mg calcite in materials such as stalactites. In either case, the sum of the magnesium and the calcium represents the amount of net carbonate removed from the system.

Assuming that the water at Ain Zoubia represents the average output water from the cave system, this would suggest that the removal of 1.3 mmol of Ca²⁺ and 1.2 mmol of Mg²⁺ per liter of water moving through the system, suggesting the removal of about 1.2 mmol of CaMg(CO₃)₂, which is equal to 219.6 mg, amounting to about 87.8 * 10⁻³ cm³ of the carbonate. Given that the amount of water moving through the system annually is 35600 cubic meters, this means that about 3.1 cubic meters of limestone/dolostone are removed in a year.

The area of the main cave is about 20000m², and the average height is about 5-6 meters, giving a total volume of the cave to be about 100000-120000m³. In order to create this cave at the rate that appears to be prevalent, it would take about 40000 years to carve out the cave as we now see it.

The basic assumptions in this calculation involve the climatic conditions. The region has been through a number of pluvial periods since the Late Pleistocene, and it is possible that during those times, the rate of weathering was higher. Thus, it is conceivable that the age is lower than what is indicated in this calculation. There are
other uncertainties in the calculation related to the actual amount of water moving through, especially during various climatic events. The runoff coefficient may have been underestimated. Moreover, the chemistry of the water was not sampled enough to give any reasonable idea about the seasonal and inter-annual variations in the chemistry. On the other hand, the water in the spring at the center of the cave had a chemistry similar to that seen at Ain Zoubia, suggesting that most of the dissolution reactions occur in the area immediately above and around the cave system. In any case, we believe that the initiation of development of the system began in the Late Pleistocene.

Isotopic nature of the speleothems

The δ18O and δ13C values of speleothem CaCO3 are related to the primary sources of oxygen and carbon in the cave seepage water. In the case of oxygen, this is meteoric water. In the case of carbon, it is soil carbon dioxide and carbonate bedrock. The process of speleothem deposition can be traced back to the soil horizon where biological activity produces high levels of CO2. This soil CO2 acidifies seepage waters, which in turn dissolve carbonate bedrock en route to underlying caves. Upon entering a cave passage of lower CO2 concentration (relative to the soil atmosphere), the seepage water releases CO2 and CaCO3 deposition takes place [15]. Because bicarbonate concentrations of karst ground waters are typically in the parts per thousand ranges, the δ18O compositions of the water and the dissolved carbonate species are dominated by the water molecules themselves, which originated as meteoric precipitation. Therefore, the δ18O values of speleothems are generally not significantly influenced by the bedrock isotopic composition [13]. Speleothem δ13C values, however, are significantly influenced by the isotopic composition of the bedrock, and the soil CO2. The latter is strongly related to the vegetation overlying the cave, and vegetation at the regional scale is strongly correlated to climate.

The cave temperature effect represents isotopic fractionation between water and calcite during calcite deposition. The temperature dependence of the fractionation has been experimental determined as ~ -0.24 ‰ per °C [7], meaning there is greater fractionation at cold temperatures relative to warm temperatures. The fractionation between the oxygen isotope composition in water and the precipitating calcite is defined by the following equation:

\[ 1000 \ln \alpha = \delta^{18}O_{\text{CaCO}_3} - \delta^{18}O_{\text{H}_2\text{O}} = 2.78 \left(10^6/T^2\right) - 2.89 \] [7].

The ~ -0.24 ‰ per °C fractionation that defines the cave temperature effect therefore reflects the mean annual temperature of the area.

Although a host of factors can potentially affect the δ13C values of speleothems, vegetation is a major factor because soil CO2 is generated largely by the microbial oxidation of soil organic matter, which is derived from vegetation. C3 and C4 photosynthetic pathways produce large differences in δ13C values. C3 plants have δ13C values averaging ca. –26 ‰, whereas C4 plants average ca. –12 ‰ [16]. C4 plants are typically warm-season grasses and a few herbs found in tropical and temperate grasslands, whereas C3 plants are mostly trees, shrubs, cool-season grasses, and most herbs.
The isotopic results of the analysis of two samples of carbonate from the speleothems are given in table 3. δ18O results shown in table 3 indicate the same water source in the cave and spring. The average δ13C in C3 plants is -26‰ and -12‰ in C4 plants [17], which means that the carbon isotope results (δ13C = -10.77‰ and -10.73‰) approach the average of C4 plants which indicate warmer climate.

Table 3: The isotopic results of the analysis of the carbonate samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>δ18O (PDB)</th>
<th>δ18O (SMOW)</th>
<th>δ13C (PDB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black center</td>
<td>-5.28</td>
<td>-31.53</td>
<td>-10.77</td>
</tr>
<tr>
<td>White center</td>
<td>-5.09</td>
<td>-31.72</td>
<td>-10.73</td>
</tr>
</tbody>
</table>

By applying the equation of Friedman and O’Neil [7] above and assuming the isotopic composition of water is the same as what is observed currently in the drip water, then it is possible to calculate the precipitation temperature of the carbonate. The calculation yields a crystallization temperature of almost 10-11°C, which is reasonably close to the ambient temperature of the cave, suggesting that the stalactites where deposited in climatic conditions similar to the present, as indicated by precipitation temperature and isotopic composition of the water.

Summary and conclusions

The study which includes mapping of the cave and description of sediments and analyzing of rock and water samples showed important results. The Dhaher cave has a whole length of 130 meters, with many large chambers, few branches and passages. These have been mapped and are shown in figure 2. The main passage and the whole cave with its passages and chambers were formed along two major fault systems in the limestone. Each system consists of many parallel faults extending in the whole cave; the two systems consist of one with a N70°W trend and a second with a N45°E trend. In general the cave has linear extension along the faults.

Three big rooms have been formed in the cave; the Yarmouk hall, Irbid hall, and Bargash hall. In general the cave sediments can be classified according to the criteria mentioned above into: speleothems (Dripstone, Flowstone, Rimstone dams), cave screes and the cave earth. δ18O results indicated to a similar source for the cave water and spring. The average δ13C in C3 plants is -26‰ and -12‰ in C4 plants, which means that the carbon isotope results (δ13C = -10.77‰ and -10.73‰) approach the average content of C4 plants which are common in this area and which indicate a warm climate. Denudation rates calculated suggest the cave began development in the Late Pleistocene.

The development of the cave as a show cave is possible, since the setting in which it exists is unique, and the cave contains many beautiful speleothems of various shapes and sizes. In any case, the site needs to be protected against vandalism if it is to become a tourist destination. Care should be given to study the stability of the ceiling before any significant development is undertaken.
Acknowledgments

We would like to thank Mr. Muwafiq Bataineh from the Faculty of Archaeology and Anthropology for his help in surveying the cave. Thanks are also due to Khaldoon Mahafzah from the Department of Earth and Environmental Sciences for his help in the chemical analysis of the sample. Mr. Ismail Mussalam from the Water Authority Laboratories analyzed the isotopic composition of the water and carbonate sample. This project was funded by the Scientific Research Council at Yarmouk University.

References

Geology of the Dhaher (Bargish) Cave System, NW Jordan


The Generalized Mathematical Model of Electrical Power System for the Optimal Power Flow

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Received on Oct. 2, 2005 Accepted for publication on June 19, 2006

Abstract

This paper aims to develop a general method for solving optimal power flow problem. A generalized mathematical model for solving specified problems based on the second order gradient method is presented and its applications are considered. The second order approximation is explored in a quadratic optimization sub-problem with Lagrangian multipliers to obtain the optimal step length. Based on Jacobian matrix, the method and the mathematical expressions for the calculations of the matrix elements using a recursive approach are presented. The model employs techniques to, automatically, adjust the power system control settings to minimize power losses. The presented optimization algorithm has been integrated as a complement to the standard load flow program in a real power system; the results of its implementation ensure its advantages in minimizing the losses and calculation time.

Keywords: optimal power flow, mathematical modeling, Jacobian matrix, gradient method.

Introduction:

Optimal Power Flow (OPF) has been widely used in planning and real-time operation of power systems for active and reactive power dispatch to minimize system losses [1,2].

In 1962, Carpentier introduced the optimal power flow problem, since that, a long period of research is being evident in developing efficient algorithms for its solution due the excessive evaluation of the non-linear mathematical programming problem [3,4,5]. The basic formulation of the optimal load flow problem includes the solutions to the optimization problem with nonlinear, functional and nonfunctional constraints and a nonlinear objective function [6,7].

The proposed optimization model in the paper is used in conjunction with a state estimator. The development of the model is based on the generalized gradient methodology of second partial derivatives.

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Problem Formulation:

The proposed structure of the generalized mathematical model (GMM) for the electric power system is based on the second order gradient method. The algorithmic and program realizations of all individual variants of the model application are expedient by using of eliminative forms of the inverse matrix obtained by the double factorization and dynamic ordering methods [8,9]. The case of unconstrained minimization on \( Z \) and \( \Lambda \) of the modified Lagrangian function takes the following form [10,11]:

\[
H(Z, \Lambda) = F(Z) + \Lambda^T G(z) + 1/2 G(z)^T S G(z) 
\]

Where, \( Z = [z_1, \ldots, z_m] \) – the vector of power system variables,

\( F(Z) \) – criterion of optimization,

\( \Lambda = [\lambda_1, \ldots, \lambda_n] \) - vector of Lagrangian multipliers,

\( G(Z) = [g_1(Z), \ldots, g_n(Z)]^T \) – equality constraints,

\( S = \text{diag. } (\sigma_1, \ldots, \sigma_n) \) – diagonal matrix of sensitivity coefficients.

At a minimum point of the function (1), the following conditions are satisfied:

\[
\partial H/\partial Z = \partial F/\partial Z + (\partial G/\partial Z)^T (\Lambda + SG(Z)) = 0 
\]

\[
\partial H/\partial \Lambda = G(Z) = 0 
\]

Expanding function (1) into Taylor series about the point of solution and neglecting the higher order terms [12,13]:

\[
\left[ \frac{\partial^2 F}{\partial Z^2} + W + \left( \frac{\partial G}{\partial Z} \right)^T S \frac{\partial G}{\partial Z} \left( \frac{\partial G}{\partial Z} \right)^T \right] \begin{bmatrix} \Delta Z \\ \Delta \Lambda \end{bmatrix} = \begin{bmatrix} \partial H/\partial Z \\ \partial H/\partial \Lambda \end{bmatrix} 
\]

Where, \( W = \sum_{j=1}^{n} (\lambda_j + \sigma_j g_j(Z)) \left( \frac{\partial g_j(Z)}{\partial Z_j} \right) \)

In (4a), \( \lambda_j \) - Lagrangian multipliers; \( \sigma_j \) – The sensitivity coefficients; \( g_j \) – The coefficients of equality constraints. The system of equations (4) includes the direct \((\partial G/\partial Z)\), transposed \((\partial G/\partial Z)^T\) Jacobian matrices and the matrix of second derivatives - \( W \) (Hessian matrix). Using special differentiation methods, the expression for the second order derivatives \( \partial^2 g_i/\partial z_j \partial z_j \) will be similar to that of the first order partial derivatives \( \partial g_i/\partial z_j \) and consequently, the structure of the matrix is similar to that of Jacobian matrix. The proposed GMM of power system is aimed to the minimization of the objective function in (1) with direct relation into equation (4).

To determine \( n \) coordinates of \( m \)-dimensional \((m > n)\) vector \( Z \), it’s assumed that [10]:

366
The Generalized Mathematical Model of Electrical Power System for the Optimal Power Flow

\[ F(Z) = 0, \Lambda = 0, \text{then} \]

\[ H(Z, \Lambda) = \frac{1}{2} G^T(z) S G(z) . \]

..............................................................(5)

System (4) can be adjusted to the following form:

\[ \left( W + \frac{\partial G}{\partial Z} \right) \left( \frac{\partial G}{\partial Z} \right)^T S \frac{\partial G}{\partial Z} = - \left( \frac{\partial G}{\partial Z} \right)^T S G(Z) \] .................................(6)

The quadratic minimization of (5) is a well-known technique for the minimization of the sum of square differences between the given and calculated injections in buses. Replacing the system of the equation (6) by the following identical system:

\[ \left[ \begin{array}{c} \frac{\partial G}{\partial Z} \\
\frac{\partial G}{\partial Z} - S^{-1} \\
\end{array} \right] = \left[ \begin{array}{c} 0 \\
G(Z) \\
\end{array} \right] \] .............................(7)

Where, \( \varepsilon = S \left( \frac{\partial G}{\partial Z} \Delta Z + G(Z) \right) \)

\( \varepsilon \) is the solution discrepancies’ vector of the power flow equation determined by Newton - Raphson method. In this case, \( \varepsilon \) is minimized. However, the system of equations (7) includes direct \((\partial G/\partial Z)\), transposed \((\partial G/\partial Z)^T\) Jacobian matrices, and the matrix of second partial derivatives.

\( W \) – The Hessian matrix is structurally similar to the Jacobian matrix. In system (7), only columns and rows that are appropriate to \( n \) coordinates of vector \( Z \) should be included. Two conditions can be addressed (7):

- If \( \partial G/\partial Z \) is not equal to zero, then matrix \( W = 0 \). In case of the normal selection of the desired coordinates, the results of the power flow calculation matches that of Newton - Raphson method,

\( (\partial G/\partial Z) \Delta Z = - G(Z) \)

- If \( \partial G/\partial Z \) is equal to zero, then the solution can’t be achieved by classical methods.

If a redundant measured data of the electric power flow are available, the amount of equality constraints will exceed the amount of the required variables \((n > m)\). In this case, there is a need to determine the values of vector \( Z \) variables at which the power flow variables are closed, as possible, to the measured values. If the sensitivity matrix \( S \) contains factors of confidence to the power flow measurement characteristics, then the criterion of calculation proximity to the actual power flow becomes the quadratic form of equation (5). The matrix \( \partial G/\partial Z \) is constructed on the basis of Jacobian matrix, and the state estimation conditions are reduced to the solution of the same system in equations (7). The elements of matrix \( W \) vanish near the point of solution. Thus, the system of equations (7) can be simplified [11] to the following form:
Solution of system (8) corresponds to the known solution of the redefined system with the help of the left Gauss Transformation.

### Power Flow with Simultaneous Optimization:

In Equation (1), if \( S = 0 \), the Lagrangian objective function becomes:

\[
    H(Z, \Lambda) = F(Z) + \Lambda^T G(Z) \tag{9}
\]

Minimization of (9) is determined by the following system of equations:

\[
    \begin{bmatrix}
        \frac{\partial^2 F}{\partial Z^2} + W \left( \frac{\partial G}{\partial Z} \right)^T + \frac{\partial G}{\partial Z} \frac{\partial^2 F}{\partial \Lambda^2} + \frac{\partial G}{\partial Z} \frac{\partial^2 F}{\partial \Lambda \partial Z}^T \left( \frac{\partial G}{\partial Z} \right)^T + \frac{\partial G}{\partial Z} \frac{\partial^2 F}{\partial \Lambda^2} \\
        \frac{\partial G}{\partial Z}
    \end{bmatrix} \Delta Z = \begin{bmatrix}
        \frac{\partial F}{\partial Z} + \frac{\partial G}{\partial Z} \frac{\partial^2 F}{\partial \Lambda^2} + \frac{\partial G}{\partial Z} \frac{\partial^2 F}{\partial \Lambda \partial Z}^T \left( \frac{\partial G}{\partial Z} \right)^T + \frac{\partial G}{\partial Z} \frac{\partial^2 F}{\partial \Lambda^2} \\
        \frac{\partial G}{\partial Z}
    \end{bmatrix} \Delta \Lambda \tag{10}
\]

From the solution of equation (10), the values of controlling variable, dependent variables, and Lagrangian multipliers are simultaneously specified [10]. It is worth mentioning that in equation (10) there is no basic difference between the dependent and controlling variables of vector \( Z \). It is assumed that any \( i \)th component of vector \( Z \) may be taken as a controlling variable. In this case the imposition and removal of equality constraints are carried out by the following conditions:

\[
    Z_i^{(k+1)} = \begin{cases} 
        Z_i^{\text{max}}, & \text{if } (Z_i^{(k)} + \Delta Z_i > Z_i^{\text{max}}) \text{ and } (\partial H/ \partial Z_i < 0) \\
        Z_i^{\text{min}}, & \text{if } (Z_i^{(k)} + \Delta Z_i < Z_i^{\text{max}}) \text{ and } (\partial H/ \partial Z_i > 0) 
    \end{cases} \tag{11}
\]

The total number of active controlling variables on each step of optimization should not be less than the number of equality constraints, in addition to the condition that they must not reach their limiting values. Otherwise, if on \( k \)th iteration the amount of active controlling variables is equal to the amount of equality constraints, and the variable \( Z_j \) \((j > n)\) exceeds the limit \( Z_{\text{min}} \) or \( Z_{\text{max}} \), then it is necessary to solve the problem of introduction of the regime into permissible region at incompatible constraints. Penalty function (8) is added to expression (9) for this purpose:

\[
    B = \frac{1}{2} \sum_j t_j (Z_j - \hat{Z}_j)^2 \tag{12}
\]

Where \( t_j \) is sensitivity coefficient for the \( j \)th disturbance of inequality constraints.

The system (10) in this case is simplified as follows:
The Generalized Mathematical Model of Electrical Power System for the Optimal Power Flow

\[ W^{(k+1)}_j = W^k_j + \frac{\partial^2 B}{\partial Z^2} \]  
\[ \frac{\partial H_{(k+1)}^{(k)}}{\partial Z_j} = \frac{\partial H^{(k)}}{\partial Z_j} + \frac{\partial B^{(k)}}{\partial Z_j} \]  

When the functional inequality constraints are subjected to a disturbance, as \( G_{\text{min}} < G(Z) < G_{\text{max}} \), they are replaced by additional equality constraint \( G^d(Z) \) and included together with the appropriate Lagrangian multiplier \( \Lambda^d \) in the objective function (9). Based on Kuhn-Tucker method, the imposition and removal of equality constraints are carried out for \( j \)-th disturbance of inequality functional constraints as follows:

\[ G_i^d(Z) = \begin{cases} 
G_i(Z) - G_{i_{\text{min}}}, & \text{if } (G_i(Z) < G_{i_{\text{min}}}) \text{ and } (\Lambda^d < 0) \\
G_{i_{\text{max}}} - G_i(Z), & \text{if } (G_i(Z) > G_{i_{\text{max}}}) \text{ and } (\Lambda^d > 0)
\end{cases} \]  

It is expedient to include in the matrix of system (10) the derivatives of the active functional constraints for which Lagrangian multipliers, based on Kuhn-Tucker conditions, are equal to zero. However, solving system (10) with respect to the mixed vector \([\Delta Z, \Delta \Lambda]^T\) preserves the structure of the matrix at all calculation stages.

This approach as compared to that in [10], considerably, simplifies the calculation for constraints. In case of their compatibility, neither the algorithms of coordination replacement between the vectors of dependent and independent variables nor the method of the Penalty functions are needed in the solution of system (9) using the proposed approach presented in [8].

**OPF based on Second Order Generalized Reduced Gradient Method:**

The Power system variables are of two sets \( Z=(X, Y) \), namely, the state variables \( X \) and control variables \( Y \). The state variables must be equal to the number of equality constraints \( G(X, Y) \), which depends on the control variables by which the optimization is performed. In this case the Lagrangian objective function can be presented as follows:

\[ H(X, Y, \Lambda) = F(X, Y) + \Lambda^d G(X, Y) \]

The power flow optimization is a nonlinear programming problem, since both objective function and constraints are nonlinear [12]. The boundary conditions on the state variables correspond as the main difficulties of the problem. Some of the solution techniques that deal with this type of problems are the generalized reduced gradient (GRG) methods. In this paper the extended GRG method is presented, which is based on both first and second order approximations of the objective function and constraints.

Partitioning each iteration process for a minimum of the objective function (9) into a step of load flow and a step of optimization calculations. At the step of load flow, the vector of control variables \( Y \) is assumed to be fixed, while at the step of optimization, vector \( \Lambda \) is fixed. The following steps form the algorithm of solution with acceptable
assumptions:

GRG Algorithm:

1. Setting the Initial approximation for vector \(Y^{(0)}\).
2. For the \(k\)-th step of optimization, load flow is calculated with Newton method.
   \[
   (\partial G(X^{(k)}, Y^{(k)}), \partial X) \partial (X^{(k)}, Y^{(k)}) = -G(X^{(k)}, Y^{(k)})
   \]
3. From the condition \(\frac{\partial H^{(k)}}{\partial X} = 0\), the periodic approximation as the vector of Lagrangian multipliers is determined as:
   \[
   \left(\frac{\partial G^{(k)}}{\partial Z}\right)^T \Lambda^{(k+1)} = -\frac{\partial F^{(k)}}{\partial X} \hspace{1cm} (15a)
   \]
4. Substituting the value \(\Lambda^{(k+1)}\) in system (10) to obtain:
   \[
   \begin{bmatrix}
   \frac{\partial^2 F^{(k)}}{\partial X \partial Y} + W^k \\
   \frac{\partial X \partial Y}{\partial X} \Delta X^{(k)} \\
   \end{bmatrix} = -\begin{bmatrix}
   \frac{\partial F^{(k)}}{\partial Y} + \left(\frac{\partial G^{(k)}}{\partial Y}\right) \Lambda^{(k+1)}
   \end{bmatrix} \hspace{1cm} (16)
   \]

As the a vector-gradient are equal zero, the matrix of system (16) is reduced using double factorization method, excluding the columns and lines that are appropriate to \(\Delta X^{(k)}\). As a result of transformation we get:

\[
A^{(k)} \Delta Y^{(k)} = -\frac{\partial H^{(k)}}{\partial Y} \hspace{1cm} (16a)
\]

Where \(A^{(k)}\) is the reduced matrix of system (16) which is structurally similar to Jacobian matrix.
5. Solving equation (16a) for \(\Delta Y^{(k)}\), new values of control variables \(Y^{(k+1)} = Y^{(k)} + \Delta Y^{(k)}\) are found, if optimization process is not completed, then return to step 2.

The calculations for constraints of control variables are carried out based on expression (11), constraints of dependent variables and functional constrains. The necessary condition for a minimum of Lagrangian functions (9) and (15) based on (10), (15a), (16), and (16a) is the positive definiteness of Hessian matrices,

\[
\begin{bmatrix}
\frac{\partial^2 F(Z)}{\partial Z^2} + W(Z, \Lambda) \\
\frac{\partial^2 F(X^Y)}{\partial Z^2} + W(X, Y, \Lambda)
\end{bmatrix}
\]

370
The Generalized Mathematical Model of Electrical Power System for the Optimal Power Flow

To overcome the negative definiteness, the direction and values of the step is selected based on the sign analysis of diagonal elements $LDL^T$ of Hessian expanded matrix. Another method is the replacement of ordinary Lagrangian functions (9) and (15) by the modified form (1). It is possible to assign sufficiently large $S > S_0$, at which Hessian matrix is positively determined [10].

System Test And Results

The optimization algorithm has been integrated as a complement to the standard load flow program in the power system analysis package RNA (Regional Network Analyses) for regional control center. The implementation included an interfacing to the state estimator and the algorithm has been executed periodically (once every 10 minutes) in order to

- Assist the operator to adjust the power system control settings with respect to voltage profile management of reactive power sources;
- Calculate the optimal control settings, i.e. generator voltages, reactive power injections and transformer tap ratios;
- Control the marginal adequacy of the reactive power production;
- Indicate (by the Lagrange multipliers) whether (or not) additional reactive sources are required to decrease the losses.

The test result uses the data file with 495 buses, 745 branches and 66 control variables, including 10 phase shifter transformers 750/330 KV. The production capacity is 27434 MW, the initial system has 10 violated constraints and the power losses are 538 MW.

Three bus type changes were needed to get a feasible system. The optimization required 39.9 sec. on PC, ten iterations in total were required to reach the optimal solution. The power losses were reduced to 508 MW, i.e. 5.6 %.

The calculation and factorization of the Jacobian and Hessian matrix require the most time for execution; it takes about 1 sec. when a new basis is constructed. For subsequent iterations on this basis, the update of the $J$ matrix uses the same sparse structure and requires only about 0.3 sec. The calculation of the reduced gradient takes about 0.14 sec. and the additional operations to obtain the Hessian, when iterations on a new basis starts, it takes only 0.02 - 0.04 sec. The Hessian’s update for subsequent iterations requires 0.04 - 0.08 sec. The calculation of an optimal search direction by quadratic optimization takes about 0.4 sec.

Expressions for components of Vector-Gradient and elements of Hessian Matrix:

The criterion of minimum active power losses is the base for the optimal power flow. The power losses $\pi$ can be expressed as the sum of real power injections at all buses of electrical network:

$$\min_{\forall \phi} \pi = \min_{\forall \phi} (\sum_{\forall \phi} P_i)$$

(17)
At the following constraints:

\[
\Delta P_i = P_i - \tilde{P}_i = V_i \sum_{k} V_k Y_{ik} \cos(\theta_i - \varphi_{ik}) - V_i^2 G_{i\bar{i}} - \tilde{P}_i = 0 \quad ............. (18)
\]

\[
\Delta Q_i = Q_i - \tilde{Q}_i = V_i \sum_{k} V_k Y_{ik} \sin(\theta_i - \varphi_{ik}) - V_i^2 B_{i\bar{i}} - \tilde{Q}_i = 0 \quad ............. (19)
\]

Where:

- \( P_i, Q_i \) - Active and reactive power at \( i \)-th bus;
- \( \tilde{P}_i, \tilde{Q}_i \) - Specified values of active and reactive power, injections,
- \( V_i \) and \( \vartheta_i \) - Magnitude and phase angle of complex voltage at bus \( i \);
- \( Y_{ik} e^{j\varphi_{ik}} \) - Admittance of the branch connecting buses \( i \) and \( k \);
- \( G_{i\bar{i}} + jB_{i\bar{i}} \) - Complex admittance for \( i \)-th bus,
- \( L \) - Number of load buses,
- \( G \) - Number of generation buses,
- \( I \) - Slack bus.

Lagrangian function (9) for the task of (15) considering the constraints in (18) and (19) will have the following form:

\[
H(V, \vartheta, \lambda) = - \sum_{i \in I} P_i + \sum_{i \in G} P_i \lambda_{P_i} + \sum_{i \in G} Q_i \lambda_{Q_i} \quad .................................. (20)
\]

Jacobian matrix elements:

a) \( i \neq k \)

\[
\frac{\partial P_i}{\partial Q_j} = V_k \frac{\partial Q_i}{\partial V_k} = V_k Y_{ik} \sin(\vartheta_i - \vartheta_k - \varphi_{ik}) \quad .................................. (21)
\]

\[
V_k \frac{\partial P_i}{\partial \vartheta_k} = - \frac{\partial Q_i}{\partial \vartheta_k} = V_k Y_{ik} \cos(\vartheta_i - \vartheta_k - \varphi_{ik}) \quad .................................. (22)
\]

b) \( i = k \) for expressions (18) and (19)

\[
\frac{\partial P_i}{\partial \vartheta_i} = -Q_i - V_i^2 B_{ii} \quad .................................. (23)
\]

\[
V_i \frac{\partial P_i}{\partial V_i} = P_i + V_i^2 G_{ii} \quad .................................. (24)
\]
The Generalized Mathematical Model of Electrical Power System for the Optimal Power Flow

\[ \frac{\partial P}{\partial \theta_i} = P_i - V_i^2 G_i \] .......................................................... (25)

\[ V_i \frac{\partial Q}{\partial V_i} = Q_i - V_i^2 B_i \] .......................................................... (26)

In expression (21) - (26), derivatives from active and reactive powers on the voltage profile are multiplied by the appropriate a voltage profile. System of equations (10) can be written in the following form:

\[
\begin{bmatrix}
\frac{\partial (\partial H)}{\partial \theta} & V \frac{\partial (\partial H)}{\partial \theta} & \frac{\partial P}{\partial \theta} & \frac{\partial Q}{\partial \theta} \\
\frac{\partial (\partial H)}{\partial V} & \frac{\partial (\partial H)}{\partial V} & V \frac{\partial (\partial H)}{\partial V} & V \frac{\partial Q}{\partial V} \\
\frac{\partial P}{\partial \theta} & V \frac{\partial P}{\partial V} & 0 & 0 \\
\frac{\partial Q}{\partial \theta} & V \frac{\partial Q}{\partial V} & 0 & 0
\end{bmatrix}
\begin{bmatrix}
\Delta \theta \\
\Delta V/V \\
\Delta \lambda_p \\
\Delta \lambda_q
\end{bmatrix}
= \begin{bmatrix}
\frac{\partial H}{\partial \theta} \\
\frac{\partial H}{\partial V} \\
\frac{\partial H}{\partial \lambda_p} \\
\frac{\partial H}{\partial \lambda_q}
\end{bmatrix}
\] ................................................ (27)

Derivatives from criterion of optimization on angle and profile of a k-th bus voltage:

\[ \frac{\partial \pi}{\partial \theta_k} = \left( \frac{\partial P}{\partial \theta_k} + \sum_{i \in k} \frac{\partial P}{\partial \theta_i} \right), K \in L + G .................................................. (28) \]

\[ V_k \frac{\partial \pi}{\partial V_k} = \left( V_k \frac{\partial P}{\partial V_k} + \sum_{i \in k} V_k \frac{\partial P}{\partial V_k} \right), K \in L + G .................................................. (29) \]

The components of vector-gradient are:

\[ \frac{\partial H}{\partial \theta_k} = \frac{\partial \pi}{\partial \theta_k} + \sum_{i \in L+G} \frac{\partial P}{\partial \theta_k} \Lambda_{pi} - \sum_{i \in L} \frac{\partial Q}{\partial \theta_k} \Lambda_{qi}, K \in L + G ................................................ (30) \]

\[ V_k \frac{\partial H}{\partial V_k} = V_k \frac{\partial \pi}{\partial V_k} + \sum_{i \in L+G} V_k \frac{\partial P}{\partial V_k} \Lambda_{pi} + \sum_{i \in L} V_k \frac{\partial Q}{\partial V_k} \Lambda_{qi}, K \in L + G .... (31) \]

Differentiating (30) and (31) with respect to \( V_i, \theta_i \) regarding (21) - (26) we have:

a) Elements of sub matrix \( \frac{\partial (\partial H)}{\partial \theta} \):

\[ \frac{\partial (\partial H)}{\partial \theta} = V_k \frac{\partial P}{\partial V_i} (\Lambda_{pi} - 1) + V_k \frac{\partial P}{\partial V_i} (\Lambda_{qi} - 1) + V_k \frac{\partial Q}{\partial V_i} \Lambda_{qi} + V_k \frac{\partial Q}{\partial V_i} \Lambda_{qi}, i \neq K \ldots (32) \]

373
The developed expressions of the system (27) have the following advantages:
- Elements of vector-gradient (28) - (31) and W matrix (Hessian matrix) (32)-(37) are developed on the basis of Jacobian matrix, by the recursive computation method of second partial derivatives;
- All elements and vector components of free members have the physical unit of power, while the vector of unknown expressions is expressed in per unit;
- The structure of matrix W is similar to that of Jacobian matrix, which considerably accelerates the process of searching for solution using double factorization method.

Conclusions:
1. The generalized mathematical model (GMM) for the solution of some mathematical modeling is presented in this paper. The problems of the optimal power flow and state estimation can be investigated by the proposed model based on second order gradient method.
2. The recursive method of the second partial derivative calculation for Hessian matrix has been constructed on the basis of Jacobian matrix.
3. Simplicity of the calculation of constraints and square speed of convergence ensure the efficiency of the algorithmic and program realization.
4. The optimization algorithm has been tested on a real system; the test results confirm its efficiency.
The Generalized Mathematical Model of Electrical Power System for the Optimal Power Flow

8. References:


Modeling and Measurement of One-Phase Mixture Using Microwave Frequencies

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Received on Sept. 14, 2005 Accepted for publication on June 4, 2006

Abstract

In this research the rigorous separation of a variable was used to solve the problem of scattering in near-field from a tube containing a mixture. The mixture to be used is to simulate the actual cases that occur frequently in chemical and petroleum engineering. From which, a novel technique was developed to measure one-phase of a mixture using microwave signals. Where the one-phase mixture is the volume fraction occupied by one of the phases.

The theoretical study has taken into consideration the case when the effective permittivity of the mixture is anisotropic. Theoretical and practical results have shown good agreement for the reflected and transmitted power. The results obtained by these results confirmed the possible utilization of this method for controlling and monitoring the value of mixture phases.

Keywords: One-Phase Mixture, Microwave, X-Band, Dielectric Properties, Scattering.

Introduction:

In order to get a better understanding of the interaction between the particles and molecules with microwave signals, the following concepts are necessary to know: Rayleigh-Jeans approximation, absorption, emission, and scattering of radiation. Microwave signals are very well-known in the field of communications, and became a very useful tool in several applications; such as measuring permittivity of liquid mixtures, measuring water content in a substance, sensing moisture levels [1, 2, 3, 4]. Other techniques are available for measuring the mixture [5].

Microwave signals had been used as a measurement tool in free space techniques to determine the moisture content by measuring attenuation and phase shift at X-band frequencies [6].

Microwave radiation transmissivity had been used to measure the liquid fraction of water by passing the liquid mixture through a device which measures the dielectric constant [7].

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Scattering from a dielectric cylinder has been studied by a number of researchers beginning from Lord Rayleigh [8]. However, the derivation of scattering coefficient for two coaxial dielectric cylinders has not been studied in detail, therefore in this research the complete scattering coefficient is derived, followed by the calculation of the reflected and transmitted powers, and then the case of anisotropic cylinder is also treated in detail.

**Theoretical analysis:**

**Dielectric properties of a mixture:**

A mixture of substances is defined to be a medium consisting of several constituents, each of which occupies an appreciable fractional volume of the composite medium [9]. When the mixture contains one type of inclusions, the mixture is called a two-phase mixture. In the case when the inclusions are isotropic, identical in size, shape, and orientation relative to the direction of the applied electrical field, dispersed randomly within an isotropic host medium, the effective permittivity of the mixture is anisotropic, and it is dyadic. De-Loor [10] has obtained the following expression of a two-phase mixture containing ordered ellipsoidal particle inclusions. Particles are assumed to be randomly dispersed within the host, and for convenience, their orientation is chosen such that, their semi-axes \( a, b, \) and \( c \) are along the \( x, y, \) and \( z \)-axes of a rectangular coordinate system respectively.

\[
\varepsilon_m = \varepsilon_h + \frac{v_i (\varepsilon_i - \varepsilon_h)}{1 + A_u \left( \frac{\varepsilon_i}{\varepsilon^*} - 1 \right)}
\]

Where;

- \( \varepsilon_m \) is the average value of the dielectric constant of the mixture, \( \varepsilon_h, \varepsilon_i \) is the average dielectric constant of the host and inclusion materials respectively, \( A_u \) is the depolarization of the ellipsoid along its \( u \)-axis (\( u = a, b, \) or \( c \)), \( v_i \) is the inclusion volume fraction, \( \varepsilon^* \) is the effective dielectrical constant of the region immediately surrounding an included particle. For small values of inclusion volume fraction \( v_i \leq 0.1 \) De-Loore assigned \( \varepsilon^* = \varepsilon_h \), while for moderate to high values of \( v_i \) De-Loore assigned \( \varepsilon^* = \varepsilon_m \). Figure (1) shows the effective permittivity of water-air mixture versus water hold-up at 10 GHz frequency [10].

**Scattering from a Dielectric Tube:**

Consider a plane wave of unit amplitude incident normally on a dielectric cylinder as shown in figure (2). The direction of incidence is along the \( x \)-axis, and it’s
polarization in the \( z \)-direction. The electric field in each region (after expansion in terms of Bessel functions [11]) using cylindrical coordinates is given by:

In region 1:

\[
E_{1z} = \sum_{n=0}^{\infty} \delta_n (j)^n \left[ J_n(\beta_n r) + A_n H_n^{(2)}(\beta_n r) \right] \cos(n\phi) \tag{2}
\]

In region 2:

\[
E_{2z} = \sum_{n=0}^{\infty} \delta_n \left[ B_n J_n(\beta_2 r) + C_n Y_n(\beta_2 r) \right] \cos(n\phi) \tag{3}
\]

In region 3:

\[
E_{3z} = \sum_{n=0}^{\infty} \delta_n D_n J_n(\beta_3 r) \cos(n\phi) \tag{4}
\]

The \( J_n \) and \( Y_n \) are the Bessel functions of the first and the second kind, respectively. The \( H_n^{(2)} \) is the Hankel function of the second kind, and the \( \beta_n \)’s are the wave numbers appropriate to the various regions \( (\beta_n=\omega(\mu_0\epsilon_n)^{1/2}) \), where the subscript \( n \) is the medium number, and \( \epsilon_n \) is the relative permittivity of the medium. \( \delta_n \) is the Neumann factor (equals 1 when \( n=0 \), and equals 2 when \( n\neq0 \)). The terms \( B_n, C_n, \) and \( D_n \) are constants. \( A_n \) is the scattering coefficient.

From Maxwell equations, the scattered magnetic fields are:

\[
H_{sr} = \frac{1}{j\omega\mu_o r} \frac{\partial E_z}{\partial r} \tag{5}
\]

\[
H_{s\phi} = \frac{-1}{j\omega\mu_o} \frac{\partial E_z}{\partial \phi} \tag{6}
\]

Where \( \mu_o \) is the free space magnetic permeability.

The scattering coefficients are calculated according to the boundary condition that the tangential component of the electric and normal component of the magnetic fields must be continuous across the boundary, in the absence of any surface currents [10].

Hence the scattering coefficient is given by:
Al-Samarrie

\[ A_n = \frac{\beta_1 M_n J_n^0 (\beta_1 b) - \beta_2 N_n J_n (\beta_1 b)}{\beta_2 N_n H_n^{(2)}(\beta_1 b) - \beta_1 M_n H_n^{(2)} (\beta_1 b)} \] ...................................................(7)

where

\[ M_n = J_n (\beta_2 b) - \frac{F_n}{J_n} Y_n (\beta_2 b) \] ...................................................(8)

\[ N_n = J_n^0 (\beta_2 b) - \frac{F_n}{J_n} Y_n^0 (\beta_2 b) \] ...................................................(9)

And

\[ F_n = \beta_3 J_n (\beta_3 a) J_n (\beta_2 a) - \beta_2 J_n (\beta_2 a) J_n (\beta_3 a) \] .................(10)

\[ K_n = \beta_3 J_n^0 (\beta_3 a) Y_n (\beta_2 a) - \beta_2 Y_n^0 (\beta_2 a) J_n (\beta_3 a) \] ......................(11)

In the case when the effective permittivity of the mixture is dyadic

\[
\begin{bmatrix}
D_x \\
D_y \\
D_z
\end{bmatrix} =
\begin{bmatrix}
\varepsilon_{11} & 0 & 0 \\
0 & \varepsilon_{22} & 0 \\
0 & 0 & \varepsilon_{33}
\end{bmatrix}
\begin{bmatrix}
E_x \\
E_y \\
E_z
\end{bmatrix}
\]

Where \( D = \varepsilon E \), it is necessary to replace \( \beta_3 = k\sqrt{\varepsilon_3} \) by \( \beta_3 = k\sqrt{\varepsilon_{33}} \) in the expression of the scattering coefficients.

**Calculation of the reflected and transmitted powers:**

Consider the experimental set-up, (figure (3)). The reflected and transmitted powers are proportional to the power density flowing at normal incidence to these apertures. The reflection and transmission regions can be defined as follows:

Reflection region \(-\Pi/2 < \phi < \Pi/2\)

Transmission region \(\Pi/2 < \phi < 3\Pi/2\)

Hence the reflected power along x-direction and perpendicular to the aperture can be calculated as follows:

\[ R = (x^2 + y^2)^{1/2}, \quad \phi_R = tan^{-1}(y/x) \]

and by Poynting theorem:

\[ 380 \]
Modeling and Measurement of One-Phase Mixture Using Microwave Frequencies

\[ P_r = -0.5r [E_{sz}(r, \phi_r) [H_s \phi(r, \phi_r) \cos(\phi_r) + H_{sr}(r, \phi_r) \sin(\phi_r)]^*_\phi] \] ......................(12)

where \( P_r \) is the reflected time average power density, \( y \) is the distance that represents the width of the waveguide; \( x \) is the distance from the center of the cylinder to the aperture. \(*\) is the complex conjugate, \( a \) and \( b \) are the waveguide dimensions. Thus by varying \( y \), the power density along the aperture can be calculated as follows:

\[ P_{r(total)} = \frac{a}{2b} \int_{0}^{\infty} P_r \, dy \] .................................................................................. (13)

The transmitted power can also be obtained using eq. (13) noting that the total shadow field in the transmitted power must be used. Figures (4 to 9) show the variation of the normalized reflected and transmitted power for different constrains.

Experimental system:

The microwave set up shown in figure (3) was used for practical measurements at different frequencies. The sweep oscillator type PM 7022x (with a frequency range of 8 to 12.4 GHz) has been used to deliver the power at a desired frequency to the system. The 10dB coupling, 40dB directivity directional coupler model x752A is used to measure the reflected power from the cylinder. The cylinder was placed in the Fresnel region from the aperture of the waveguide. The measurements of the received and reflected powers were carried out by using the HP model 415E SWR meter, and PM 7325x detector.

Results and discussion:

The practical results obtained in this research are confirmed by theoretical analysis. The practical measurements were done in the x-band frequencies. Meanwhile, the theoretical equations presented in this research can be used in theoretical analysis in the x-band up to 20GHz.

Figures (4&5) show the normalized reflected and transmitted powers calculated for the waveguide WR(90), which are greater than the density delivered to the aperture without the cylinder. This is due to the focusing action of the tube. The focusing action occurs always in the shadow region for different values of \( \phi \), depending on the radius, and the permittivity of the cylinder. Figures (4&5), indicate that the reflected power is more sensitive to the variation of the phase mixture than the transmitted power. The peaks in these figures are due to the phase transition that occurs in the illuminated shadow fields. Figures (6&7) show the reflected and transmitted power for different phase mixture at 20GHz calculated using waveguide WR(42), based on theoretical analysis. Results in figures (6&7) illustrate larger variations than the results in figures (4&5). In figures (8&9) the variation of the reflected and transmitted power for different frequencies at specific mixture phases were plotted. The value of the mixture was chosen
to be 1 for simplicity. The same procedure can be used to draw the transmitted and the reflected power versus frequencies at any other value of phase mixtures in theoretical and practical measurements.

Experimental results (figures (4,5,8, &9)) show that the discrepancy between theoretical and experimental results can be attributed to several factors such as spurious response of the detector and accuracy of the reading apparatus. During the measurements, a calibration of the oscillator output power was done before each reading. Finally, it is worth mentioning that the practical measurements have been done in the X-band frequencies only because of instrument limitations. On the other hand the theoretical equations presented in this research can be used for theoretical analysis at different microwave frequencies.

Conclusion:

This research outlines a novel method in controlling and monitoring the value of a one-phase mixture by using microwave signals. The results were confirmed by both theoretical analysis and practical measurements.

From the above results we can conclude that, there are three parameters which can be varied to obtain a variation at a specific phase mixture. These are: the radius of the tube, the operating frequency, and the distance between the cylinder and the receiving apertures.

Further investigations are needed in other bands of microwave frequencies (below and above the x-band), with cautions on the effect of frequency on some of the parameters in the high part of the spectrum.

![Graph](image)

**Figure (1):** Water-Air mixture permittivity versus water phase. Series1 is the real component of permittivity and, Series 2 is the imaginary component of permittivity
Figure (2): The geometry of the problem

Figure (3): The experimental set-up
Figure (4); Normalized reflected power versus water phase.
Series 1 is the theoretical plot and,
Series 2 is the practical plot.

Figure (5); Normalized transmitted power versus water phase.
Series 1 is the theoretical plot,
Series 2 is the practical plot.
Modeling and Measurement of One-Phase Mixture Using Microwave Frequencies

Figure (6); Theoretical calculation of the normalized reflected power versus water phase at 20GHz frequency.

Figure (7); Theoretical calculation of the normalized transmitted power versus water phase for 20GHz frequency.
Figure (8): Normalized reflection power versus frequency for one water phase.
Series 1 is the theoretical plot and,
Series 2 is the practical plot.

Figure (9): Variation of transmitted power versus frequency for one water phase.
Series 1 is the theoretical plot and,
Series 2 is the practical plot.
Modeling and Measurement of One-Phase Mixture Using Microwave Frequencies

نمذجة وقياس أحد الأطوار لمزيج باستخدام الأمواج الدقيقة

عياد خلف السامرائي

ملخص

في هذا البحث استخدمت طريقة فصل المتغيرات الدقيقة جداً لحل معادلات البختر في المجال القريب من أنبوب يحتوي على مزيج. يستخدم المزيج لتمثيل الحالات التي تحدث بصورة متكررة في تطبيقات كثيرة كما في الهندسة الكيماوية والتغليفية وغيرها. استنادا إلى طريقة فصل المتغيرات تم استخدام طريقة جديدة لقياس المحتوى الجزئي لأحد الأطوار باستخدام الوجبات الدقيقة. الدراسة النظرية أخذت بنظر الاعتبار الحالات التي يكون فيها المزيج ذو خواص ليست واحدة في جميع الاتجاهات. النتائج النظرية والنتائج العملية كانت متقاربة من حيث القدرة المتكافئة والمرونة. نتائج هذا البحث أثبتت إمكانية استخدام هذه الطريقة للمرافقة والسيطرة على قيم أطوار المزيج.

References


<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using a Compact Scintillation NaI(Tl) Detector to Study the Environmental Radiation</td>
<td>Jehad K. Mulhem and Jabbour N. Jabbour</td>
<td>189</td>
</tr>
<tr>
<td>Borate Glass with Lead and Nickel Oxides for Radiation Attenuation</td>
<td>Fawzi A. Ikraiam, A. El-Suyed Abd, A. Abd El-Latif and M. El-Desoky</td>
<td>195</td>
</tr>
<tr>
<td>Transfer of Natural and Artificial Radionuclides to Selected Plants in Jordanian Soils</td>
<td>Mohammad. I. Awadallah and Dia-Eddin. M. Arafah</td>
<td>207</td>
</tr>
<tr>
<td>Radon Monitoring at Khartoum Using the Charcoal Technique</td>
<td>Osman Mustafa Mukhtar and Abd Elmoniem Ahmed Elzain</td>
<td>225</td>
</tr>
<tr>
<td>Longitudinal Space Charge Impedance of Non-Resistive Cylindrical Pipe in the Presence of a Uniform Background of Charged Particles</td>
<td>Nidal M. Ershaidat</td>
<td>237</td>
</tr>
<tr>
<td>Influence of Nd-YAG Laser Pulses on Aluminum Alloys, Study of Chemical Distribution of Elements</td>
<td>Layla Baziz, Abdul-Kader Nouiri and Yaser A. Yousef</td>
<td>257</td>
</tr>
<tr>
<td>Performance Evaluation of AES/Triple-DES/Blowfish Ciphers under W2K and Linux Operating System Platforms</td>
<td>Najib A. Kofahi</td>
<td>265</td>
</tr>
<tr>
<td>Two Enhanced Fuzzy Similarity Approaches for Arabic Web Pages Classification</td>
<td>Ahmad T. Al-Taani and Noor Aldeen K. Al-Awad</td>
<td>287</td>
</tr>
<tr>
<td>Improving the Effectiveness of Web Caching at the Client’s Site</td>
<td>Samia Abul-Rub and Sami Serhan</td>
<td>303</td>
</tr>
<tr>
<td>Mathematical Model of Real Physical Processes in Control Systems</td>
<td>Mamoun S. Al Rababaa</td>
<td>319</td>
</tr>
<tr>
<td>A Generic XML-(Relational : Object) Mapping Scheme (GXROMS)</td>
<td>Munib A. Qutaishat, Sherenaz W, Al Haj Baddar and Majdi Bsaiso</td>
<td>335</td>
</tr>
<tr>
<td>Geology of the Dhaher (Bargish) Cave System, NW Jordan</td>
<td>Nizar Abu-Jaber, Hakam Mustafa and Deema Melhem</td>
<td>351</td>
</tr>
<tr>
<td>Modeling and Measurement of One-Phase Mixture Using Microwave Frequencies</td>
<td>Aied K. M. Al-Samarrie</td>
<td>377</td>
</tr>
</tbody>
</table>
التوثيق:
  • تعد قائمة بالمصادر والمراجع المنشورة في نهاية البحث حسب الترقيم الوارد في النص.

إذا كان المرجع كتابًا يكتب هذا:
[ 1 ] [ ]

إذا كان المرجع بحثًا في دورية يكتب هذا:
[ 1 ] [ ]

ب- توثيق المواضيع والمصادر غير المنشورة: يتم ذلك في المثنى بكتابة كلمة (هامش).
متبوعة بالرقم المتسلسل للهامش داخل فوسين، هكذا: (هامش 1). وتذكر المعلومات التفصيلية لكل هامش في نهاية البحث تحت عنوان الهامش وقبل قائمة المراجع:
هامش 1: خضر، بسام راشد، قياس تركيز الرادون222 في قطاع حديقة مدينة اربد، الأردن، رسالة ماجستير غير منشورة، جامعة اليرموك 1990، ص 8-11.

مراجعات الكتب: تنقل للنشر في المجلة مراجعات الكتب الحديثة القيمه.
التصرف: يحق لرئيس التحرير إجراء التغييرات التي يراها ضرورية لأغراض الصيغة.
المستقبل: يمنح كل من ينشر بحثه نسخة واحدة من عدد المجلة الذي ينشر فيه البحث بالإضافة إلى عشرين نسخة منه.

ترسل البحوث والمراسلات إلى رئيس تحرير مجلة:
أبحاث اليرموك "سلسلة العلوم الأساسية والهندسية" عمادة البحث العلمي والدراسات العليا جامعة اليرموك
ارب-الملكة الأردنية الهاشمية

يمكن الحصول على أبحاث اليرموك من قسم التبادل في مكتبة جامعة اليرموك، أو عمادة البحث العلمي والدراسات العليا لقاء دينار للنسخة الواحدة.
الاشتراك السنوي: ديناران ونصف في الأردن، وثمانية دنانير أو أثنا عشر دولاراً أمريكيًا في الوطن العربي، وثمانية عشر دولاراً أمريكيًا أو ما يعادلها في البلدان الأخرى.
 bácحاث البرموك
سلسلة العلوم الأساسية والهندسية
مجلة علمية محكمة
تنشر المجلة البحوث الأصلية التي تتوافر فيها
المنهجية السليمة، والتي لم تقدم للنشر في أي مكان آخر

قواعد وإجراءات النشر

- اللغة: تكتب البحوث باللغة العربية أو باللغة الإنجليزية ولا تستلم البحوث بغير
  هاتين اللغتين.

- تقديم البحوث: تقدم البحوث في أربع نسخ مطبوعة بغرامات مزادوجة وعلى وجه
  واحد، و هوذاش حجم الواحد منها 2.5سم.

ب) يجب أن لا يزيد عدد صفحات البحث بما في ذلك الأشكال والرسوم والمراجع
  والخلافات والملحق من (30) صفحة.

- يقدم الباحث ملخص البحث في صفحتين منفصلتين أحدهما باللغة العربية والآخر
  باللغة الإنجليزية في ما لا يزيد على 200 كلمة لكل منهما.

- يكتب عنوان البحث واسم المؤلف ورتبته العلمية والمؤسسة التي يعمل بها على
  الصفحة منفصلة. ثم يكتب عنوان البحث مرة أخرى على الصفحة الأولى من البحث
  وعلى صفحة كل مفصل.

- يقدم البحث بعد الموافقة على نشره مطبوعًا ومحفوظًا على قرص كمبيوتر قياس
  IBM (Microsoft Word 2000, XP) 3.5 إنش متوافق مع أنظمة

الأشكال والرسومات:

- توضع الأشكال والرسومات والخلافات في نهاية البحث مع الإشارة إلى أماكنها المناسبة في
  المتن. ووصف لها صفحة منفصلة.

- تقدم الأشكال والرسومات والخلافات مرسمة بالحبر الأسود على ورق شفاف
  (Tracing Paper) وفي صفحات منفصلة بحيث لا تتجاوز أبعاد هذه الأشكال والرسومات
  (19سـم×12سـم).

اسماء الأعلام الأجنبية: عند وروى اسماء أعلام أجنبية في البحوث المقدمة بالعربية
فإنها تكتب باللغة العربية تليها الأسماء بالإنجليزية بين قوسين.
هيئة التحرير

رئيس التحرير

الأستاذ الدكتور عبدالرحمن عطيات

الأعضاء

الأستاذ الدكتور عمير الريماوي
الأستاذ الدكتور محمد أبوصالح
ال исследاطي الدكتور حامد زيادات

سكرتير التحرير

غلا شاكر عقله
لجمع حقوق الطبع محفوظة لجامعة اليرموك 2006
لا يجوز نشر أي جزء من هذه المجلة أو اقتباسه دون الحصول على موافقة خطيّة مسبقة من رئيس التحرير

ما يرد في المجلة يعبر عن آراء أصحابه، ولا يعكس آراء هيئة التحرير أو سياسة جامعة اليرموك

المراجعة اللغوية
الاستاذ الدكتور ابراهيم جبريل
قسم الكيمياء - جامعة اليرموك

تنسيق وإخراج
أحمد أبوهمام ومجدي الشناق
أبحاث اليرموك

سلسلة العلوم الأساسية والهندسية
مجلة علمية محكمة

المجلد الخامس عشر
العدد الثاني
1427ه/2006م
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