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V.T. LAZURIK, G.F. POPOV, SAWAN SALAH
V.N. Karazin Kharkiv National University
Z. ZIMEK
Institute of Nuclear Chemistry and Technology

APPROBATION METHODS OF NUMERICAL DIFFERENTIATION THE DEPTH DOSE DISTRIBUTION MEASURED WITH APPLICATION DOSIMETRY WEDGE METHOD

Approbation methods of numerical differentiation the depth dose distribution of electron emission is performed on the base of measured data obtained with dosimetry wedge method application. The stability of these methods is evaluated in respect to the value of random component of the measured data uncertainty.

Keywords: numerical differentiation, the depth dose distribution, electrons energy.

В.Т. ЛАЗУРИК, Г.Ф. ПОПОВ, САВАН САЛАХ
Харківський Національний Університет ім.В.Н.Каразіна
З. ЗІМЕК
Інститут Ядерної Хімії та Технологій. Варшава, Польща

АПРОБАЦІЯ МЕТОДІВ ДИФЕРЕНЦІЮВАННЯ ГЛИБИННОГО РОЗПОДІЛУ ДОЗИ ВИПРОМІНЮВАННЯ, ВИМІРЯНОГО МЕТОДОМ ДОЗИМЕТРИЧНОГО КЛИНУ

Апробація методів чисельного диференціювання глибинного розподілу дози електронного випромінювання виконується на основі даних, отриманих в спеціально проведених вимірюваннях. Оцінюється стійкість цих методів до величини випадкової складової похибки результатів вимірювань.

Ключові слова: чисельне диференціювання, розподіл дози випромінювання, енергія електронів.

В.Т. ЛАЗУРИК, Г.Ф. ПОПОВ, САВАН САЛАХ
Харьковский Национальный Университет им.В.Н.Каразина
З. ЗИМЕК
Институт Ядерной Химии и Технологий. Варшава, Польша

АПРОБАЦИЯ МЕТОДОВ ДИФФЕРЕНЦИРОВАНИЯ ГЛУБИННОГО РАСПРЕДЕЛЕНИЯ ДОЗЫ ИЗЛУЧЕНИЯ, ИЗМЕРЕННОГО МЕТОДОМ ДОЗИМЕТРИЧЕСКОГО КЛИНА

Апробация методов численного дифференцирования глубинного распределения дозы электронного излучения выполняется на основе данных, полученных в специально проведенных измерениях. Оценивается устойчивость этих методов к величине случайной составляющей погрешности результатов измерений.

Ключевые слова: численное дифференцирование, распределение дозы излучения, энергия электронов.

The problem formulation

Computer modeling of depth dose distributions in the irradiated objects requires the data sets related both to the properties undergoing radiation treatment, and the topical parameters of radiation installation. The standards [1, 2] describe the formal procedures for the electron energy determination as fundamental parameter of radiation installations equipped with electron accelerators. The methods of electron energy determination, which are commonly used in radiation centers, are based on depth dose distribution measurements with dosimetric wedge or stack of plates application. When the results of measurement are composed as discrete data sets, the formal procedures for electron energy determination demand the solution of incorrect mathematical task - numerical differentiation of depth dose distribution deposited by electron beam.

Analysis of recent investigations and publications

The comparison of numerical differentiation methods of depth dose deposited by electron beam with the use of various types approximations of the sets of discrete data are given in literature [3]. The values of the first and second derivatives with polynomial approximation method and fitting of semi-empirical model to the results of numerical experiments were calculated. It has been shown that methods of fitting the semi-empirical models or polynomial approximation allow with satisfactory accuracy calculate the values of first derivative of dose distribution as function of depth. It should be noticed, that considered computational methods for the values of second derivatives the dose distribution in depth are only suitable for estimation. However, according to the paper [3], estimation accuracy of computational methods performed on the basis of the results of numerical experiments is obtained by Monte Carlo method with a very small statistical error. It is obvious, that assessment accuracy of the measurements results should be performed taking into account the effect of random errors of the processed data.

Therefore in the paper [4] the statistical errors connected to the results of numerical experiments were chosen comparable to the errors of measurement results performed with standard methods in radiation technology centers (3-5%). Comparisons computational methods of calculating the practical range of electrons were performed on the basis of the data set obtained by simulation with Monte Carlo method of depth distributions of electron radiation dose using software RT-Office [5].

The results presented in literature [4] allow formulate recommendations for the choice of processing method of measurement and electron energy determination. In particular it should be noticed that the method of fitting the semi-empirical model and approximation method with polynomial of the 4th degree of measured depth dose distribution allow with high accuracy calculate the values the effective energy of electrons.

Formulation of research objective

The methods of numerical differentiation of the depth dose distribution of electron radiation is continued in this paper with the data base obtained in performed experiments [6] with the use of standard dosimetric wedge made of aluminum. Computing methods for determination the first and second derivatives of the dose distributions with respect to depth which use the fitting semi-empirical model or approximation with polynomial of 4th degree the measurement results were investigated. It was estimated on the basis of experimental data processing the stability of these computational methods to the value of random component of the errors of processed data.

The use of numerical differentiation methods of dose distribution with respect to depth.

Determination the first and second derivatives of dose distribution with respect to depth based on a parametric fit of semi-empirical electron energy absorption model to measured results were performed according to the procedure described in literature [3].

Fig. 1 (left) shows the results of numerical differentiation data related to depth dose distribution in the standard dosimetry wedge, which were obtained by averaging the three sets of measurements performed during radiation processing in radiation-technological facility in "regime 1" of irradiation [3].

Fig. 1 (right) shows the calculation results of derivatives for the case "1" and dose distribution measurements performed in "regime 2" of irradiation.

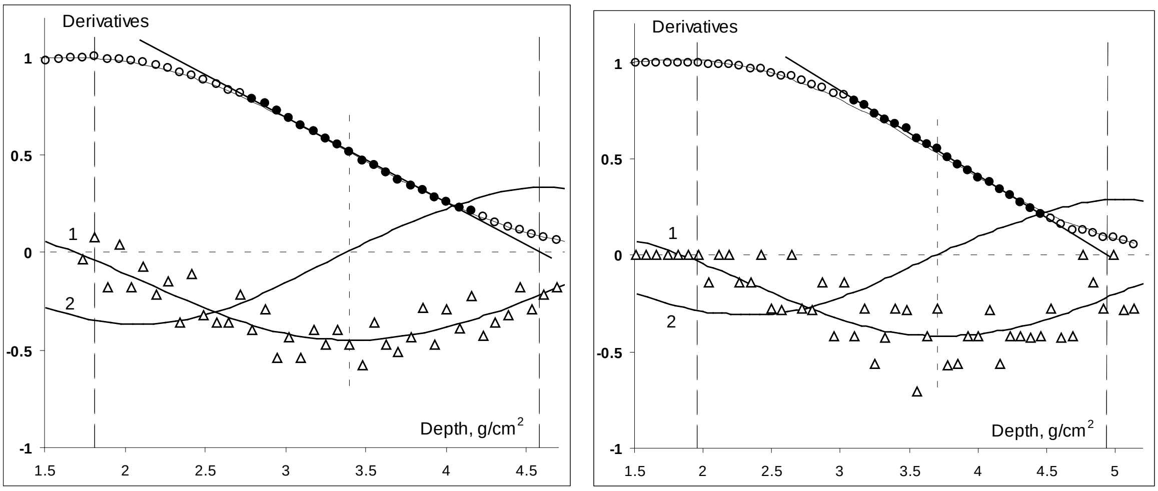

Fig.1. The depth dose distribution and the first and second derivatives of dose distribution with respect to depth, calculated on the basis of method parametric fitting of semiempirical model to the measurement results. Empty circles - data measuring the dose distribution, filled circles - selected data for the linear approximation (solid line), triangles - the results of the numerical differentiation of measurement data. Solid curves - dose distribution, the first derivative (curve 1) and the second derivative (curve 2) dose distribution with respect to depth.

As can be seen from the Fig. 1 the method of parametric fitting of semi-empirical model allows to perform satisfactory of evaluation derivatives of dose with respect to depth, random measurement error distributions of depth dose distribution defined by standard methods in radiation processing (sterilization) centers.

Approximation with a polynomial of 4th degree of measured data was applied to the "broad" area of the depth dose distribution where is observed a decrease of the dose value.

The lower boundary of this area was considered as the position depth of maximum dose value $\boldsymbol{D_{max}}$. If $\boldsymbol{D_{max}}$ value is available in a set of depth dose distribution data, the boundary region is considered to be the greatest depth value of this set.

The upper boundary of the depth dose distribution was considered for evaluation the value of practical range of electrons penetration $\boldsymbol{R_p}$, calculated on the base of linear interpolation of data in the region depths of (0.8 - 0.2) $\boldsymbol{D_{max}}$.

The procedure for determination the value of $\boldsymbol{R_p}$ and the boundary field of depth (vertical lines) allocated for processing of data using a polynomial approximation of the 4th degree are shown in Fig. 1.

Fig. 2 shows the results of numerical differentiation the dose distributions using the approximation of measurement results (shown in Fig. 1) polynomials of 4th degree in "wide" area of depths.

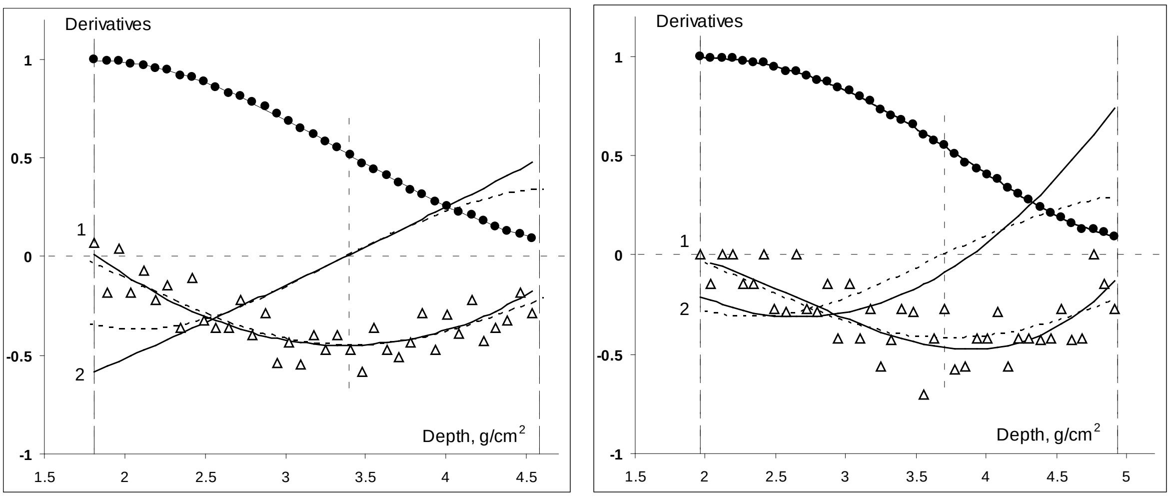

Fig.2. Approximation with a polynomial of 4th degree the measurement results in "wide" area of depths. Circles filled - selected measurement results for the approximation. The curve passes through the filled circles -approximation data. Solid curves 1 and 2 the first and second derivatives of dose with respect to depth, calculated on the basis of a polynomial approximation.

Fig. 3 shows the results of numerical differentiation of dose distribution using the approximation of measurement results (shown in Fig. 1) with polynomials of 4th degree in the region of depth dose distribution, where close to a linear relationship is observed and decrease of depth dose distribution ("narrow" area of depth). The region of depth dose value in diapason from 0.8 to 0. 2 of $\boldsymbol{D_{max}}$ was used.

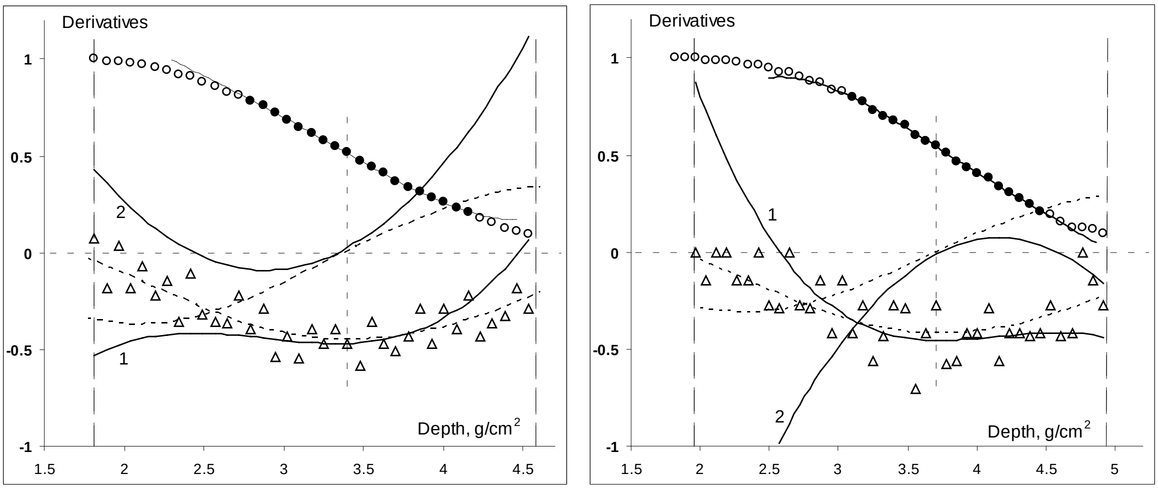

Fig.3. Approximation with a polynomial of the 4th degree of measurement results in "narrow" area of depths. Empty circles - data measuring the dose distribution, filled circles - selected measurement results for the approximation. The curve passes through the filled circles - approximation data. Solid curves 1 and 2 - the first and second derivatives of dose with respect to depth, calculated on the basis of a polynomial approximation.

The dashed lines presented on Fig. 2 and 3 show the first and second derivatives of the dose calculated on the basis of a parametric fitting of semi-empirical model.

As can be seen on Fig. 2 derivatives which were calculated on the base of the method of polynomial approximation dose measurement results in "wide" area of depths are in satisfactory agreement with calculated data in the semi-empirical model. When polynomial approximation of dose measurement results in the "narrow" area of the depth dose distribution are applied the derivatives are greatly differ from those calculated in the semi-empirical model. It can be observed even the qualitative difference of the derivatives according to results presented on Fig. 3. However, the values of derivatives at point "inflection" (vertical dotted line) are close to depth dose distribution and hence the value of $\boldsymbol{R_p}$, calculated using these methods will coincide with good accuracy.

The results and conclusions

The application of parametric fitting semi-empirical model and the polynomial approximation of the 4th degree of data over a wide range of depth dose distribution were compared. It can be concluded on the basis of the results comparison that these methods of numerical differentiation of the dose distribution are resistant to the value of the random component of the data error to be processed. This conclusion means that sets of experimental data usually obtained in radiation technology center could be applied for more deep investigation to characterize the electron energy based on numerical studies presented in literature [4].

Methods for measuring the polynomial approximation results in a narrow range of depths, where there is a linear decrease of the depth dose distribution, are not resistant to the random component of the error data to be processed, as shown in the presented examples. This means that the formal use of polynomial approximation of measurement results to solve practical problems of a class of numerical differentiation dose distribution can lead to great uncertainty and error in results of calculation. In particular this conclusion applies to the proposed in literature [7] method, where practical range of the electrons was determined on the base of polynomial of the 4th degree approximation of the electronic measurement of radiation dose distribution in the depths with linear decrease of the depth dose distribution.

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