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Selection of calculation methods for the analysis of absorbed depth-dose distributions of electron beams

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Abstract. The work is dedicated to comparison methods of processing the results of measurements of the absorbed depth-dose distributions (DDD) of the electron radiation to determine the practical range of electrons. The sets of test data were obtained by modeling the DDD with use Monte Carlo method. The accuracy of the calculation method is determined by the mean square error of processing results the sets of test data. In the paper it was performed the comparison of computational methods of processing the measurement results that differs in the sizes of the array of data being processed and types of functions which use for approximation the data. Comparison the accuracy methods is base for the recommendations on the selection of computational methods for determining the practical range of electrons for computational dosimetry of electron radiation.

Keywords. Electron Radiation, Computational Dosimetry, Practical Range, Depth-Dose Distribution.

INTRODUCTION

In practice of the radiation-technological centers, measurement of DDDs in the dosimetric wedge or stack is used in the standard method dosimetry of electron radiation [1]. On the base of these measurements it is determined the spatial characteristic of the absorbed dose such as the practical range R_p. The standard describes the formal pro-cedures for determining the spatial charac-teristics of the dose distribution [1]. However, the measurements results of depth-dose distribution are usually provide as the set of discrete data. Consequently, the formal procedures for determining the practical range R_P are connected with solving of incorrect mathematical tasks. The various types of Approximations of tabular data are used for obtaining quasi solutions of this tasks.

In particular, to use of approximation the measuring results of the depth-dose distributions with software tool EMID [2] was proposed in [3]. The method of Parameter Fitting of Semi-Empirical Model (PFSEM) [3, 4] was used in this approach, for processing the measurement results obtained with dosimetric wedge. Approbation of computational method PFSEM was successfully performed in processing the results of measurements with using of dosimetric wedge in the Institute of Nuclear Chemistry and Technology, Warsaw, Poland [5].

FORMULATION OF THE PROBLEM

The accuracy of the determination of the practical range R_p depends on methods and type of functions which are used to approximate the measurement results of the DDD of electron radiation. In this work a comparison of various methods of processing of measurement results, which have different sizes of data area and type of functions was used for approximation of discrete data. The sets of test examples of the DDDs for the statistical estimates of the random errors of the methods were calculated. The accuracy of the methods is defined as the statistical estimate of the uncertainty in results of data processing.

SELECTION OF COMPUTATIONAL METHODS

The following methods were selected for performing comparison:

- Linear approximation of the DDDs in a limited diapason of the dose values,

- Approximation of the DDDs in a limited diapason of the dose values using the polynomials of 4th degree,

- Parametric fitting of semi-empirical model to the DDDs in the depths area, where the values of doses were determined.

By comparing the methods, it was selected the sets of dose values from different areas with symmetrical boundaries relatively values the dose $D(x_p)$ at the inflection point x_p of the DDD. On the basis of numerical studies of DDDs the $D(x)$ in the aluminum target irradiated with electrons energy of 10 MeV, it can be assumed

$$K_p = \frac{D(x_p)}{D_{\max}} \approx 0.50, \quad \text{where}$$

$$D_{\max} = \max_{x \in [Rm, Ro]} (D(x)).$$

As example, the following values are presented in the Table 1: K_{min} values for lower and K_{max} for upper boundaries of the doses values.

Table 1. Practical ranges and dose of electrons

Area	K_{min}	K_{max}	N_p	R_P-Line	R_P-Pol
A_1	0	1	27	--	2.024
A_2	0.2	0.8	12	2.036	2.017
A_3	0.25	0.75	10	2.030	2.015
A_4	0.3	0.7	6	2.024	2.014
A_5	0.4	0.6	4	2.018	--

The column N_p shows the calculated number of dose values, which belong to the data treatment area (number of processed nodes). Region A_1 has the maximum number of nodes (N_p = 27), because it contains the entire set of data on the decline of depth-dose distribution. Region A_4 has a minimum number of nodes (N_p = 6) to approximate polynomial of the 4th degree, because the number of nodes to be processed should be more than five.

Table 1 shows the values of practical range R_P of electrons (in units of [cm]) calculated on based processing of the DDDs, which has been obtained with low statistical errors (<0.05%), with use the Monte Carlo method. The processing of DDDs was performed using a linear approximation (data in column R_P-Line) and the approximation by polynomials of 4-th degree (R_P-Pol column).

CONCLUSIONS

A comparison of various computational methods for determining the practical range of the electrons on the basis of processing of the results of measurements of the DDDs of electrons radiation, was performed. The set of test cases for DDDs were calculated by the Monte-Carlo method in the detailed physical model for this purpose. The accuracy of the computational method was defined as the mean square error for the set of test cases. Compared computational accuracy of measurement results of processing methods, which vary in size and field processed data types of functions, were used to approximate the data. The results of the comparison makes possible formulation of scientifically substantiate recommendation of two-parametric method of fitting a semi-empirical model (PFSEM method) for computational dosimetry of electron irradiation in radiation processing technologies.

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