RT-OFFICE FOR ELECTRON BEAM, X-RAY, AND GAMMA-RAY DOSIMETRY

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Abstract

The Radiation-Technological Office (RT-Office) - software tools for EB, X-ray, and gamma-ray dosimetry for industrial radiation technologies was developed by authors. The specialized programs for simulation of EB, X-ray, and gamma-ray processing and for decision of special tasks in dosimetry of various radiation technologies were designed on basis of the RT-Office modules.

INTRODUCTION

Necessity of further development of dosimetry methods for industrial radiation technologies is connected with continual diversification of objects under radiation treatment, and with sophistication of irradiation modes. Besides, the conventional methods of dosimetry within the irradiated materials do not ensure the data gaining accuracy to be necessary for modern radiation technologies in the case of heterogeneous targets irradiation. There are no methods permitting to solve effectively the problems of optimum choice of irradiation modes for the vast list of practically important cases. Success of the use of ionizing radiation in different radiation technologies depends largely on development of theoretical notions, semiempirical models and computer codes for simulation of irradiation processes on the radiation-technological lines (RTL).

The Radiation-Technological Office (RT-Office) - software tools for EB, X-ray and ν-ray dosimetry was developed by authors. RT-Office implements computer technology for dosimetry of all basic stages of radiation processing on the RTL using irradiators of EB, X-ray, and gamma-ray in the energy range from 0.1 to 25 MeV. It is beginning from the computer expertise of the commissioning of a new radiation facility; a choice of optimum parameters of irradiation regimes; a quality control and execution of irradiation process; and ending by a preparation of a scientifically – justified report on the fulfilled work.

RT-OFFICE STRUCTURE

RT-Office is the common program shell, which provides flexible and intellectual interaction between specialized modules and databases for optimum planning of process of an irradiation and control of its realization.

The wide opportunities of the RT-Office are based on the authors developments of last years: semiempirical models for dose distribution of an ionizing radiation in spatially non-uniform objects irradiated by electron, X-ray and ν-ray; high effective programs for simulating by Monte Carlo (MC) method of the irradiation processes in heterogeneous objects; databases for the equipment characteristics and objects used in radiation technologies; computer methods of expertise and control of conditions for an irradiation realization; the methods validation of theoretical predictions on the basis of comparison of calculation data obtained by different independent simulation methods and/or comparison with experimental results [1, 2, 3]. At implementation of the simulation MC methods the specially designed schemes which allow to reduce a running time for receiving of the end results in about hundreds time were applied.

The RT-Office includes the list of the following functional modules and databases:

- *Module of MC simulation* of dose distribution for electron beam into heterogeneous targets irradiated by EB on moving conveyer.
- *Module of MC simulation* of dose distribution for electron beam into heterogeneous targets irradiated by EB in stationary regimes via scatterer.
- *Module of MC simulation* of dose distribution for EB into thin dosimetric films.
- *Module for calculation by special developed semiempirical model* of 2-D dose distribution for targets irradiated by EB on moving conveyer.
- *Module of MC simulation* of charge deposition into heterogeneous targets irradiated by EB.
- *Module of MC simulation* of conversion of electron energy to X-ray (bremsstrahlung) energy.
- *Module of MC simulation* of dose distribution into heterogeneous targets irradiated by X-ray beam on moving conveyer.
- *Module of MC simulation* of dose distribution for cylindrical turntable target irradiated by X-ray beam.
- *Module of MC simulation* of ν-ray intensity from distributed source with radionuclides.
- *Module of MC simulation* of dose distribution from distributed source with radionuclides in an environment.
- *Calorimetry module.* Calculation of spatial distribution of radiation-induced temperature and analytical estimations of integral characteristics of a heat transmission for process of cooling of the irradiated products in a thermostable environment

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∉ *Comparison module.* Methods of mathematical physics for handling and comparative analysis of depth dose curves obtained by different calculation and experimental methods.

∉ *Dosimetry module.* Specialized tool for entering and processing of experimental dosimetry data and their transmission to the Comparison module.

∉ *RTL configuration module.* Entering and saving of the operational characteristics for all construction elements of RTL.

∉ *Wizard for control and validation* of input data for working regimes of RTL.

∉ *Module for cognitive visualization* of results for 2-D and 3-D view of dose distribution.

∉ *The processing technologies database* for equipment characteristics and objects used in radiation technologies.

The interaction between functional modules and databases is carried out by means of a set of service blocks.

SPECIALIZED SOFTWARE

Application program package with specialized software for EB, X-ray, and ν-ray processing in the form of the programs ModeRTL, XR-Soft, and ν-ray-Soft was developed on the basis of simulation and calculation modules of the RT-Office.

The programs ModeRTL and XR-Soft were designed specially for simulation and optimization of industrial radiation processes, calculation of the absorbed dose, temperature and charge distribution within products irradiated by scanning electron and X-ray beams on industrial RTL that is based on the pulsed or continuous type of electron accelerators in the electron energy range from 0.1 to 25 MeV and for X-ray energy range from 0.1 to 50 MeV.

The special problem for the program ν-ray-Soft is the shielding analysis from a source with a radioactive wastage. Simulation of ν-ray characteristics from a large source with distributed radionuclides and simulation of spectrum and dose distribution from a distributed source in an environment was performed by MC method. The program ν-ray-Soft can be used for the dose distribution mapping in ν-ray processing of medical device or foodstuff in the multi-pencil type of ν-ray irradiator.

EB DOSE MAPPING

Simulation of EB absorbed-dose mapping in targets irradiated with scanned EB on moving conveyer is considered in detail. EB facility is the base for many radiation technologies which utilize electrons and X-ray beams. Simulation was carried out by the program ModeRTL. The program ModeRTL provides simulation of transport of EB from outlet window of electron accelerator and EB interaction with irradiated target. Simulation of EB dose mapping in an irradiated target was fulfilled in two-dimensional (2-D) geometrical model. The 2-D dose distribution in the target is represented as function of two coordinates - of the target depth (axis X) and the target width along scan direction (axis Y). Conveyer moves along axis Z (see Fig.1.).

The example of simulation of a dose field formation in polymer modified wood (PMW) irradiated by EB is considered. EB dose mapping within PMW compound for optimal target thickness at double-sided irradiation are shown in Fig.1. Regimes irradiation: electron beam energy - 5 MeV; beam current – 1 mA; triangular scanning; target - compound with density 0.8 g/cm^3 (wood of aspen + 70% polymethylmethacrylate); width of target - 100cm; width of scanning -100cm; conveyer speed -1cm/s. Target has not cover box. A current in magnet of scanning system has the saw-tooth form. This current form is often used in scan magnet of industrial electron accelerator. The optimal thickness for maximum dose uniformity for electron beam in compound is 5.6 cm relatively of dose distribution at the center of a target.

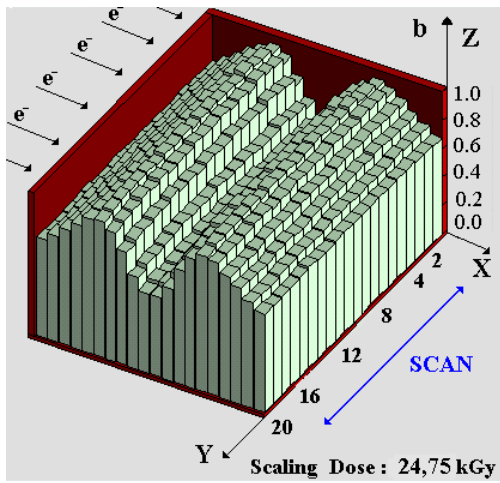
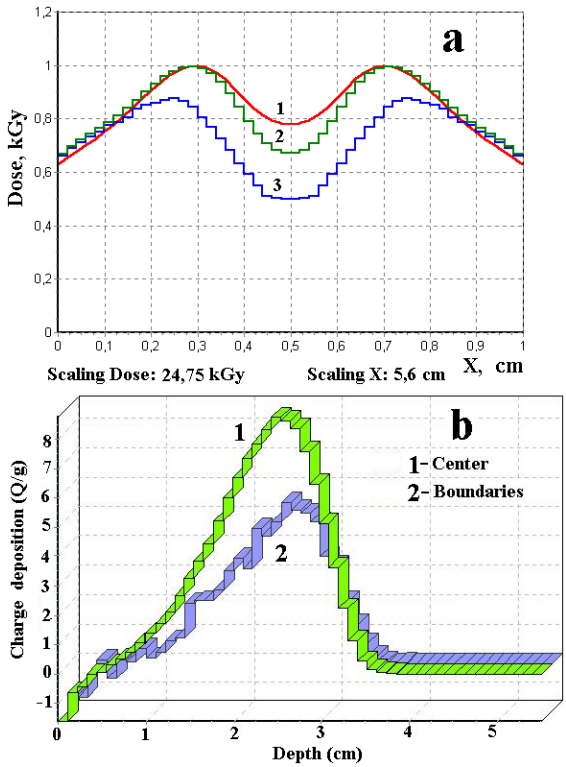


Figure 1. 3D-view of the EB dose mapping within compound for optimal targets thickness at double-sided irradiation.

The compare results for EB depth-dose distributions in a plane, which cross the center (curves 1, 2) in the direction of moving conveyer, and the boundaries (curve 3) of an irradiated target at the end of scan beam direction (see Fig.1) at double-sided irradiation are shown in Fig. 2 (a). Curves 2 and 3 simulated by MC method, curve 1 - by Analytical method. As it is seen from Fig. 2(a), the good agreement between depth-dose distributions in a plane, which cross the center calculated by Analytical method (curves 1) and simulated by MC method (curve 2) is observed. It allows using analytical method for fast optimization of irradiation regimes and integrates it in control system of radiation facility [2].

The simulation results by MC method of the charge deposition in the center and the boundaries of compound

irradiated by 5 MeV electron beam are presented in Fig.2(b).



Figs. 2 (a) and (b). The compare results for EB depth-dose distributions in a plane, which cross the center (curves 1, 2) in the direction of moving conveyer, and the boundaries (curve 3) of an irradiated target at the end of scan beam direction at double-sided irradiation (a). Charge depositions in the center and the boundaries of compound irradiated by 5 MeV electron beam (b).

As it is seen from Fig.1 and Fig.2 (a), the EB depth-dose distribution within compound has minimal value on the boundaries of a target along direction of the scanning electron beam and maximal value at plane that cross the target center in direction of moving conveyer.

From standpoint of the absorbed-dose limits, the location of the minimum dose limit $D_{min\text{-}lim}$ must be chosen as a minimum dose value $D_{min\text{-}bound}$ on the boundaries of an irradiated target, the maximum dose limit $D_{max\text{-}lim}$ - as a maximum dose value $D_{max\text{-}center}$ in the target center. In this case the dose uniformity ratio will be determined for all irradiated volume as $DUR_V = D_{max\text{-}center}/D_{min\text{-}bound}$.

As evident from simulation results and Fig.1 and Fig.2(a) for the center of a target the EB dose uniformity ratio $DUR = D_{max}/D_{min}$ is 1.51. For the target boundaries at the end of scan beam direction the DUR is 2.12. As a result, the dose uniformity for all irradiated volume DUR_V is 2.7. This value is greater than $DUR = D_{max}/D_{min}$ for the targets center. EB dose uniformity ratio DUR_V can be decrease by decreasing of the optimal target thickness, or by the choice of the special shape of current in scan magnet, or with help of special filters [1, 4].

The validation and verification of the results simulated by the program ModeRTL were carried out in compare with theoretical calculated data, with results obtained by the universal packages such as ITS, EGS and PENELOPE, and some experimental data of authors and data in published work [1,5,6]. The comparison investigations indicated that the developed physical and mathematical models are reliable and correct, and the program ModeRTL are accurate.

CONCLUSION

RT-Office for designing of the software for decision of special dosimetric tasks in different radiation-technological processes was developed. Specialized software for EB, X-ray and and ν-ray dosimetry in the form of the programs ModeRTL, XR-Soft, and ν-ray-Soft were developed on the basis of simulation and calculation modules of the RT-Office. As a minimum, the 2-D simulation model for EB, X-ray, and ν-ray dose mapping must be used for correct analysis of the optimum product thickness, EB, X-ray and ν-ray power utilization, max/min dose ratio, and processing capacity. Programs ModeRTL, XR-Soft, and ν-ray-Soft were utilized as predictive tools for of EB, X-ray, and ν-ray dose mapping, for determination of zones location D_{min} and D_{max} in targets irradiated by EB, X-ray beams, and ν-ray on RTL, for optimization of regimes EB, X-ray, and ν-ray irradiation, and for reducing the volume of routine dosimetry measurements of an absorbed dose within materials at realization of the radiation-technological processes. The flexible and friendly interface of the programs ModeRTL, XR-Soft and ν-ray-Soft is implemented in the Windows environment. It allows effectively to use these programs to a broad audience of end users.

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