RT-OFFICE FOR OPTIMIZATION OF INDUSTRIAL EB AND X-RAY PROCESSING

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The conception for design of the Radiation-Technological Office (RT-Office) was developed by authors. RT-Office realize computer technologies at all basic stages of works execution on the radiation-technological lines (RTL) using irradiators of electron beam (EB), X-ray and γ-ray. The description of the programs ModeRTL and XR-Soft which are intended for simulation of EB and X-ray processing is considered in the paper.

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1. INTRODUCTION

At present an electron beam (EB), X-ray (bremsstrahlung) and γ-ray processings are widely used in different industrial radiation technologies. 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).

Now there is no a set of consistent simulation methods for radiation processes which allow to fulfil correct and agreed simulation at all stages of radiation-technological process realization. There are the powerful universal packages as ITS, EGS, GEANT, MARS, PENELOPE and others for simulation of electron and photon transport through arbitrary multielement constructions, which allow to fulfil simulation at separate stages of radiation-technological process. The development of the programs for specific radiation-technological processes on basis these packages demands a lot of time, and calculation are carried out long enough. With these universal programs only experienced personnel of physicists - the experts in the field of transport of an ionizing radiation through matter, mathematicians, programmers and interpreters of calculations results can work. There are no computer programs accessible to a broad audience of users without a special knowledge in the field of transport of ionizing radiation and computer technologies.

For decision above problems, the conception for design of the Radiation-Technological Office (RT-Office) - software tools for EB, X-ray and γ-ray processings was developed by authors. The modules structure, geometrical and physical models of the EB and X-ray irradiators for the programs ModeRTL and XR-Soft that were constructed from the RT-Office modules are considered in the paper more closely.

2. RT-OFFICE CONSIDERATION

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 [1,2,3]: semiempirical models for dose distribution of an ionizing radiation in spatially non-uniform objects irradiated by electron, X-ray and γ-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. 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 γ-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.
- *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.

• *Module for the choice of geometrical model for irradiated objects.* This module will be designed in the form of a Database with different geometrical model of irradiated objects, such as tube, tubes package, box with bottles, box with syringes, box with Petry cups, and others. The module is under development.

The interaction between functional modules and databases is carried out by means of a set of service blocks. Simulation and calculation modules of the RT-Office are the basis for construction of the specialized software for EB, X-ray and γ-ray processing [1,2,3].

3. MODERTL AND XR-SOFT PROGRAMS

An electron accelerator, a scanner of electron beam, a conveyor line, an irradiated product and a package are the major components of the radiation-technological lines (RTL) for EB irradiator. An additional element of RTL for X-ray irradiator is an X-ray converter with cooling system. The detailed physical and geometrical models of the EB and X-ray irradiators were realized on the base of RT-Office modules in the form of new mathematical software: the program ModeRTL for EB and the program XR-Soft for X-ray processings respectively [1,3].

These programs 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.

The processing rate of EB and X-ray absorbed dose distribution within of the irradiated materials depend on a lot of parameters of the radiation facility of RTL and characteristics of target material. *Input data* for the programs ModeRTL and XR-Soft are the following: *Parameters of electron beam*: average beam current, or pulse duration and repetition frequency in pulsed accelerators, electron spectrum, beam diameter and spatial distribution of the beam intensity. *Parameters of scanning system*: modes of operation, the triangular or non-diverging irradiation treatment field in target material; form of current in magnet of scanning system; repetition frequency of scanning; angular distribution of electron beam at the outlet of a scanning system; parameters of the exit window for electron beam. *Parameters of the X-ray converter with cooling system:* geometrical characteristics of the X-ray converter, thickness of plates (layers) and cooling agent, materials composition, distance between exit window and X-ray converter. *Parameters of conveyor line*: speed and geometrical characteristics of the line. *Parameters of irradiated product*: geometrical characteristics of the irradiated product; elemental composition of the target; material and size of the covering for irradiated product. *Regimes of target irradiation*: one-, two-sided irradiation on moving conveyer for electron and X-Ray beams, and additional irradiation of turning target for X-ray beams.

4. EB AND X-RAY DOSE MAPPING

Some results of simulation of EB and X-ray dose mapping in the target irradiated at double-sided on moving conveyer are presented in Fig.1 and Fig.2 (a) and (b) respectively. Regimes irradiation for EB processing: 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 –100 cm; width of scanning –100 cm; conveyer speed –1 cm/s. Target has not cover box. A current in magnet of scanning system has the saw-tooth form. 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.

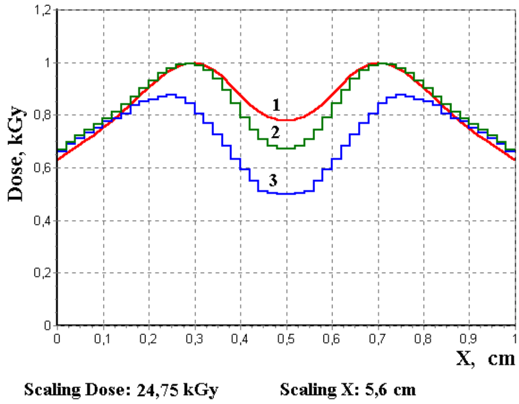

Fig.1. 2-D view of the EB depth-dose distributions in the center and in the boundaries of a target

X-ray beam was generated by scanning electron beam with electron energy 5 MeV in a tantalum converter. Converter construction includes the tantalum target plate with thickness 1.2 mm, the cooling water channel – 2 mm, and the Al backing plate - 5.0 mm. X-ray yield in the forward direction for 5 MeV electron is 8.62%.

Simulation of EB dose mapping in irradiated target materials was conducted by MC and Analytical methods, for X-ray dose mapping - by MC in 2-D 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.

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 are shown in Fig.1. Curves 2 and 3 simulated by MC method, curve 1 - by

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Analytical method. As is seen from Fig.1, 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 to use Analytical method for fast optimization of irradiation regimes and integrate it in control system of radiation facility [2].

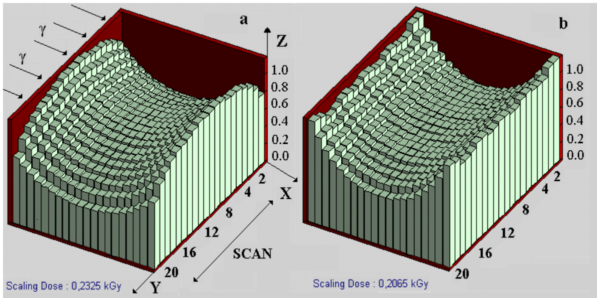

Fig.2(a) and (b). X-ray dose mapping within compound for optimal target thickness and for the saw-tooth (a) and special (b) forms of current in scan magnet

X-ray dose mapping within above compound for optimal target thickness at double-sided irradiation for saw-tooth and special forms of current in scan magnet are shown in Fig.2,a and (b) respectively. The optimal thickness of compound for maximum X-ray power utilization is 38.5 cm relatively of dose distribution at the center of a target. X-ray beam power utilization in this case is 58%.

For each product to be treated in the X-ray irradiation facility, there will usually be a minimum dose limit $D_{min\text{-}lim}$ to obtain the desired effect and a maximum dose limit $D_{max\text{-}lim}$ to avoid product degradation. As is seen from Fig.2,a, the X-ray depth-dose distribution within compound has minimal value on the boundaries of a target along direction of the scanning X-ray beam and maximal value at plane that cross the target center. From standpoint of the dose limits, 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 $DUR_V = D_{max\text{-}center}/D_{min\text{-}bound}$.

For the center of a target the dose uniformity ratio $DUR = D_{max}/D_{min}$ is 1.51. For the target boundary the DUR is 1.94. The value DUR_V is 2.91. Significant dose gradient in volume of irradiated target in direction of X-ray scanning can be decrease by the choice of the special shape of current in scan magnet, or with special methods of irradiation [1,3,5].

The validation and verification of the results simulated by the programs ModeRTL and XR-Soft 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 [1,3,4]. The comparison investigations indicated that the developed physical and mathematical models are reliable and correct, and the programs ModeRTL and XR-Soft are accurate.

5. CONCLUSIONS

The functional modules of the RT-Office can be used as the basis for designing of the software for decision of special tasks in different radiation-technological processes. Specialized software for EB and X-ray processings in the form of the programs ModeRTL and XR-Soft were developed on the basis of simulation and calculation modules of the RT-Office.

Programs ModeRTL and XR-Soft can be used as predictive tools for of EB and X-ray dose mapping, for determination of location D_{min} and D_{max} in volume of target irradiated by scanning EB and X-ray beams on RTL, and for optimization of regimes EB and X-ray irradiation to receive maximum processing capacity with the minimum for dose uniformity ratio.

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РТ-ОФИС ДЛЯ ОПТИМИЗАЦИИ ПРОМЫШЛЕННЫХ ПРОЦЕССОВ НА ОСНОВЕ ПУЧКОВ ЭЛЕКТРОНОВ И ТОРМОЗНОГО ИЗЛУЧЕНИЯ

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Концепция Радиационно-Технологического Офиса (РТ-Офис) была разработана авторами. РТ-Офис реализует компьютерные технологии на всех этапах выполнения работ на радиационно-технологических линиях с излучателями электронов, X-ray и γ-ray. Представлено описание программ ModeRTL и XR-Soft, предназначенных для моделирования радиационно-технологических процессов.

РТ-ОФІС ДЛЯ ОПТИМІЗАЦІЇ ПРОМИСЛОВИХ ПРОЦЕСІВ НА ОСНОВІ ПУЧКІВ ЕЛЕКТРОНІВ І ГАЛЬМОВОГО ВИПРОМІНЮВАННЯ

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Концепція Радіаційно-Технологічного Офісу (РТ-Офіс) була розроблена авторами. РТ-Офіс реалізує комп'ютерні технології на всіх етапах виконання робіт на радіаційно-технологічних лініях з

випромінювачами електронів, X-ray і γ-ray. Представлено опис програм ModeRTL і XR-Soft, призначених для моделювання радіаційно-технологічних процесів.