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Optimization of electron beam crosslinking for cables

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HIGHLIGHTS

- Dose distribution simulation was performed using ModeCEB computer program.
- Simulated and experimental data on dose homogeneity were compared.
- High influence of EB divergence on the dose distribution was found.

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ABSTRACT

Relationship between electron beam parameters (energy, energy spread, and electron beam distribution in irradiation zone), electrical cable geometry (thickness of polymer layers and metal wire diameter), construction (jacked, insulation) and dose distribution represented by the D_{max}/D_{min} coefficients were investigated. The simulations were performed using ModeCEB computer program (Lazurik et al., 2011) and then compared with the experimental data. It was demonstrated that computer simulations based on the ModeCEB program are sufficient for modeling absorbed dose distribution in the multi-layers circular objects irradiated with scanned electron beam. The calculations revealed (1) significant inhomogeneous circumferential dose distribution in polymeric sub-layers (2) relatively low influence of electron beam energy spectrum on homogeneity of irradiation and (3) high influence of beam divergence on the circumferential dose distribution.

1. Introduction

Wire and cable radiation crosslinking is one of the most successful implementation of radiation technology and sustain to be attractive method for modification variety new polymer material implemented in cable industry (Chmielewski et al., 2005; Rouif, 2005). The process was found to be less expensive requiring less factory floor space, accepting wide range of insulating materials and offering faster processing rate in comparison with chemical methods. Electron beams applied for radiation processing of electrical wire and cable are the most frequently used within electron energy range 0.5–3 MeV and occasionally up to 10 MeV. The requirements associated with the construction of accelerator-based facility are related to the product characteristics and process capacity. The throughput is directly linked with beam power level that can vary in the range of 20–500 kW depending on the accelerator type. Usually in wire and cable processing absorbed dose is situated in the range from 50 to 200 kGy. Difficulties in handling irradiation process may appear at a very high rate of irradiation what correspond to a very high beam power level. Wire and cable handling equipment should allow work with sufficiently high speed of the rewinding and obtain adequate homogeneity of irradiation what is directly related to the final product quality and reliability.

The economical condition of any industrial activity requires process optimization to reduce unit cost of the operation but sustaining adequate quality of the final product. The computer simulation method becomes a very effective tool for optimization process providing necessary information in short time and reducing cost in comparison with conventional approach based on experimental dosimetry (Weiss et al., 1997; Kaluska et al., 2007; Ciappa et al., 2012).

2. Accelerator facility

The quality of modified polymer is defined mostly by homogeneity of irradiation. The radiation technology (accelerator and rewinding or transport systems) should allow provide homogenous dose distribution of suitable level for all sizes and dimensions of processed wires and cables. The number of cable and wire handling techniques were developed and tested to obtain two, three and even four sided irradiation. The so-called rotary techniques and specific configuration of the irradiation zone provided by

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the external magnets were tested as well. Accelerator is the crucial equipment which defines basic technical and economical parameters of any radiation facility. The under beam equipment which is dedicated to rewinding wires and cables should be capable of utilize efficiently energy provided by electron beam.

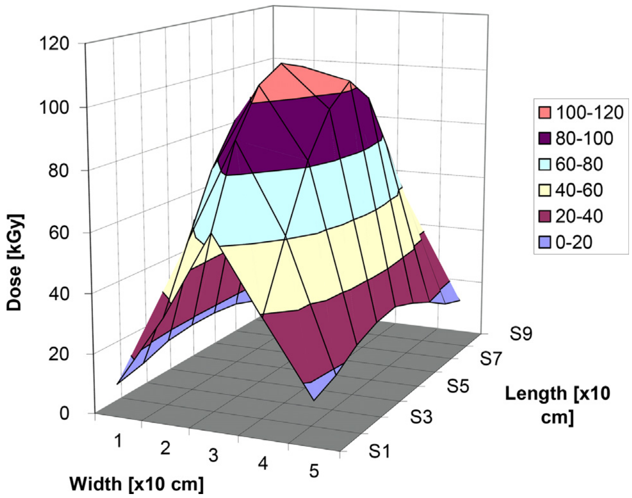

Fig. 1. Dose distribution in irradiation zone measured at a distance of 45 cm bellow exit window (electron energy 1.5 MeV; scan path 40 cm).

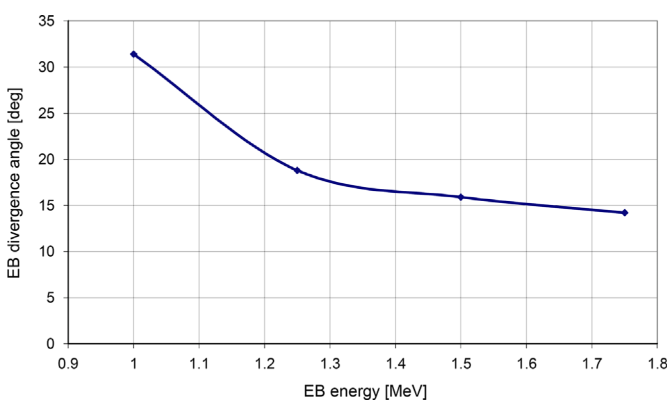

Fig. 2. EB divergence angle versus electron energy for the distance 25–65 cm from the exit window.

Electron beam spatial distribution in the irradiation zone is one of the important parameter of radiation processing. The detail knowledge is needed to select the most appropriate conditions and to optimize the radiation processing.

Fig. 1 shows an example of electron beam spatial distribution measured by cellulose triacetate dosimetric foil to characterize spatial deposition of electron beam energy. The dosimetric foils where placed of 45 cm from the exit window. Length axis is defined as direction parallel to eb scanning path whereas width axis is perpendicular to eb scanning path as it can be seen on Fig. 1. Electron energy 1.5 MeV and scan path length 40 cm at exit window level were set during irradiation procedure.

It should be noted that these particular measurements were performed in the pilot plant facility equipped with an electron accelerator ILU 6 type which is installed at INCT. ILU 6 accelerator is capable to accelerate electrons in 0.5–2 MeV range, up to 20 kW average beam power and is equipped with scan horn with adjustable scan width 30–80 cm (electron beam scan angle varies from $\pm$10 to $\pm$25 deg). Scan horn is mounted vertically at 90 deg to the product pathway. The specific constructions of different accelerators may lead to the slightly different spatial beam distribution measured at accelerator output due to different configuration of accelerating process, focusing system, beam current level, material and thickness of the exit foil, and finally electron energy and energy spread levels. The influence of electron beam intensity on spatial beam characteristics can be neglected in most cases. In practice only electron beam energy and beam current levels are being set according to process parameters. Electron energy spread and beam divergence effects can not be adjusted directly despite the fact that those parameters may have significant influence on radiation processing.

On a basis of dosimetric measurements the electron beam divergence angle was calculated for various electron energy, taking into account the beam width observed below the level of exit window (Fig. 2). It was found that electron beam divergence angle has not been changed significantly over the distance of 25–65 cm from the exit window for selected electron energy. The electron beam divergence in accelerator facility described by Studer, 1979 revealed similar tendency, but beam divergence for 1 MeV was

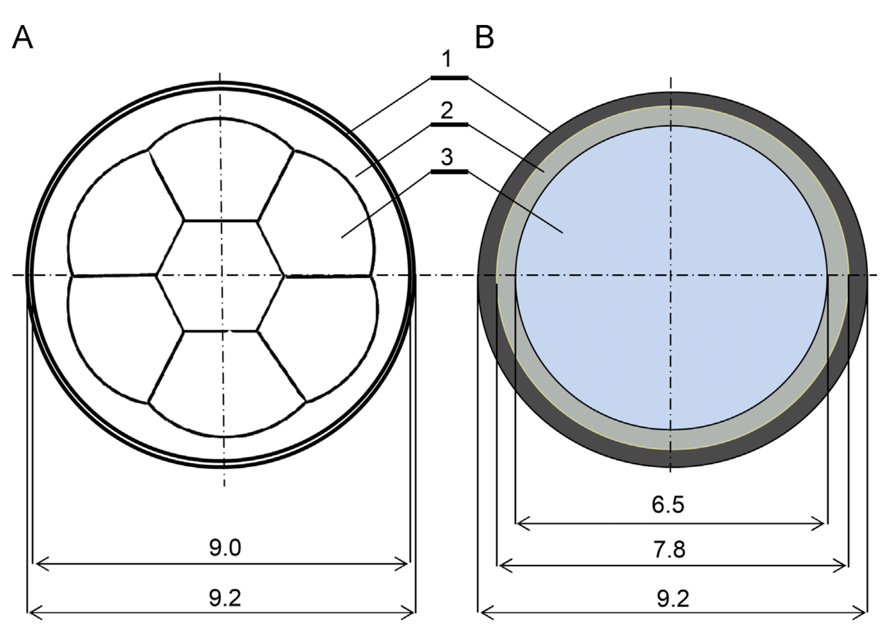

Fig. 3. Cross section of electrical cable: (A) cable with segmented aluminum conductor; (B) equivalent dimensions of cable used for simulation of dose distribution. 1—Jacket; 2—insulation, 3—aluminum conductor.