Investigation of depth-dose profile of electron radiation in continuous and discontinuous materials based on Monte Carlo simulations and measurements

Van-Chung Cao[1,2], Anh-Tuan Vo[1], Hoai-Nam Tran[3]

[1] Research and Development Center for Radiation Technology, VINATOM, Thu Duc, Ho Chi Minh city, Vietnam

[2] Faculty of Physics and Engineering Physics, VNUHCM-University of Science, Ho Chi Minh city, Vietnam

[3] Institute of Fundamental and Applied Sciences, Duy Tan University, Ho Chi Minh city, Vietnam

Abstract

Investigation of the depth-dose profiles of electron radiation induced by 10 MeV electron beam linear accelerator (UELR-10-15S2) in continuous and discontinuous materials has been performed based on Monte Carlo simulations and experiments. Three materials were chosen such as water (density of 1.0 g/cm³), plastic (1.05 g/cm³) and food-like dummy (1.0 g/cm³). In the discontinuous mediums, the materials were separated into layers with the thickness of 0.2-0.4 cm by air gaps, but the total thickness of the material mediums are kept the same. No significant difference of the depth-dose profiles in the continuous and discontinuous materials was found (less than 5%). The results are similar with the three materials, and an agreement between simulations and experiments is obtained. The simulation depth-dose profile show that the practical range in plastic is 5.23 g/cm², which is greater than that in water (5.02 g/cm²) and food-like dummy (4.94 g/cm²). This indicates that for plastic products irradiated by the double-sided electron beam, it is possible to use a thicker package of 9.6 g/cm² compared to the usual thickness of 8.8 g/cm².

Introduction

Hundreds ton of food, non-human food and heath care products are being irradiated by 10 MeV electron beam accelerator (UELR-10-15S2) for pasteurization and sterilization purpose at Research and Development Center for Radiation Technology (VINAGAMMA). Product package is a discontinuous medium with air-gaps between materials. Thus, it is a difficulty to acurately estimate the dose distribution in irradiated product based on depth-dose profile in continuous material.

In this work, investigation and comparison of depth-dose profiles of electron radiation in continuous and discontinuous materials have been performed based on Monte Carlo simulations and experiments.

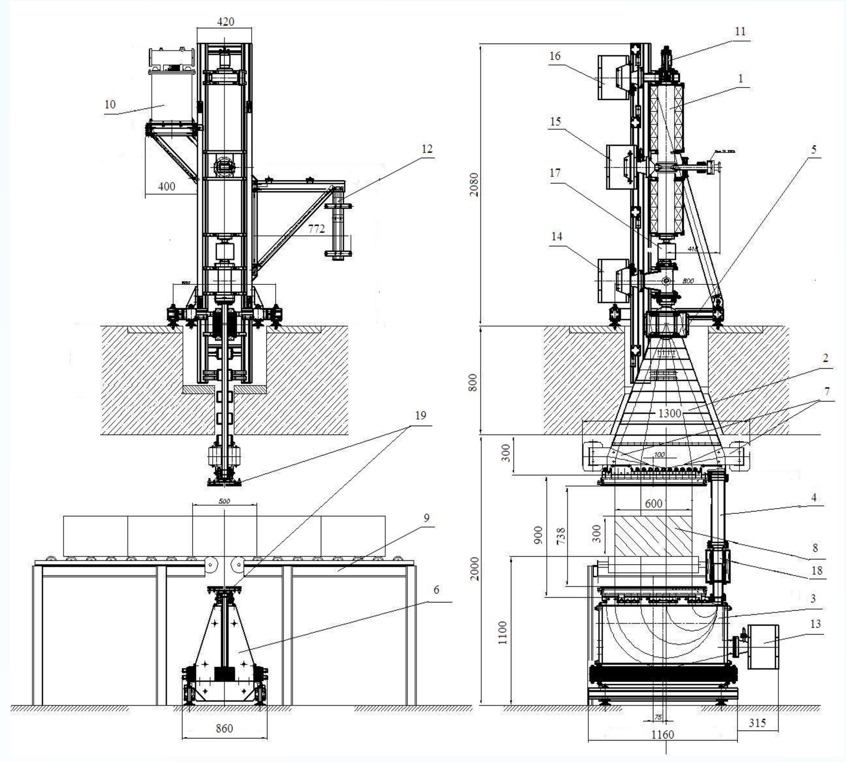

Fig1. The cross sectional view of UELR-10-15S2 accelerator; 1 - accelerating structure (diaphragmatic waveguide); 2 - Chamber of a scanning electromagnet; 3 - Chamber of banding and scanning electromagnet; 4 - electron beam canal; 5 - scanning electromagnet; 6 – banding and scanning electromagnet; 7 - bending electromagnets; 8 - a box with irradiated products; 9 - the conveyor dragging irradiated boxes through ribbons electron beams; 10 - electron gun pulse transformer; 11 - electron gun; 12 - ferrite isolator (circulator); 13 - 16 - ion pump; 17 and 18 - magnetic induction sensors of beam current; 19 – beam stops.

Methodology

- Depth-dose profile of 10 MeV electron radiation in materials were computed using the MCNP4c code.
- Measurement of the depth-dose profiles induced by the double-sided electron beam were performed using the B3 dosimeter (see Fig. 2).
- Three types of dummy were selected which are similar with common product materials including water (density of 1 g/cm³), MDF (Medium density fiberboard - 1.05 g/cm³) and plastic (PE – 1.05 g/cm³).
- The material components were defined in the MCNP4c code, each materials were defined as an 30x30x30 (cm) cubic-box and slip into several layers to estimate the dose.

Methodology (cont.)

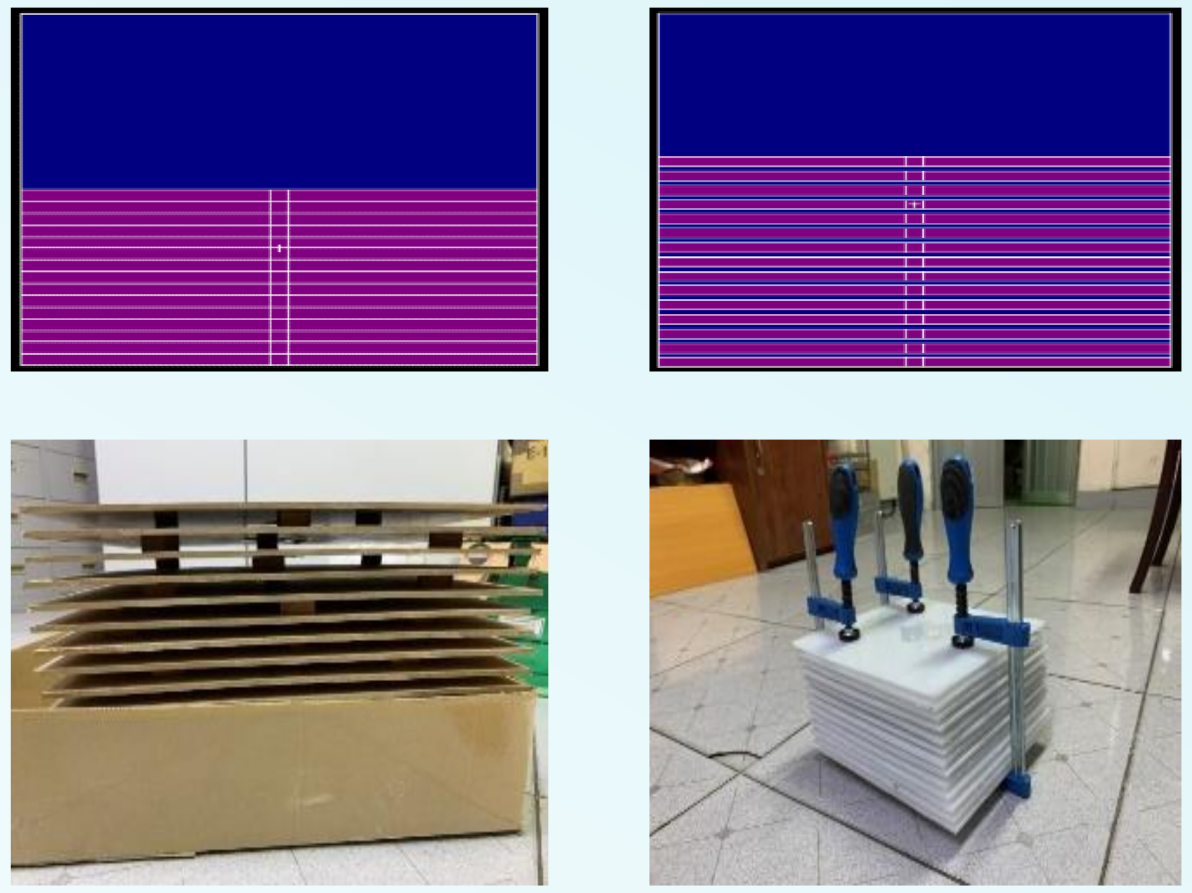

Fig 2. Simulation and Experiment measurement

Results

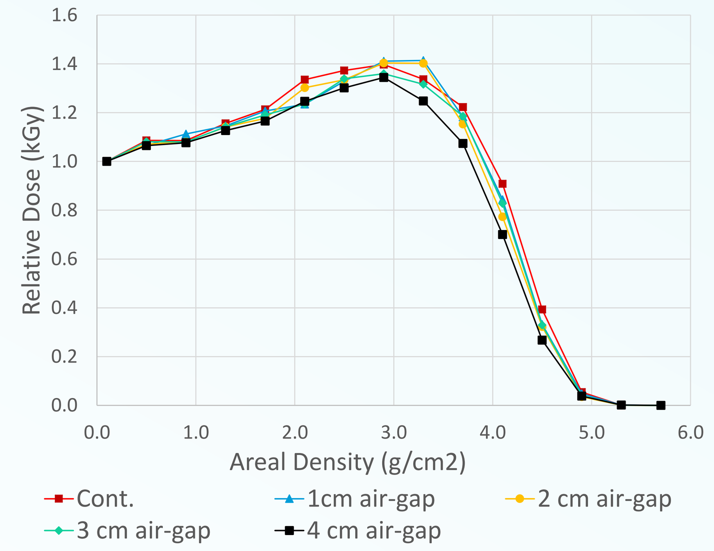

Fig 3. Depth-dose profile of 10 MeV electron in food like dummy in case continuous and discontinuous.

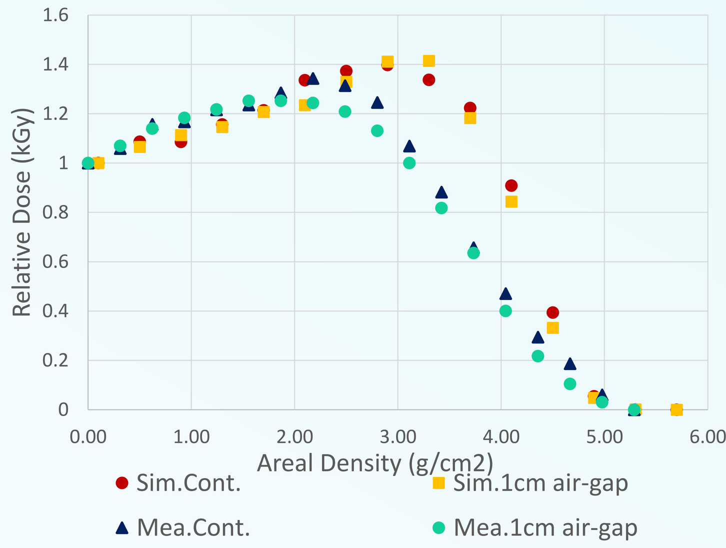

Fig 4. 10 MeV electron depth-dose profile simulated and measured in food like dummy with continuous and discontinuous case.

- The absorbed dose increases with the depth to a maximum value at 3.0 g/cm², followed by an approximately linear decrease. At the depth of 5 g/cm², the absorbed dose reduces to near zero.
- By increasing the gaps between material layers, the depth-dose decreases within 5%. This value is small and would not effect the quality of food irradiation.
- The experimental results has the same trend with the simulations. The discrepancy of the absorbed doses in continuous and discontinuous materials is within 5%.
- The maximum difference of 27% between simulations and measurements was found at the depth of 3.4 g/cm². At edge of box, the decrease of depth-dose profile more affected to 20% when increasing the gap thickness.
- Practical range of electron radiation increases with the increase of material density.
- The results suggest the possibility to extend the irradiated material thickness to 9.6 g/cm².

Results (cont.)

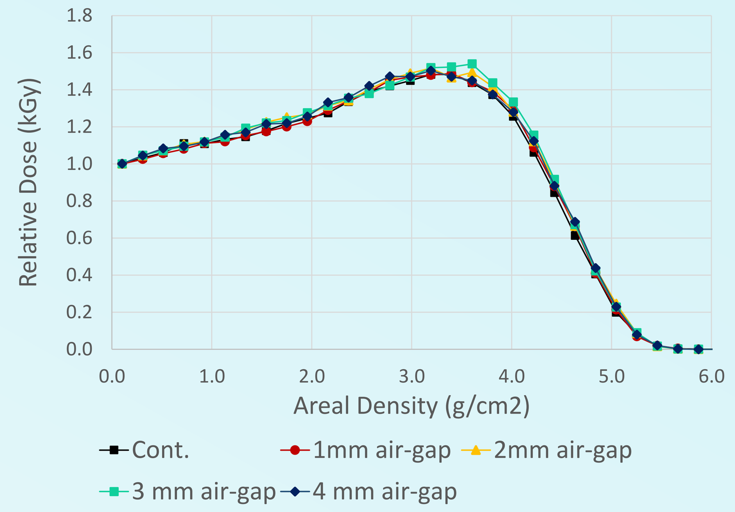

Fig 5. Depth-dose profile of 10 MeV electron in plastic incase continuous and discontinuous.

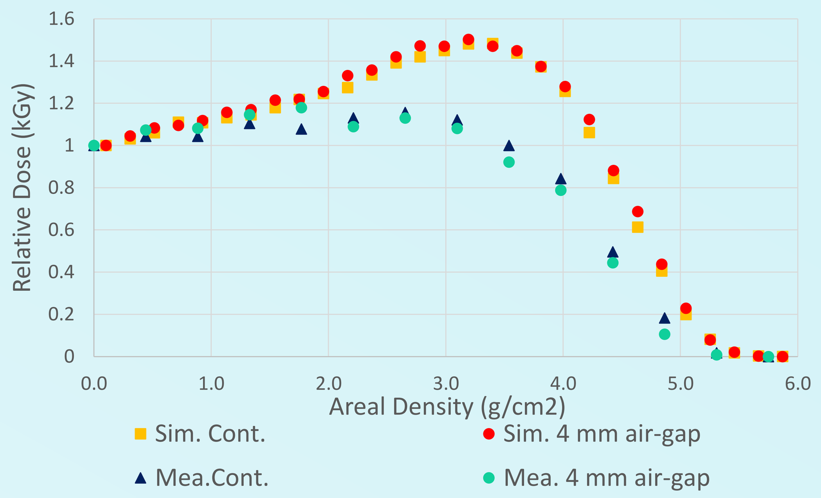

Fig 6. 10 MeV electron depth-dose profile simulated and measured in plastic with continuous and discontinuous case

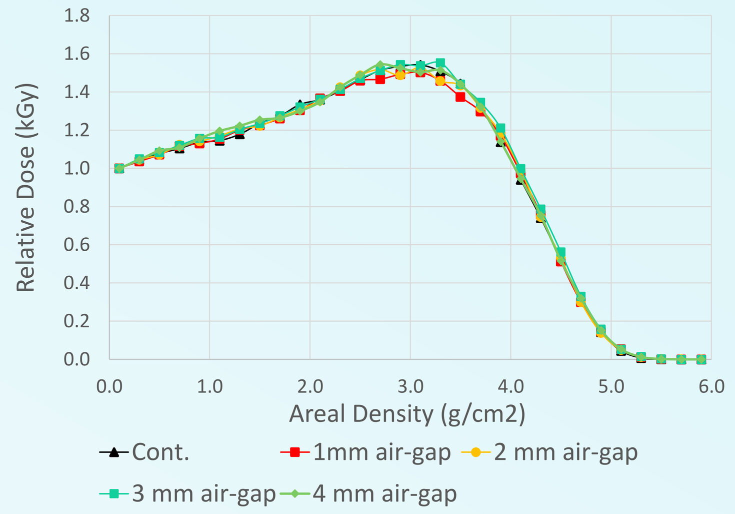

Fig 7. Depth-dose profile of 10 MeV electron in water in case continuous and discontinuous

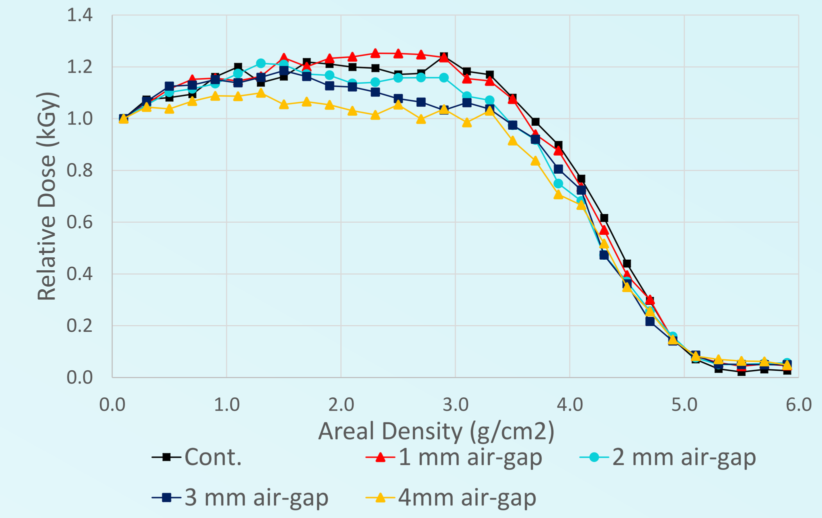

Fig 8. Depth-dose profile of 10 MeV electron in water in case continuous and discontinuous

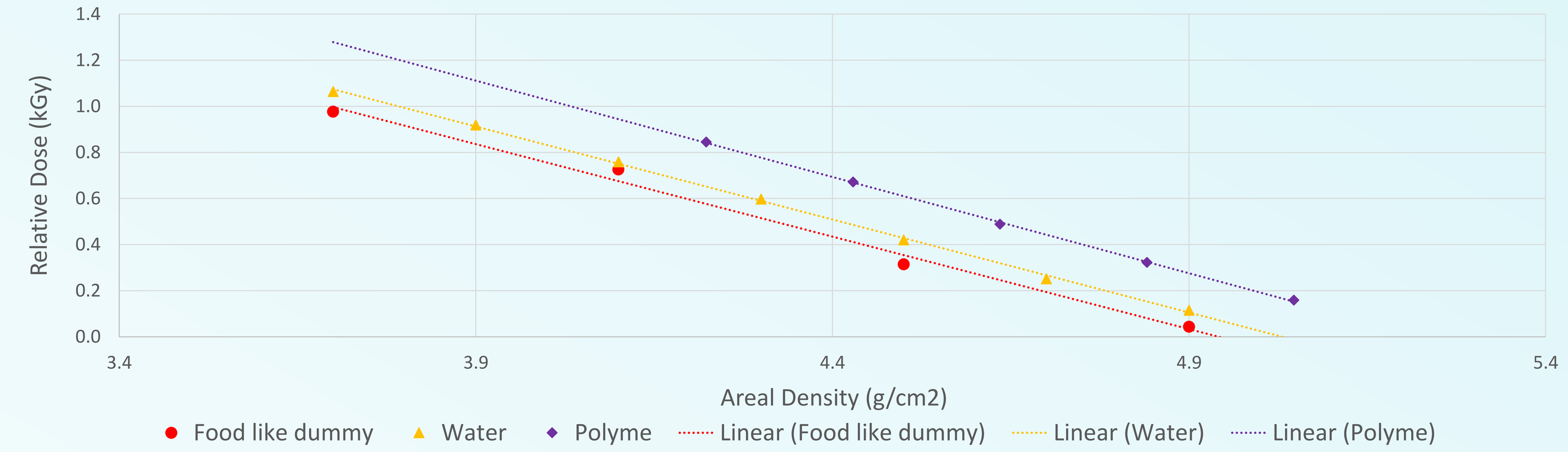

Fig 9. Electron practice range in popular irradiated material, food like dummy, water and polymer

Conclusions

- No significant difference between the depth-dose profiles in continuous and discontinuous material was found. The discrepancy is less than 5%.
- The largest discrepancy of the absorbed doses obtained from the simulation and measurement is about 27% at the depth of 3.4 g/cm².
- The electron practice range in polymer is 5.23 g/cm², which is higher than that in water (5.02 g/cm²) and food-like dummy (4.94 g/cm²).
- It is possible to extend the material thickness from 8.8 g/cm² to 9.6 g/cm².