Thermal analysis on water cell of calorimetric dosimeter standard

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1. Introduction

Maintaining the therapeutic accuracy by a standardized measuring method is important to patients during radiation therapy. Hence many countries are developing the absorbed dose evaluation technique using the calorimetry. According to this need, research on development of water calorimeter and standard measurement method of absorbed dose is in progress in Korea. An initial step in the research on the development of a water calorimeter and standard measurement is ongoing by the Korea Research Institute of Standards and Science (KRISS). In parallel with the development of devices, we developed the calculation methodology about thermal behavior analysis of water calorimeter for radiation dosimetry [1].

In this study, the geometry of the water phantom for the calorimeter is designed refers to the NIST model [2]. To overcome the heat defect, sealed water core was applied [3]. Simulation of the radiation transport and energy deposition and calculation of the thermal behavior of the sealed water core are carried out.

2. Methods

2.1 Mesh generation

Geometry of the water calorimeter is shown in Figure 1. The internal volume of water phantom is 30 × 30 × 30 cm^3 and the air space is included top end of the outer wall which is maintained at 4 ℃. Sealed water core and thermistors are located in the direction of the γ-ray beam entrance window. X-axis is parallel to thermistors, y-axis is parallel to gravity and z-axis is parallel to the direction of ^{60}Co beam.

ANSYS ICEM-CFD is used to generate the mesh. The hexahedral type of mesh was used. In order to improve the quality of the mesh, we focus the mesh grid into the region of thermistors. Figures 2 to 4 show the mesh by part.

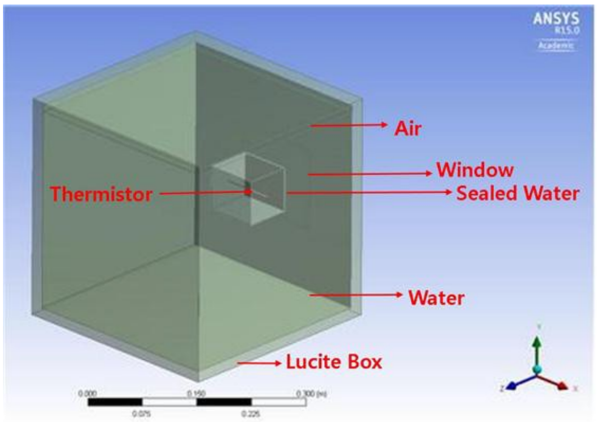

Fig. 1. 3D modeling of the water calorimeter.

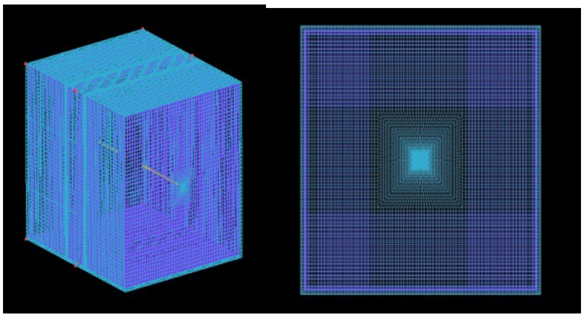

Fig. 2. Mesh of the sealed water core.

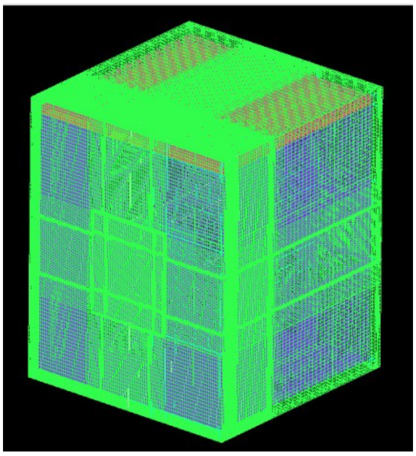

Fig. 3. Mesh of the water phantom including a Lucite box, air and water.

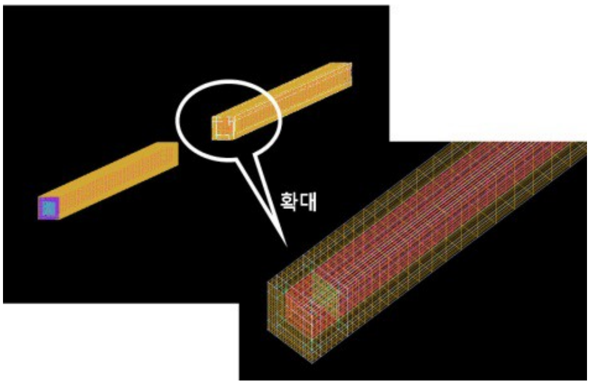

Fig. 4. Mesh of the thermistors including epoxy glue and Pyrex tubes.

2.2. Calculation of thermal behavior and temperature distribution in the sealed water core by KRISS ^{60}Co beam irradiation

Simulation of thermal behavior and temperature distribution in the sealed water core irradiated by KRISS ^{60}Co gamma-ray beam was carried out by the finite element analysis code, ANSYS-CFX. The convection phenomenon of the sealed water core was evaluated by checking the speed and direction of the water flow due to temperature changes. When the radiation is absorbed by the water and the material, the energy is mostly converted into kinetic energy. In this study, we assume that all of absorbed dose is converted into thermal energy.

3. Results

When the 10 minutes elapsed since the ^{60}Co beam irradiation start, the velocity distribution without sealed water core in the water phantom was as shown in figure 5. It was found out that the heated water was moving upward about 5 cm from the thermistor position. It seemed that water flow began from the central region, where the temperature rose up by the incident beam. Figure 6 shows the velocity distribution in the water phantom with sealed water core. The water flew relatively less with the sealed water core than without the sealed water core. The average absorbed dose rate in the sealed water core was about 9 mGy/sec. The maximum velocity of water flow without the sealed water core was 2.5 cm/min and the maximum velocity with the sealed water core was 1.75 cm/min. So we could estimate that the sealed water core worked as a convection barrier.

4. Conclusions and Further Work

To overcome the heat defect, sealed water core was applied and it could minimize the convection effect. The results of this study will be used as the basic data for development of the standard water calorimetry in KRISS. Through a parallel development and comparison with the graphite calorimeter, this result is expected to be utilized to improve the standard dosimetry. And sensitivity analysis of beam centering will be carried out.

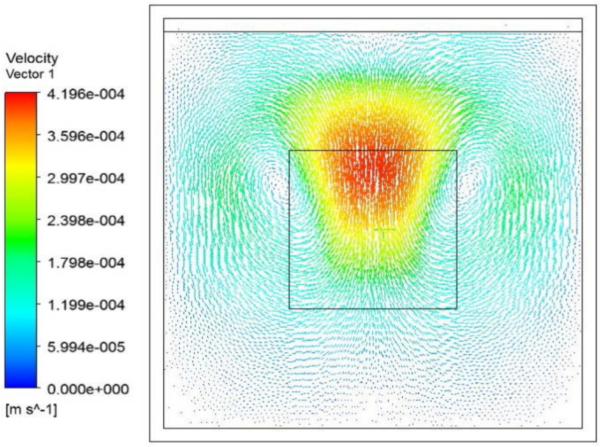

Fig. 5. Velocity distribution in the water phantom without sealed water core.

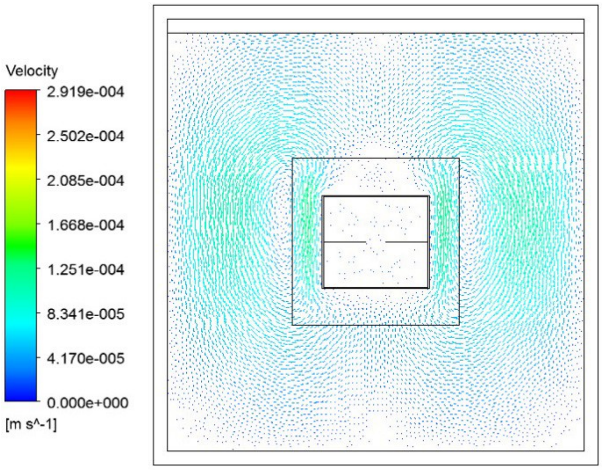

Fig. 6. Velocity distribution in the water phantom with sealed water core.

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REFERENCES

[1] M.Y. Kang, J.H. Kim, Jinhyeong Kim, H.D. Choi and I.J. Kim, Analysis of transient and thermostatic behavior of water calorimeter, Transactions of the Korean Nuclear Society Spring Meeting, May 7-8, 2015, Jeju, Korea.
[2] J.P. Seuntjens, C.K. Rose, N.V. Klassen and K.R. Shortt, "A Status Report on the NRC Sealed Water Calorimeter", PIRS-0584 (1999).
[3] S.R. Domen, "A sealed water calorimeter for measuring absorbed dose", Journal of Research of National Institute of Standards and Technology, 99 (1994) 121.