Simulations of Radiation Dose Rate of Spacer in CANDU for TEM specimen preparations

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1. Introduction

Spacer, called garter spring as another name, is one of important components in CANDU fuel channel. 4 spacers are installed between calandria tube and pressure tube as Fig.1. It protect gas flow from the pressure tube sagging. Surveillance test has been done with pressure tube periodically for safety and reactor operation license. Observation of irradiation behavior of spacer is important in surveillance test as well as pressure tube is. Helium cavities in spacer have been produced during neutron irradiation in reactor, which are observed by TEM observation[1]. To make TEM specimen from spacer, unfortunately, it must works at out of hotcell.

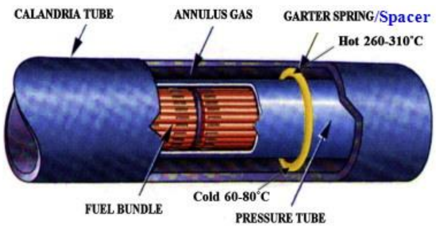

Fig. 1 CANDU fuel cannel and spacer

The purpose of this study is calculation of radiation dose of spacer during preparation of TEM specimen. Inconel X-750 was recommended and interested in this calculations

2. Methods and Results

ORIGEN code in SCALE 6.2 and Micro-shield code were used to calculate isotope generation and radiation dose[2,3].

2.1 Calculation of isotope generation

Properties of X-750 were shown in Table.1. The coil size and ring dia. are 4.8 mm and 110 mm, respectively. The coil has rectangular shape(0.76 mm each side)[4].

Table. 1 Elements of X-750[5]

Element	w/o	Element	w/o
Cr	16.0	Al	0.8
Fe	8.0	Ti	2.5
Nb	1.0	Si	0.5
Co	1.0	C	0.08
Mn	1.0	Ni	68.62
Cu	0.5		

To obtain the radiation activities of isotopes generated by irradiation, several assumptions were applied as bellows;

- EFPD(Effective Full Power Day) : 20 years
- Weight : 16.5 grams(including zry-2 wire)
- Neutron flux : 3.0E14 #/cm^2.s
- Cooling condition : 5days ~ 120days

Co-60 was generated with highest activity with strong gamma rays even 1 w/o of composition in X-750 as shown in Fig.2.

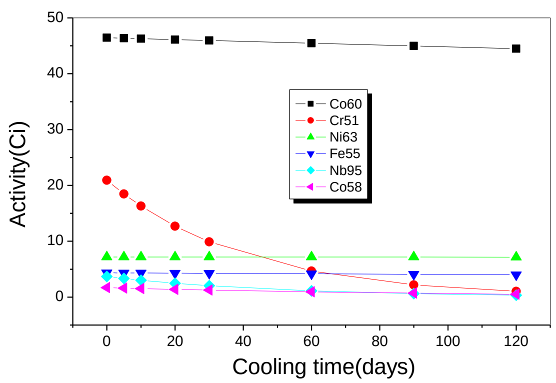

Fig. 2 Activities of dominant isotopes with cooling time

Total activities of irradiations was 178.5 Ci and it was reduced to 58 Ci after 120 days of cooling. However, Co-60 showed almost steady line.

2.2 Calculation of radiation dose rate

The isotopes and activities generated by ORIGEN were applied to Micro-shield code. Spacer dose rates from 10 cm, 30 cm and 100 cm of distance were calculated without shielding and with buildup factors. Detector positions were placed on X-direction as shown in Fig.3. Positions of Y-direction are not allowed in the code.

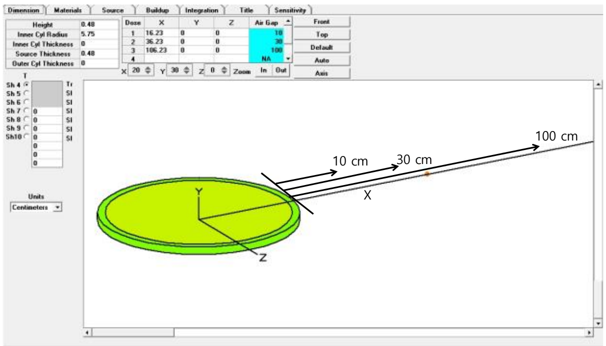

Fig. 3 Geometric modeling of spacer

Fig.4 shows radiation dose rate with cooling time and distance. Except irradiation end point, 459~421 mSv/h in 100 cm in 5~120 cooling days were shown.

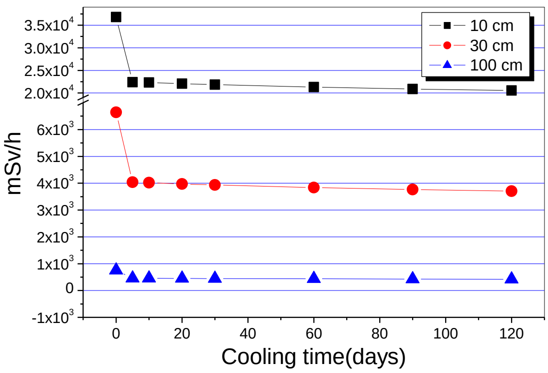

Fig. 4 Dose rate of spacer with cooling time and distance

2.3 MCNP calculations

MCNP code was used to compare with results of Micro-shield. As shown in Fig.5, Torus geometry on Z-axis was applied and detector positions were set as same as Micro-shield.

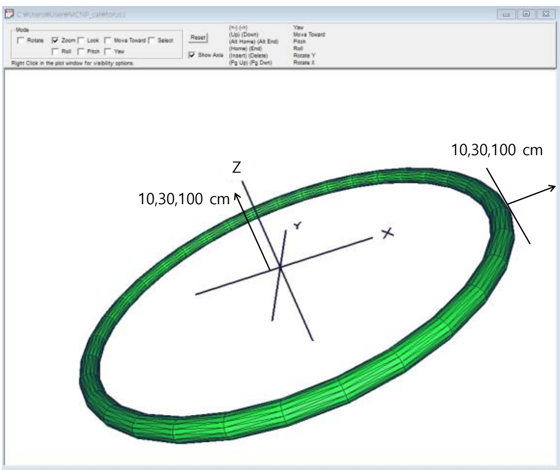

Fig. 5 Geometric setup in MCNP

The results from MCNP were higher than those from Micro-shield by 5~10%. Except irradiation end point, 474~435 mSv/h in 100 cm in 5~120 cooling days were shown. The dose rate calculations using MCNP were performed on Z-direction with the same distance. The results were higher than those on X-direction by 1.3~1.9 factors. 10cm of detector position were higher by 190%.

2.4 Dose rate for TEM specimen preparations

To make TEM specimen, spacer must be cut by a single turn coil in hotcell due to high dose rate. A single turn coil take out from hotcell, then make TEM specimen. In this case, radiation dose rate is considered. Dose rate of 210 turns in a spacer(X-750) can be shared as single turn coil, which is 106.6~97.9 mSv/h at 10 cm away with 5~120 cooling days as results of Micro-shield. In the case that single turn coil would be treated by hand, contacting dose rate is significantly considered based on the results in this study.

3. Conclusions

Radiation dose rate of spacer were needed to make TEM specimen preparations. At least, a single turn coil in spacer is required to take out from hotcell. 107 mSv/h at 10 cm away is expected for TEM specimen preparations. Special tools are needed to handle on a single turn coil during works in out of hotcell.

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