A Study on the Optimized Segmentation of RVIs (Reactor Vessel Internals) of Kori unit 1

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***Keywords** : Reactor vessel internals, Optimized segmentation, Waste packaging*

1. Introduction

Kori Unit 1 and Wolsong Unit 1 were permanently shut down so various R&D have been carried out for safe successful decommissioning of the plants. One of the prime concerns and issues in the R&D phase is the segmentation of RVIs of Kori unit 1 because some part must belong to the ILW (Intermediate Level Waste) due to the activation by neutron irradiation during life time, which requires deep geological disposal [1-3]. Worldwide experiences show that the segmentation of the RVIs are the most difficult, dangerous, and time-consuming task in the decommissioning of aged PWR [4-6]. In fact, there are various aspects in the optimization of the RVI segmentation such as minimization of waste generation, radiation exposure to the workers, and cost and maximization of segmentation technology efficiency. In this study, among many RVI components, two ILW components (core barrel and thermal shield) and one LLW (core flange) were selected to examine the segmentation optimization in terms of the minimum waste generation and radiation exposure to workers.

2. Optimal Segmentation Methods

2.1 Selection of the Target Components

Basically the components around the beltline of the reactor vessel becomes radioactively activated during the reactor life time [1-3], as shown in the diagram below (red color). Core barrel and thermal shield are the typical examples so chosen in this optimization study. On the other hand, core flange resides in the upper part of the RVI, thus undergoes less neutron irradiation and becomes LLW. However, its shape is somewhat complicated thus selected for this study.

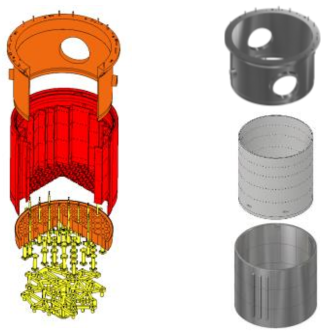

Fig. 1. Components of Reactor vessel internals

Table I: Size of Cutting Components

	Height	Outer diameter	Inner diameter	Thickness
Core flange	1,880	2,860	2,770	362 45
Core barrel	2,850	2,860	2,770	45
Thermal shield	2,650	3,106	2,928	89

2.2 Chosen Cutting Technologies

There are a few cutting technologies which have proven to be applicable for the nuclear power plant decommissioning. In this study, two popular technologies were chosen for the segmentation technologies. One is plasma cutting which is fast but difficult to cut thick objects. The other is mechanical cutting technology which is slow but can cut thick objects [7].

2.3 Segmented Waste Storage Container

MOSAIK container was selected for ILW storage while IP-2 storage container was used for LLW storage. The technical standards for radioactive waste storage containers are mostly the same as the IAEA standards [8-9].

2.4 Optimal Segmentation Scenario

Our task aims to find the optimal point that minimizes volume, cutting length, and cutting time. In the optimal cutting scenario, the sizes of the core flange, core barrel, and thermal shield were checked and applicable cutting technologies were evaluated according to the thickness of the cutting target. Scenario was developed according to the radiation level and the geometry and the shape of the components based on the premise that generated waste are stored in the container accordingly, either MOSAIK or IP-2 after the segmentation.

In the case of the core flange, there is a method of removing the thick pipe through which the coolant flows by considering all three axes, X, Y, and Z, and a method of cutting including the thick pipe by considering only the two axes, X and Y. Depending on the path excluding or including pipes, applicable cutting techniques differ, which also results in differences in cutting length, working time, and storage.

When Segmentation the core barrel and thermal shield, equal and angle cutting were applied. Likewise, this causes differences in cutting length, working time, and storage.

3. Results

3.1 Core Barrel and Thermal Shield segmentation

For core barrels, cutting by angle is better than cutting by equal parts. The cutting length and cutting time are the same, but one storage container is saved.

For thermal shields, cutting by angle is better than cutting by equal parts. The cutting length was 35,410 mm, the working time was about 2,360 minutes, and one storage container was saved.

Quantity of segmented waste was evaluated as the number of required containers for storage. Fig 2 show the number decrease with increasing fine segmentation since small and fine pieces can fill the container more compact. On the other hand, fine segmentation lengthens cutting length and time thus inevitably increase radiation exposure to the workers. Fig. 3 shows the cutting length vs. the number of segmentation pieces.

There must be an optimum segmentation between the low and high number of the segmentation.

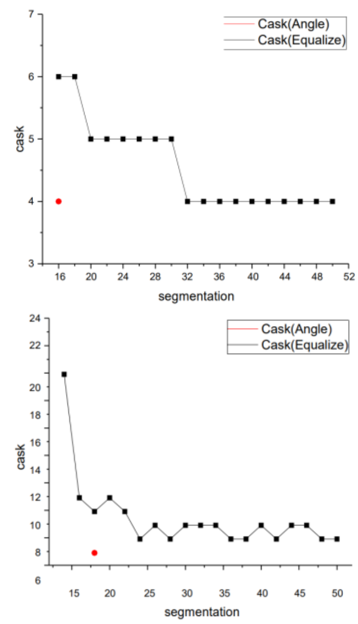

Fig. 2. Storage container changes according to core barrel, thermal shield cutting method

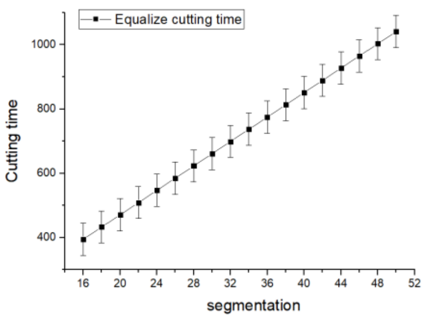

Fig. 3. Cutting time change rate according to the number of cuts

3.2 Core Flange segmentation

As mentioned, core flange looks somewhat complicated because it holds neighbor parts and offers opening for coolant flow. Therefore, cutting seems to require tri-axial motion for the precise and efficient segmentation. Unexpectedly, however, this study reveals that the tri-axial motion is not efficient but time-consuming.

For the core flange, thus cutting considering only the x and y axes saved the total cutting length by 10,024 mm, working time by about 21 minutes, and one storage container compared to cutting considering all the x, y, and z axes. Fig. 4 show the improved bi-axial segmentation.

Table Core flange X,Y vs. X,Y,Z cutting Results

Core flange		Thickness (mm)	Cutting length (mm)		Band saw cutting time (min)	Plasma cutting time (min)	Number of Container
			Band saw cutting	Plasma cutting			IP-2
X,Y	U	362	2,896	-	193	-	3
	L	45	772	27,739	51	185	
X,Y,Z	U	362	2,896	-	193		4
	L	45	-	38,535		257	

U: Upper, L: Lower

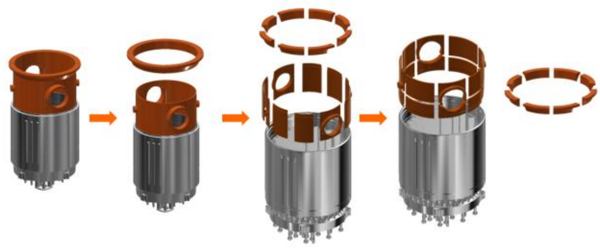

Fig. 4. Core flange cutting scenario (improved)

4. Conclusions

Through the study of the ILW components (core barrel and thermal shield segmentation) it is found that here must be an optimum segmentation between the low and high number of the segmentation, in terms of waste generation and radiation exposure minimization.

LLW core flange examination reveals that segmentation with bi-axial motion is simple and efficient enough to satisfy the optimization objectives.

Acknowledgement

This research was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP), funded by the Ministry of Trade, Industry & Energy (MOTIE), Republic of Korea (No. RS-2023-00247243).

REFERENCES

[1] Kyomin Lee, Preliminary Evaluation of Decommissioning Wastes for the First Commercial Nuclear Power Reactor in

South Korea, World Academy of Science, Engineering and Technology, Vol:11, No:8, 2017

[2] Duk-woon Jung, A Study on the Conceptual Design of Package for the RV/RVI Cutting Wastes During Decommissioning of Kori Unit-1 NPP, (2018) Korean Radioactive Waste Society Spring Academic Conference

[3] IAEA, Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purpose, TRS.389, ISBN 92–0–103198–X

[4] EPRI, Maine Yankee Decommissioning – Experience Report, "Detailed Experience 1997-2004"

[5] EPRI, Connecticut Yankee Decommissioning – Experience Report, "Detailed Experience 1996-2006"

[6] Heejin An, Consideration on packaging containers for radioactive waste generated during nuclear power plant decommissioning, (2016) Korean Radioactive Waste Society Spring Academic Conference

[7] Ga-ram Lee, Selection methodology of the optimal cutting technology for dismantling of components in nuclear power plants, (2022), Annals of Nuclear Energy

[8] IAEA, "IAEA Safety Standards Series No. ST-1: Regulations for the Safe Transport of Radioactive Material," 1996.

[9] GNS. MOSAIK casks – A Comprehensive Solution for Packaging ILW, (2019): Paper 1157