Case Study of the Cutting Techniques of Reactor Vessel and Reactor Vessel Internals

Min Seong Kim*, Hyu Chang Choi, Suk Bon Yoon, and Suk Won Jung
Korea Hydro & Nuclear Power (KHNP) Central Research Institute (KHNP-CRI)
**Corresponding author: minseongkim@khnp.co.kr*

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1. Introduction

The reactor vessel and reactor vessel internals (RV/RVIs) become radioactive due to neutron irradiation during the operation of nuclear power plant. Therefore, the level of radioactivity is relatively high compared to other radioactive wastes. Therefore, RV/RVIs must be cut into small pieces for ease of storage, disposal, and transportation[1].

Cutting of the RV/RVIs generates dust, gases, etc. This may result in internal exposure to workers through inhalation, and external exposure due to lack of shielding, and nearby work. In addition, cutting requires costs such as purchasing cutting equipment and disposal of waste. In this regard, appropriate cutting technology should be applied to the cutting of RV/RVIs. In order to apply appropriate cutting technique for decommissioning of domestic nuclear power plants in the future, it is necessary to analyze the foreign cutting techniques of RV/RVIs. Therefore, the objective of this study is a case study of the cutting techniques of RV/RVIs.

2. Overview of Cutting Techniques

The cutting methods of RV/RVIs are mainly categorized into Mechanical cutting and Thermal cutting. Table 1 showed the major techniques of mechanical cutting and thermal cutting.

2.1 Mechanical Cutting

Mechanical cutting is a method in which a cutting tool directly contacts with the RV/RVIs. This method is categorized into cylindrical cutting, band saw cutting, water jet cutting, wire cutting, etc. RV/RVIs cutting equipment is used by modifying commercially available cutting tools to suit the purpose of cutting. In particular, in the case of underwater mechanical cutting to reduce the radiation dose, water purification facilities are required to ensure visibility. Water purification equipment is also utilized by modifying it to be suitable for nuclear power plant decommissioning.

2.2 Thermal Cutting

Thermal cutting methods include plasma arc, flame cutting, Contact Arc Metal Cutting, etc. In these methods, the cutting tools do not directly contact with the RV/RVIs. Due to indirect contact, there is no rebound force. so these tools don't need to be heavy and strong. In addition, the size is small and the cutting speed is relatively fast. In general, thermal cutting generates a lot of airborne pollutants. So it is necessary to prepare ventilation facilities and barriers for air collection and purification.

Table 1. Major techniques of mechanical cutting and thermal cutting

Cutting Method		Cutting Material	Thickness (mm)	speed	Manual Possibility	Generation of Waste
Mechanical Cutting	Saw	Metal	10 ~ 3,000	Intermediate	○	Low
	Shearing	Metal	0~10	High	○	Low
	Grinding	Metal	0~5	Low	○	Intermediate
		Concrete	0 ~500	Intermediate	×	High
	Diamond Wire	Metal	50 ~	Low	×	High
		Concrete	300~	Intermediate	×	Intermediate
	Abrasive Water Jet	Metal	0~300	Low	×	Intermediate
		Concrete	0~500	Intermediate	×	High
Thermal Cutting	Flame	Carbon Steel	5~600	High	○	Intermediate
	Powder Flame	Metal	100~	High	○	High
		Concrete	0~1,000	High	×	Very High
	Plasma Arc	Metal	130~	High	○	Intermediate
	EDM	Metal	10~	Low	×	Low
	CAMC	Metal	0~200	High	×	Intermediate
	Laser	Metal	0~10	High	○	Intermediate

3. Foreign RV/RVIs Cutting Techniques

In this study, we analyzed the examples of RV/RVIs cutting techniques. The following companies were investigated: ① Holtec International, ② Orano TN, ③ Westinghouse Electric Corporation, ④ SKB (Svensk Karnbranslehantering AB), and ⑤ SCK-CEN. Table 2 showed the Examples of RV/RVIs cutting techniques.

3.1 Holtec International

Holtec International developed the HI-CUT system for cutting RV/RVIs in 2020. The first HI-CUT machine was used in 2022 to cut the Indian Point Energy Center Unit 3 RV/RVIs. The cutting speed is 25 mm/min, and the saw cutting method is applied as the optimal cutting technology considering the optimization of the operator's radiation dose, ensuring safety, contamination spread control, and multi-layered protection.

3.2 Orano TN

ORANO TN has performed cutting of RV/RVIs for nuclear power plants such as Rancho Seco and Maine Yankee. The cutting speed is 2.5 to 5 mm/min. The abrasive water jet cutting technology was selected in consideration of ALARA, radioactive contamination control, decommissioning schedule, secondary waste disposal, cost efficiency, and the ability to penetrate metal when cutting[2].

3.3 Westinghouse Electric Corporation

Westinghouse Electric Corporation has performed cutting of RV/RVIs for Bohunice and other nuclear power plants. Mechanical cutting methods in underwater were selected to prevent the spread of fluid contamination such as gases, aerosols, and turbulence[3].

3.4 SKB (Svensk Karnbranslehantering AB)

SKB has performed cutting of RV/RVIs for Oskarshamn nuclear power plant. Depending on the thickness of the workpiece, cutting speeds range from 1 to 200 mm/min for flat plates with a thickness of 10 mm, and from 1 to 40 mm/min for flat plates with a thickness of 50 mm[4].

3.5 SCK·CEN

SCK·CEN has performed cutting of RV/RVIs for BR-3 nuclear power plant. Depending on the type of cutting, the cutting speed is about 7 to 9.5 mm/min for horizontal cutting and about 15 mm/min for vertical cutting.

4. Conclusion

In this study, we investigated ① type of cutting techniques and ② cases of foreign cutting techniques. As a result, Although there are various cutting techniques, the cutting technique actually used appears to be underwater remote-based mechanical cutting. Considering these overseas cases, it is worth considering the application of underwater remote-based mechanical cutting for domestic RV/RVIs in the future. The results of this study can be useful in the future for the application of cutting techniques in domestic nuclear power plant decommissioning.

REFERENCES

[1] IAEA, Application of Configuration Management in Nuclear Power Plants, IAEA Safety Reports Series (SRS) No.65, 2010.
[2] Jean-Michel Chabeuf, Orano's Overseas Project Experience on NPP Decommissioning, 2022.
[3] Joseph Boucau, Tomas Klein, Innovative D&D at Bohunice V1, Nuclear Engineering International, 2019.
[4] Helena Larsson, Ake Anunti, Mathias Edelborg, Decommissioning Study of Oskarshamn NPP, SKB R-13-04, 2013.

Table 2. Example of RV/RVIs cutting techniques

Company	Cutting Method	Characteristic	Speed (mm/min)	Generation of Secondary Waste	Example of Nuclear Power Plant
Holtec International	Saw Cutting	Underwater/ Remote	25	Low	Indian Point Energy Center
ORANO	Abrasive Water Jet	Underwater/ Remote	2.5 ~ 5	Intermediate	Rancho Seco Maine Yankee
Westinghouse	Saw Cutting	Underwater/ Remote	-	Low	Bohunice V1
SKB	Saw Cutting	Underwater/ Remote	1 ~ 200 (10 mm plate) 1 ~ 40 (50 mm plate)	Low	Oskarshamn
SCK·CEN	Saw Cutting	Underwater/ Remote	(Horizontal) 7 ~ 9.5 (Vertical) 0 ~15	Intermediate	BR-3