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A Study on the Mechanism for PWR Spent Fuel Rod Extraction

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1. Introduction

Mechanical head-end processing of SF disassembly, extraction of the rods, and the shearing of the extracted rods shall be performed in advance as the head-end process of the pyro electro-reduction process. Generally, whether to extract the rods in head-end process is decided by wet method or dry method. Pyro process, which is a dry process, the analysis in terms of efficiency with connection to the post process of the mechanical head-end shall be carried out in advance. Therefore, this study analyzed the feasibility of the extraction method of PWR spent fuel rod, which is a part of the unit process, for the design of a high efficiency head-end process. For this, the cutting force and degree of maintaining original form of the entire spent fuel assembly and the crowded rods were compared and analyzed Also, the technical method for rods extraction was compared. For this, the vision method which extracts with video processing and mechanical method which uses a jig were analyzed. Considering the decladding process, which is a post process, the rods extraction method selection criteria were prepared in terms of the reaction efficiency, purity of the supplied raw material, production efficiency, whether there is a mechanical decladding, the limitation of locations, and the shape of the cut surface. Through the analysis of the spent fuel extraction method, the above analysis results can be utilized in the head-end process design of the spent fuel nuclear fuel cycle dry process.

2. Main Contents

2.1 SF assembly and extraction rods

After assembly cutting and extraction to extract nuclear fuel rods from SF assembly, the degree of maintaining the original form and the cutting force of the crowded rods were compared. The purpose of this analysis, considering the mechanical decladding, is to find whether the cut surface of the rods satisfies the condition to maintain the degree of the original form (degree of maintaining the original form, 90% or higher), and to compare the efficient cutting forces required for the assembly cutting and for the crowded rods after the extraction when the rods were cut.

In figure 1 and figure 2, the shape of the cross section of the rods is cut skewed as much as rods sagging, which is $\delta = L \cdot \tan \alpha$, so the cross section shape of the rods is distorted. Therefore, if the same cutting force is applied, the force of slant cutting the assembly is less than the force of radial cutting of the assembly, and it is cut skewed as much as δ, so the shape of the rods is distorted in the assembly cutting method. As a result of comparing the degree of maintaining the original form and the cutting force of the crowded rods cutting after assembly cutting and extraction, the force for cutting of the crowded rods cutting method after the extraction is more efficient and had better degree of maintaining the original form of the spent fuel rod-cuts than the assembly cutting.

[P_A: assembly radial cutting force, $P_{A\text{-}1}$: assembly slant cutting force, P_C: crowded rods radial cutting force, d_2: rods outer diameter, d_1: rods inner diameter, δ: rods sagging amount, α: rods sagging angle, θ: cutting slope angle]

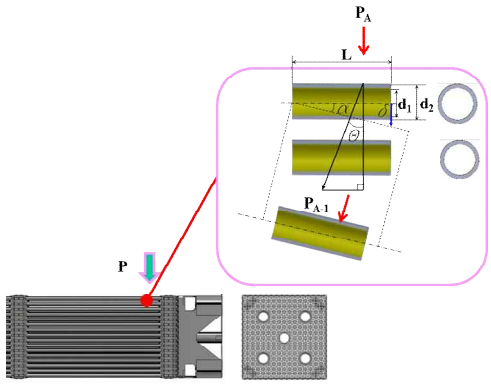

Fig. 1. PWR SF assembly cutting for decladding.

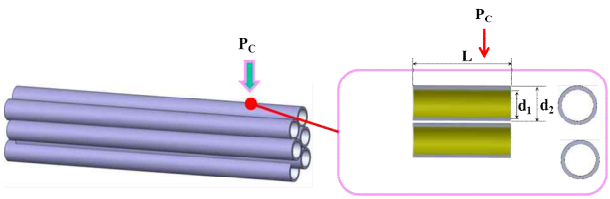

Fig. 2. Consolidated rods cutting after extraction.

2.2 Methodological comparison of extraction

As the technologies to extract the rods from SF assembly, vision method (VISION) which is a video processing method and mechanical rods extraction method (JIG) which is composed of mechanical structure are compared. (Figure 3 and Figure 4) As you see in Table 1, the vision method has comprehensive functions that can extract from each assembly type, but the gap between the rods is small in multi rods

extraction, which is difficult to design the collet part, and the sensor that requires precise control is vulnerable in radiation environment. But the mechanical rods extraction method is structurally simpler than the vision method, and has less failure ratio in radiation environment. Also, in the extraction of multi rods, the structure to hold the rods is simple. Therefore, the mechanical rods extraction method is better than the vision method in the rods extraction methods.

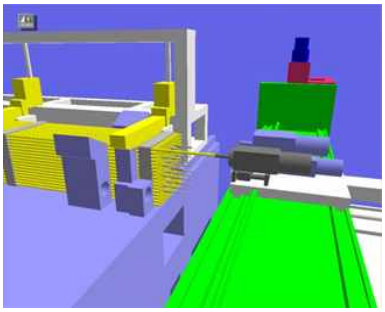

Fig. 3 Vision method.

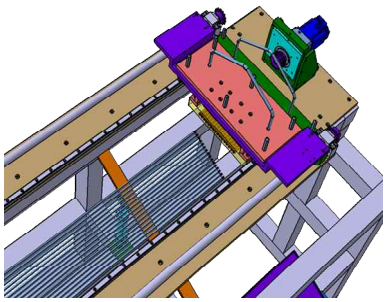

Fig. 4 Jig method.

Table 1 Comparison of vision and jig methods

Method	VISION method (Video processing)	JIG method (Mechanical)
Advantages	- Nut socket has long replacement cycle - Has comprehensive functions to extract each type of assembly - If abnormal rod is generated, it can handle such as extracting with another tool	- Extraction by simple mechanical method, having a simple structure - Low failure ratio - No need for shielding structure - Requires small space - The structure to hold the rods is simple in multi rods extraction
Disadvantages	- Requires precise control method - Sensor, etc. are vulnerable. - Radiation shield structures are required a lot for each element - Device failure ratio is high - Requires a big space - Difficult to design collet for multi rods extraction	- Jig shall be replaced at certain cycle - Jig needs to be made for each assembly

2.3 Selection criteria for extraction device

The elements affecting the post process are reaction efficiency, purity of the supplied material, production quantity, whether mechanical decladding device is used, whether there is a limitation of hot cell space, and the shape of the cross section. Therefore, requirements of the extraction device considering the post process are high reaction efficiency of the post process, high purity of the rod cut supply material of the post process, high production quantity of the post process, necessity of mechanical decladding device and there is a device size limitation in the post process, and the case of requiring high degree of maintaining the original form of the cross section in the post process. Also, the elements that are not required for the extraction device considering the post process are low reaction efficiency of the post process, low purity of the rod cut supply material of the post process, low production quantity of the post process, mechanical decladding device is not required and there is no device size limitation in the post process, and the case of requiring low degree of maintaining the original form of the cross section in the post process.

3. Conclusions

For the feasibility analysis of PWR spent fuel assembly rods extraction method, assembly cutting and crowded rods cutting method after extraction, and the vision method and the mechanical extraction method were analyzed. As a result, crowded rods cutting method had more efficient force for cutting and had superior degree of maintaining spent fuel rod cut cross section original form than the assembly cutting. In the technical methods, the mechanical rods extraction was better than the vision method. Also, considering the decladding process, which is a post process, the rods extraction method selection criteria were provided. The above analysis result of SF assembly rods extraction methods can be utilized for the design of SF rods extraction device that will be applied to the head-end facility in PRIDE.

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