

Preliminary Study on Laser Cutting for Dismantling of Pressurized Heavy Water Reactors in Nuclear Decommissioning

Jae Sung Shin^{a,b,*}

^aQuantum Optics Research Division, Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon 34057, Republic of Korea

^bDepartment of Radiation Science, University of Science and Technology, 217 Gajeong-ro, Yuseong-gu, Daejeon 34113, Republic of Korea

*Corresponding author: jsshin12@kaeri.re.kr

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1. Introduction

Laser cutting is gaining attention as a promising technology for nuclear decommissioning due to its potential for high-speed cutting, minimal secondary waste generation resulting from the narrow kerf width, and ease of remote operation. Consequently, many researchers are actively exploring the application of laser cutting in nuclear power plant dismantling [1-7].

In the case of pressurized heavy water reactors (PHWRs), laser cutting can also serve as an effective tool for segmentation and removal tasks. PHWRs contain numerous fuel channels within the calandria vessel. The calandria vessel itself is composed of ~30 mm thick stainless steel, and the fuel channels include pipe-shaped components such as pressure tubes and calandria tubes, both made of zirconium alloys.

For this reason, the present study conducted and summarized a preliminary investigation of laser cutting applied to the dismantling of various structural components constituting PHWRs.

2. Methods and Results

2.1 Laser Cutting System

A ytterbium-doped fiber laser with a maximum output power of 6 kW (YLS-6000, IPG Photonics) was used as the cutting source. The laser beam was delivered from the generator to the cutting head through a 20-m long process fiber with a core diameter of 100 μm .

The cutting heads used in this study were custom-fabricated and each was equipped with a collimation lens with a focal length of 160 mm, along with one of three focusing lenses with different focal lengths ($f=300$ mm, 400 mm, and 600 mm) selected according to the test conditions.

To enable effective ejection of assist gas, a supersonic nozzle was applied to the cutting head, and two types of nozzles with throat diameters of 2 mm and 3 mm were used. These nozzles were optimally designed for a gauge pressure of 1 MPa. The cutting head was mounted on XYZ stage, which allowed

precise control of its movement by a CNC (computerized numerical control) machine.

The following cutting conditions were kept constant across all tests. The stand-off distance was set to 10 mm. Compressed air was used as the assist gas, and the supply pressure at the gas inlet was maintained at 1 MPa.

2.2 Cutting of 30-mm Thick Stainless Steel Plates

In response to the dismantling of the calandria shell, cutting tests were performed on stainless steel plates with a thickness of 30 mm. In this study, the focusing lens with a focal length of 400 mm and the nozzle with a throat diameter of 3 mm were used. For the 30 mm thickness, the optimal cutting speed at a laser power of 6 kW was 270 mm/min. To ensure cutting capability, the cutting speed was reduced to 200 mm/min for the initial and final 10 mm section.

As shown in Fig. 1, all attempts resulted in successful cuts, achieving a cutting success rate of 100%. This confirms that laser cutting is stably performed at the optimized speed.

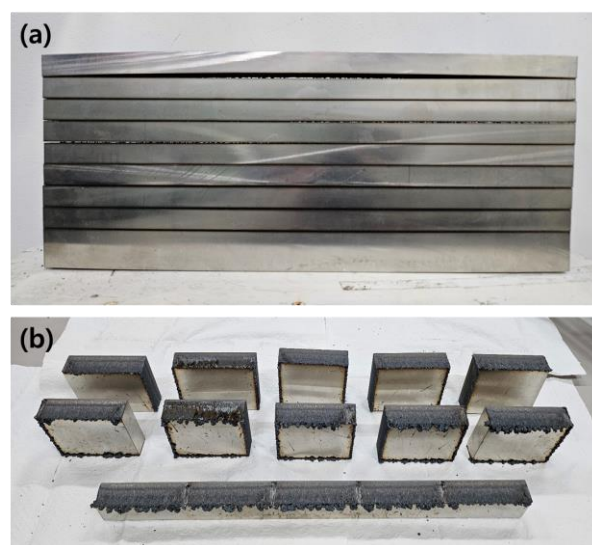


Fig. 1. (a) Specimen cut with a straight-line path and (b) specimen cut into 11 pieces by direction-changing cutting.

2.3 Cutting of Stainless Steel Pipes

PHWRs contain various pipe-shaped structures as well as thick sections. Therefore, one-sided laser cutting experiments were performed on different sizes of stainless steel pipes. In this study, the focusing lens with a focal length of 600 mm and the nozzle with a throat diameter of 3 mm were used.

As a result, cutting was possible even for pipes with dimensions up to 165.4 mm in diameter and 6.7 mm in thickness at a laser power of 6 kW. In addition, a comparison between single-pass and double-pass cutting showed that the double-pass method provided improved cutting performance in terms of speed.



Fig. 2. Laser cutting of the stainless steel pipe in progress.

2.3 Cutting of Zirconium Alloys

The study also investigated the laser cutting characteristics of two types of zirconium alloys used as the materials for pressure tubes and calandria tubes. In this study, the focusing lens with a focal length of 300 mm and the nozzle with a throat diameter of 2 mm were used.

Fig. 3 shows the maximum cutting speeds of zirconium alloys and stainless steel as a function of laser power. The cutting performance of the two zirconium alloys was nearly identical, and their thermophysical properties enabled cutting at speeds 1.7-1.9 times higher than that of stainless steel.

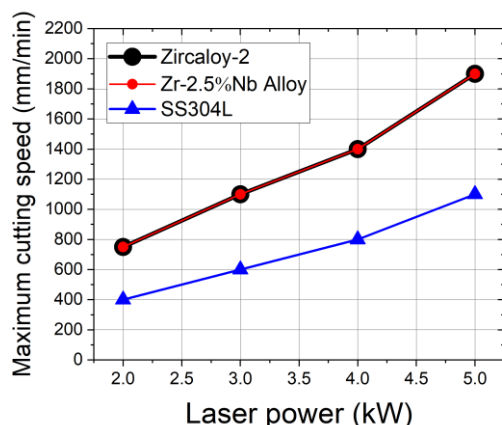


Fig. 3. Maximum cutting speeds of zirconium alloys and stainless steel as a function of laser power [6].

3. Conclusions

In conclusion, a preliminary laser cutting study was conducted for application to the dismantling of PHWRs. The feasibility of laser cutting was demonstrated for thick-section cutting relevant to the calandria shell, pipe-shaped components, and zirconium alloys, and appropriate cutting conditions were established. These results are expected to serve as important foundational data for the future dismantling of PHWRs.

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