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# Laser Welding Test Results with Gas Atmospheres in Welding Chamber

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## 1. Introduction

Laser welding using high-density energy has been widely used in the manufacturing process, and its main advantages are a small HAZ (heat-affected zones) and high weld aspect ratio in the penetration welding. Thus, it can be applied to precise and effective metal joints [1]. To measure the irradiation properties of nuclear fuel in a test reactor, a nuclear fuel test rod instrumented with various sensors must be fabricated with assembly processes. A laser welding system to assemble the nuclear fuel test rod was designed and fabricated to develop various welding technologies of the fuel test rods to joint between a cladding tube and end-caps [2]. It is an air-cooling optical fiber type and its emission modes are a continuous (CW) mode of which the laser generates continuous emission, and pulse (QCW) mode in which the laser internally generates sequences of pulses. In a previous experiment on this system, some problems were found in welding properties such as an irregular bead by the oxidation and low penetration depth of the FZ (fusion zone) [3]. Thus, we considered the system welding a sample in a chamber that can weld a specimen in a vacuum and inert gas atmosphere, and the chamber was installed on the working plate of the laser welding system. In the chamber, the laser welding process should be conducted to have no defects on the sealing area between a cladding tube and an end-cap. Therefore, the laser welding techniques need to be developed to accurately and precisely instrument for the nuclear fuel test rod.

This paper describes not only the composition and function of the laser welding system installed with a welding chamber for a nuclear fuel test rod but also the welding condition and results from the laser welding experiments.

## 2. Experimental

To assembly a nuclear fuel test rod, a laser welding system installed with a welding chamber is shown in Fig. 1. It is made up of a laser source, a laser head mounted on a 3-axis (x, y, z) servo stage, an index chuck installed in a welding chamber, and a control PC. The laser source is an YLR-150/1500-QCW-AC model made by IPG, Co. The laser head is used to emit a laser beam and its lens focus distance and beam size are 180 mm and ø276 µm. The movable length of the 3 axis-serve stages is 900 mm on the X axis, 300 mm on the Y axis, and 200 mm on the Z axis. A new index chuck (θ axis) replaced from a previous index chuck is existed in a welding chamber and its rotation (360 degrees) can be controlled with a CNC program.

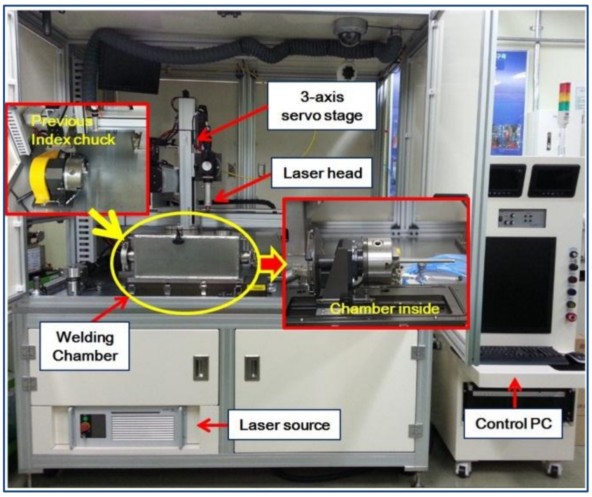


Fig. 1 Laser welding system before and after chamber installation.

To maintain a vacuum and/or an inert gas atmosphere, a welding chamber was installed with a vacuum pump and a gas supply system. It is used to obtain a clean surface of the specimens with vacuum and inert gas filled inside the welding chamber. The entire laser welding process using the welding chamber is carried out under various gas conditions. It is as follows: First, a specimen is fixed in an index chuck and then put into a welding chamber cover. Second, after vacuuming the welding chamber by a vacuum pump, a test sample is filled with the inert gas according to the pressure conditions. Finally, turn on the start button of the laser welding system. It is automatically welded by the CNC program. The specimens are composed of the cladding tube and end-cap of STS (stainless steel) 316L. The size of the cladding tube is 9.53mm in outer-diameter and 7.75mm in inner-diameter, and that of an end-cap is 9.53mm in outer-diameter and 5.0mm in inner-diameter. All process welding conditions listed in Table 1 are used to check the width and penetration depth of the HAZ and to confirm the welding properties. To analyse the specimens welded by the laser welding system, visual and metallographic tests were carried out for all test specimens using metallography methods.

**Table 1**. **Welding Conditions in a welding chamber**

| Items | Conditions |
|---|---|
| Mode | QCW (pulse) |
| Atmosphere in the chamber | Vacuum (7Torr), He (2bar), Ar (2bar) |
| Power | 900~1500 W |
| Pulse repetition | 10 Hz |
| Turn speed of a specimen | F300 (0.087rad/sec.) |
| Focus length | 175.05mm (corrected length) |

## 3. Results and discussions

Photographs of a bead and a microstructure on the STS316L specimens welded in vacuum, helium gas and argon gas atmospheres of the welding chamber with the welding conditions fixed with 100% laser powers, a 10Hz repetition, a F300 (0.087rad/s) turn speed and a 175.05mm focus length, are shown in Fig. 2. In the case of the vacuum, the weld bead of a specimen surface welded under identical conditions is shown to be more irregular and unsteady than those in helium and argon gases, and which may be due to the reaction gas produced by residual oxygen during the laser welding process.

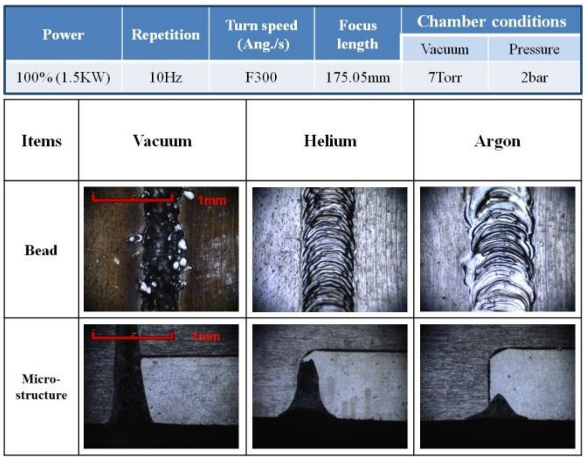


Fig. **2** Weld beads of the STS316L specimen welded with the welding conditions in the chamber.

In the helium, the weld bead generated with the laser welding is shown to be cleaner, more regular, and steadier than any other atmosphere, and its bead width is about 600um. In the case of the argon, the weld bead is clean but irregular, and its bead width is larger than any other atmosphere. In the microstructures, the penetration depth of the FZ in the vacuum is much deeper than those in inert gases and the depth of a pit formed with the laser welding is shown to be shallow on the surfaces of specimens welded in the helium and argon gas.

## 4. Conclusions

To improve the properties of the weld penetration depth and bead for a laser welding process, a laser welding experiment using the laser welding system mounted in a welding chamber was carried out for a tube and end-cap specimen of STS316L. The weld beads of specimens welded under identical conditions in the helium and argon gas were cleaner, more regular, and steadier than those in a vacuum. The penetration depth of the FZ in the vacuum was much deeper than those in the helium and argon gas.

## Acknowledgement

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