Comparison of laser welding conditions of Zircaloy-4 and stainless steel for nuclear fuel irradiation rig

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1. Introduction

An FTL, where a test of nuclear fuel and materials is carried out, is a facility based on the environment of commercial reactors during operation. Various materials for Zircaloy-4, SUS 316L, such as Inconel, are used as a survey rig that has been produced for fuel irradiation testing. Precision sensors, thermocouples, LVDT, and SPND should also be assembled. Therefore, a welding device for connecting them is necessary.

With a high density of energy, laser welding can be properly used in a deep permeation, and in precisely welding narrow and deep joints. In particular, it has been applied to other fields such as metal welding. Since the technology bears no pores or cavities, resulting in a clean surface after the welding process, it does not require an 'after-process' such as grinding or polishing, which is useful where high water-tightness is required. Therefore, we developed and researched a special fiber laser welding system for the production of a nuclear research rig.

2. Comparison of fiber laser welding conditions

2.1 Fiber laser welding configuration and conditions

The laser source of a developed laser welder is as follows: it is an air-cooling optical fiber, its wave length is 1070 nm, and a pulse mode or CW mode is optional. A CCD camera and vision system are applied for easy use, and it consists of an internal beam reflex structure to minimize damage to its head, and welding protection gas is provided; in addition, the focus distance of the head lens is 180 mm and its beam size is ø276 µm. In addition, the moving length of a 3 axis-serve stage is 900 mm on the X axis, 300 mm on the Y axis and 200 mm on the Z axis; its precision rate is ±0.02 mm, its index axis (θ axis) is placed to joint with a welding object, and its rotation (360 degrees) can be controlled with a CNC program (Fig. 1).

The fiber laser welding system used for the performance test was conducted for Zircaloy-4 and AISI 316L, which are the materials of a nuclear fuel researching rig for research test; cladding of ø9.5 mm in diameter and an end cap of 0.57 mm in thickness were assembled and their joint was then welded. The welding conditions are the distance between the focus lens and welding object, frequency of the laser, laser output power, and protective gas. Its range is shown in Table 1.

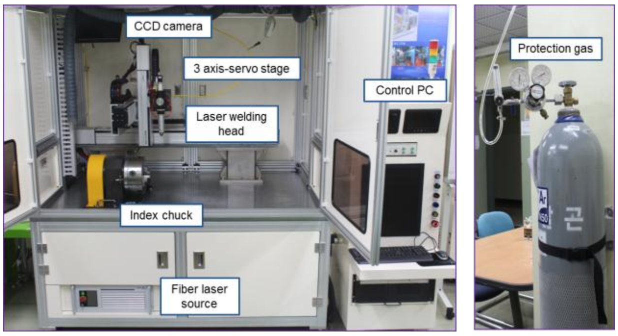


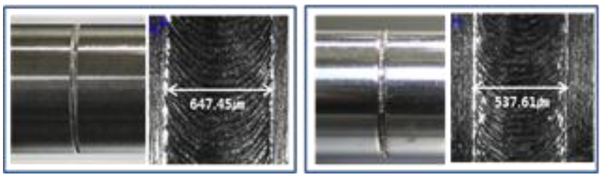
Fig. 1 Fiber laser welding system

Table 1. **Range of process variables**

Process variable	Range
Distance from focal length (mm)	175 ~ 191
Frequency of laser pulse (Hz)	6 ~ 14
Laser power (W)	900 ~ 1500
Shield gas	Helium, Argon

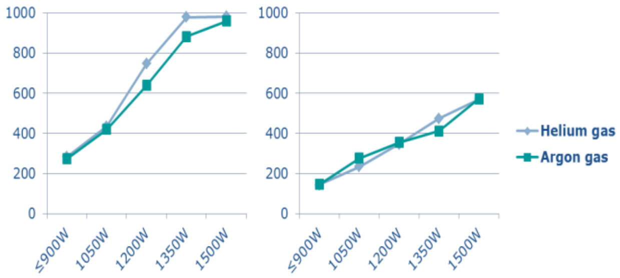
2.2 Laser welding experiments Zircaloy-4 and AISI 316L

Laser welding experiments were performed by changing one variable by fixing the other conditions at the welding condition in Table1. The distance between a focus lens and an object is 187 mm for Zircaloy-4, and the frequency of the laser is 189 mm for AISI 316L when the frequency of its laser pulse is 10 Hz; at this time, damage to the welded part occurred the least, its surface was even and the regular bead structure was shown to be the most optimal condition. In addition, the maximum input length was 0.98 mm for Zircaloy-4 and 0.57 mm for AISI 316L, in accordance with each material, and its most optimal condition from the result of the welding test according to the rate of output power after the above result was fixed. The degenerated rate on the welded part was the least when helium gas and argon gas for Zircaloy-4 and AISI 316L were used as a shield gas respectively. (Fig. 4)



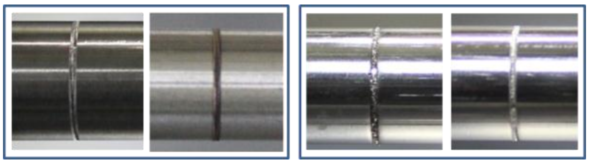
(a) Zircaloy-4 (b) AISI 316L

Fig. 2 The results of the optimal value using laser welding: distance and frequency



(a) Zircaloy-4 (b) AISI 316L

Fig. 3 Comparison of output of the laser welding depth



(a) Zircaloy-4 (b) AISI 316L

Fig. 4 Appearance of welding area according to the shield gases (Left: Helium gas, Right: Argon gas)

3. Conclusions

Through the above test, the different conditions of laser welding were found for Zircaloy-4 and AISI 316L used for producing a nuclear fuel research rig. Therefore, we will complete a nuclear fuel research rig, performing the most optimal welding conditions according to the properties of the materials in the future.

Acknowledgements

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