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Study on Conditions of Laser Welding for Manufacturing Irradiation Rig of Dual cooled Fuel

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1. Introduction

Dual Cooled Fuel is a concept that was first considered in gas-cooled reactors, and no-studies on whether Dual Cooled Fuel can be used as the nuclear fuel of a large output had been conducted. Dual Cooled Fuel is larger in external diameter than cylindrical fuel and is a form making space with cooling water inside and has a characteristic that cooling water flows inside and outside of the nuclear fuel. As the thickness of nuclear fuel is wide and thin in surface area compared with previous cylindrical nuclear fuel, there is a strong point in that the temperatures and heat flux of the surface of fuel rods can be lowered. Therefore, using this strong point, by copying the inspection environment such as temperature, pressure, flow, neutron flux, and so on of the core conditions of commercial furnaces installed at HANARO, Dual Cooled Fuel that can be utilized in FTL (Fuel Test Loop) as a facility to implement the testing of nuclear fuel and materials is to be developed.

Since STS316L steel used as a material for Dual Cooled Fuel Irradiation Rig manufacturing prevents the corrosion of pitting and restrains intergranular corrosion, there is an effect in preventing oxide film. However, as we can see in Fig. 1, because various precious sensors such as nuclear fuel, SPND, T.C MI cable, and LVDT, should be assembled, special welding is needed to not damage them. In particular, in the case of T.C., which measures central temperatures of nuclear fuel, because the connecting part with the MI cable should be welded, precise welding that parts of welding are Φ3 mm and under is necessary. Since laser welding can obtain a density of high energy and blend narrowly and deeply, the hot creep of welded materials or deterioration of materials is low, it is easy to conduct precise welding, and thus conditions of laser welding were studied.

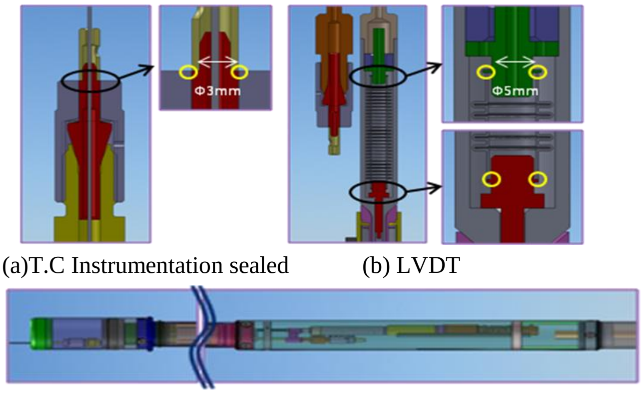

Fig. 1. Dual Cooled Fuel Irradiation Rig

2. Laser Welding

2.1 Laser welding device configuration

The laser devices used in this study are composed of laser source, a laser welding head, CNC controller, index chuck (θ), three axis servo stages of X, Y, and Z, and a system frame. In terms of welding depth, this is a fiber air cooling-system laser that uses small parts of welding, deep penetration phenomena, and fast welding speed. In addition parallel use is possible. Also, since a CCD camera and vision system are installed on the same axle, it is possible that a worker can check and change the welding locations and monitor the welding conditions through a LCD monitor and an X-Y generator. Thus, the welding conditions can be checked in real time.

The three axis servo stage is equipped with a laser welding head and it is possible to control the transfer (degree of precision: ±0.02 mm) into the X-axis (900 mm), Y-axis (300 mm), and Z-axis (200 mm). This has a structure of an internal reflection beam, minimizes the damages to the optical fiber, and prevents oxidation by supplying welding protection gas. As the index chuck (θ axis) is put on the plane of a worktable, nuclear rods are set on the chuck. In addition, with the CNC program, the rotation (360 °) can be controlled. The system frame can support devices being installed and a weld specimen (150 kg).

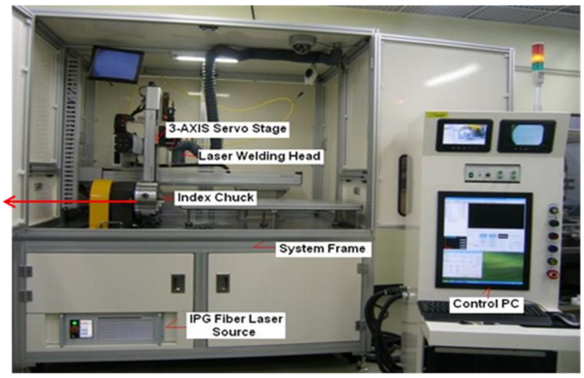

Fig. 2. Laser welding device configuration

2.2 Laser welding conditions

Ahead of the welding of the Dual Cooled Fuel Irradiation Rig, through a trial test using a specimen of the same material, the most stable welding condition was determined. To lessen damages to the basic material owing to continuous torching, it was processed using a purse mode. Considering important variable variables, i.e., focal distances of the head and output according to Table I, the welding condition according to changes of repetition was checked.

Table I: Selection of process variables

Focal distance(mm)	261.5 ~275.5
Laser current(%)	40,50,60,70,80,90
Laser Repetition	3,5,7,9,11

First, an experiment according to the focal distances of the head was conducted. As a result of the inspection of the maximum output point according to the height of the laser head, it was determined that the point is 265.5 mm. However, in the welding result, since damage is done to the basic material and deeply dug phenomena appear, by controlling ±2 mm, less damaged points were inspected. From the results, it was confirmed at which the point that damages are fewer and the most maximum output can be obtained is 275.5 mm.

Fig. 3. Laser welding result (Condition: Focal distance)

Next, the weld specimen according to current was checked. As we can see kin the figure, it was confirmed that a wide and deep welding is achieved as the output values are higher. It was confirmed that values of stable penetration depth are 0.9 and greater when the output value is 50 or more. However, when the output values are 80 or more, since the penetration depths are deeper and damages to the the basic material, i.e., a hole occur, the welding output of Fig.4 within ranges in which the penetration depth is stable should be selected.

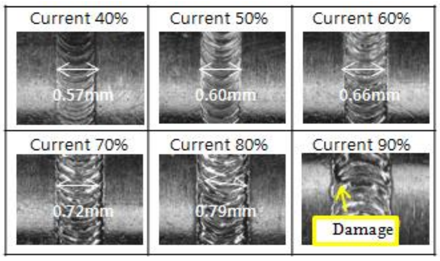

Fig. 4 Laser welding result (Condition: Current)

According to repetition, using a naked eye examination, it was confirmed that there were no damages of welding parts due to flames. As the values of repetition were higher, the welding parts were welded minutely and precise welding was possible. However, when the values became 11 or more, because oxidation of the welding parts was occured, stable values of repetition from 5 to 9 were selected.

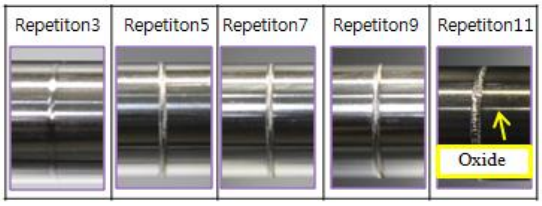

Fig. 5. Laser welding result (Condition: Repetition)

As the optimal values of welding caused by this, by selecting the head focus distance, current, and repetition, final welding was conducted. Clean and precise welding parts that had no damages to the basic material and no oxide film were gained. In addition, using these conditions for a Dual Cooled Fuel Irradiation Rig, minute and stable welding of precise sensors was achieved.

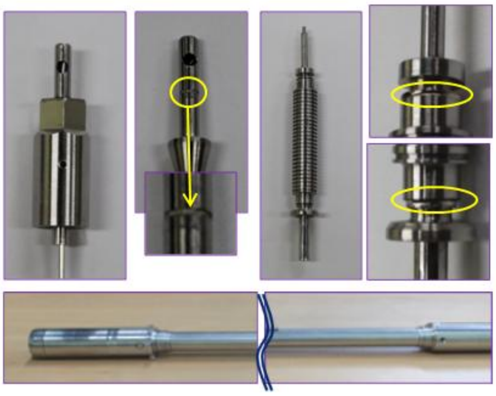

Fig. 6. Dual Cooled Fuel Irradiation Rig Laser welding

3. Conclusions

Through this study, optimization of laser welding conditions for use at Dual Cooled Fuel Irradiation Rig manufacturing was extracted. In addition, using laser welding, it was confirmed that the welding of more minute conditions was possible.

Acknowledgement

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