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Surface Modification Technology of ODS Alloying Treatment by using Laser Heat Source

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1. Introduction

The ODS (Oxide Dispersion Strengthed) alloys can be applied as structural materials for components in the core of a nuclear power plants since these components must have a high mechanical strength at high temperature up to 700°C [1]. This type of alloy was generally manufactured by mechanical alloying from its source metal and Y_2O_3 powders. The mechanical alloyed powder is subjected to the HIP (Hot Isotatic Pressing) or hot extrusion; and this product is heat treated at target temperature and time. Thus, the Y_2O_3 particles are dispersed in the metal matrix. These manufacturing process of ODS alloy is very complex and expensive. Also, it is necessary the special techniques to obtain the uniform dispersion and volume control of Y_2O_3 particles. Another problem is the final product forming such as tube and sheet because the intermediated-product has a high mechanical strength due to the dispersion of Y_2O_3 particles.

The laser cladding techniques was applied on the surface cladding of ceramics and inter-metallic compounds on metal base and ceramic base components to increase corrosion and wear resistance [2, 3]. The laser heat source can be used to the alloying the metal and ceramic materials, because thermally melting of metal and ceramic is possible. So, we are applied on ODS alloy manufacturing by using the laser hest source. The main advantages and disadvantage of this technology can be resumed as follows:

- It is possible to apply to the sheet and tube shape component, directly.
- Metallurgical damage such as HAZ and severe grain growth is considerably reduced.
- Good control of the alloying element of the treated zone
- Highly reproducible homogeneous zone
- The pores and cracks are suppressed in the treated zone
- Oxidation can be prevented during the process.
- Good control is possible for the irregular shaped components.
- The bulk material alloying is limited by the power of laser source.

So, this work is studied on the ODS alloy manufacturing methods on the zirconium, stainless steel, and nickel base alloy by using the laser source.

2. Methods and Results

This technique consists basically in supplying particles (Y_2O_3, other oxides and inter-metallic compound powder) and the base metal components. The insulation gas to prevent the oxidation was flowed over the matrix and particles.

2.1 Source material

The matrix alloy was prepared as a sheet shape. The prepared alloy was Zircaloy-4 (Zr-1.5Sn-0.2Fe-0.1Cr), T91 (Fe-8.29Cr-others), and In 738 (62Ni-16Cr-8.5Co-others). The mean size of Y_2O_3 particle was less than 10 micron and their shape was very irregular as shown in Fig.1.

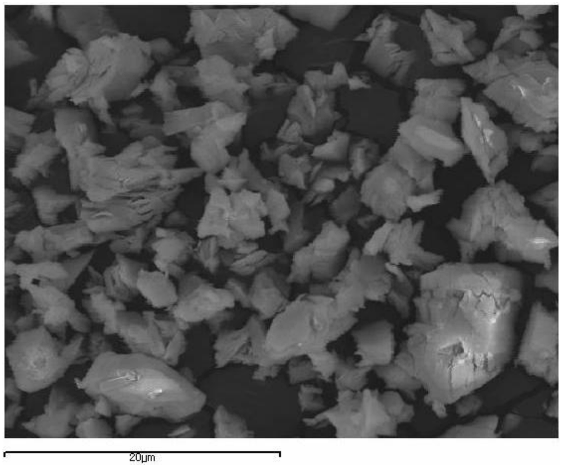

Fig. 1. SEM observation of the Y_2O_3 particle before the laser alloying

2.2 Y_2O_3 particle Alloying using the Laser Power

Initially, the 300 W power of fiber laser was applied to mix the Y_2O_3 particles into three types of metal base alloys. For the 30 x 70 mm area as shown in Fig. 2, the alloying process was done in a time of 20 s. After the ODS alloying, the matrix was confirmed by using the SEM observation as shown in Fig. 2. The reaction layer between Zircaloy-4 and Y_2O_3 particle was about 300 micron, and this thickness was about 12.5% of the Zircaloy-4 sheet thickness. In detail, the surface modification of ODS treatment is possible. However, the ODS layer thickness can be controlled by the laser power and scanning speed, easily. So, this technology can be used in the field of surface modification to increase the strength without major change of substrates.

In the high magnification SEM observation, it was observed that the Y_2O_3 particles were uniformly distributed in the Zircaloy-4 matrix. The size of Y_2O_3 particles was smaller than 0.5 micron in diameter. So, the Y_2O_3 particle size was considerably decreased by the laser ODS alloying method when compared to the initial particle size as shown in Fig.1. This trend was shown in the T91 and In 738 alloys. From this, it is known that the ODS alloy (laser ODS alloy) can be manufactured by using the laser beam scanning method. Of course, the ODS layer thickness have to be expanded by controlling the laser source power, focusing area of laser beam, and scanning speed.

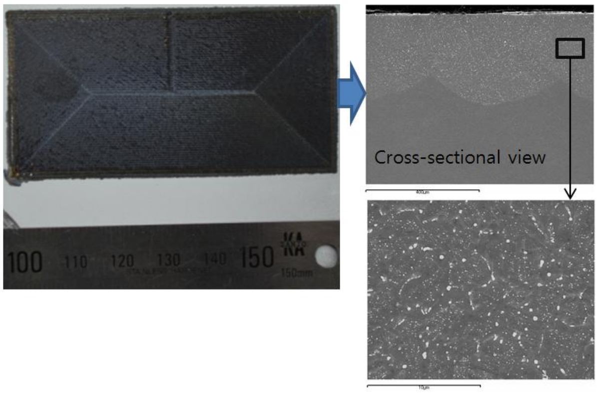

Fig. 2. Surface appearance after laser beam scanning of Zircaloy-4 alloy and the cross-sectional view of the laser ODS alloying area.

2.3 Tensile Test for the Laser ODS Alloy

For the laser ODS alloy, the tensile teat was performed. The tensile test samples were prepared for the laser scanned area of sheet. The ODS layer thickness was about 12.5% when compared to the initial sheet thickness of alloys. The results of the tensile test at room temperature were shown in table 1.

Table I: Summary of the tensile test result for the initial alloy sheet and after the laser ODS alloying on the surface

Alloy		YS (MPa)	UTS (MPa)	El (%)
Zircaloy-4	Initial	406	566	20.3
	After	648	827	15.2
T91	Initial	817	1021	18.5
	After	1183	1336	13.1
In 738	Initial	786	1232	14.1
	After	1122	1338	7.0

The YS (Yield Strength) and UTS (Ultimate Tensile Strength) were considerably increased by the laser ODS alloying of each alloy, respectively. Whereas the El was decreased after the laser ODS alloying on the surface of each alloy.

3. Conclusions

The Y_2O_3 particles can be successfully distributed in the matrix of Zircaloy-4, T91, and Inconel 783 alloys by using the laser beam scanning. The distributed Y_2O_3 particles were formed as a sub-micron size. From the tensile test, it was revealed that the strength of the test alloy can be increased by surface modification, which was showed as ODS layer by laser beam scanning with Y_2O_3 particles. This technology showed a good application for the surface modification of materials to increase the strength without major change of substrates.

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