Fatigue characteristics of ODS surface treated Zircaloy-4

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1. Introduction

Various accident tolerant fuel (ATF) cladding concepts are considered and have being developed to increase the oxidation resistance and ballooning/ rupture resistance of current Zr-based cladding material under accident conditions [1-4]. One concept is to form an oxidation-resistant layer on Zr cladding surface. The other is to increase high temperature mechanical strength of Zr tube. The oxide dispersion strengthened (ODS) zirconium was proposed to increase the strength of the Zr-based alloy up to high temperatures. The ODS treatment on the Zr surface layer was successfully performed using a laser beam scanning (LBS) process, as shown in Fig. 1 [5].

ODS treatment is a way of improve the high temperature- oxidation resistant and mechanical stress by disperse the hardened particles inside of metal to interrupt the movement of the electric potential. In this study, the accident tolerance improved zirconium alloy by the ODS surface treatment was evaluated for the fatigue characteristics which is one of the significant items of the integrity assessment.

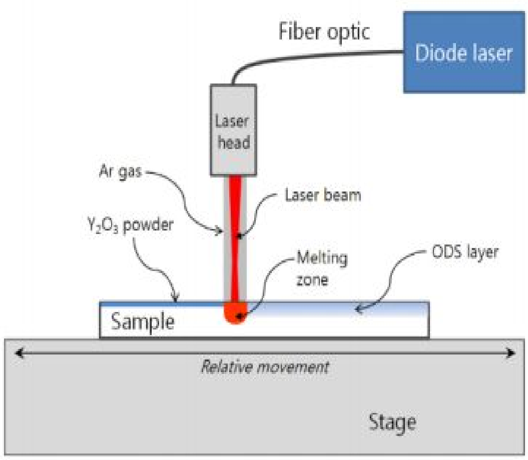

Fig. 1. Schematic illustration of ODS treatment using a laser beam scanning [5].

2. Methods and Results

A Zircaloy-4 (Zr-1.5Sn-0.2Fe-0.1Cr) alloy sheet with 2 mm in thickness was used as a substrate. Oxide powders of Y_2O_3 (99.9%, 1 μm, Alfa Aesar, USA) was purchased, and coated on Zircaloy-4 sheet with the thickness of 10–55 μm. Oxide coating was prepared using a water-based slurry containing a polyvinyl alcohol (3 wt% to oxide powders) as a bonder. The slurry was coated on Zircaloy-4 plate by a doctor blade, and dried in an oven at 80C for 30 min. The coated Zircaloy-4 samples were laser beam scanned by a continuous wave diode laser with a maximum powder of 250 W (PF-1500F, HBL Co, Korea). Beam diameter was 260 μm, and hatching distance was set as 0.2 mm to overlap the laser affected zones. Schematic illustration of LBS was shown in Fig. 1. To prevent oxidation during the LBS, Ar gas was continuously blew onto the melting zone through a laser nozzle.

In the same manner as above, the samples were prepared to form ODS treated surfaces. Then HIP was conducted to bond multilayers of surfaces ODS treated samples. Finally, the HIP sample was hot-rolled and cold-rolled to become plate samples. The mechanical stress of the samples were evaluated via the fatigue test, and the fractured cross sections were observed by SEM to find out the difference between the fatigue behaviors of existing zirconium alloy and ODS surface treated alloy.

In order to compare the fatigue behaviors of the existing zirconium alloy and ODS surface treated alloy, we performed an experiment that putting different stress of 400 MPa and 500 MPa. For fresh Zircaloy-4 the fracture occurred at 43297 and 9407 cycle for stresses of 400 and 500 MPa. Whereas ODS surface treated Zircaloy-4 was fractured at 61346 and 15412 cycle for stresses of 400 and 500 MPa, as shown in Fig. 2. It is concluded that ODS surface treated Zircaloy-4 has 1.5 times of improved fatigue property than fresh Zircaloy-4.

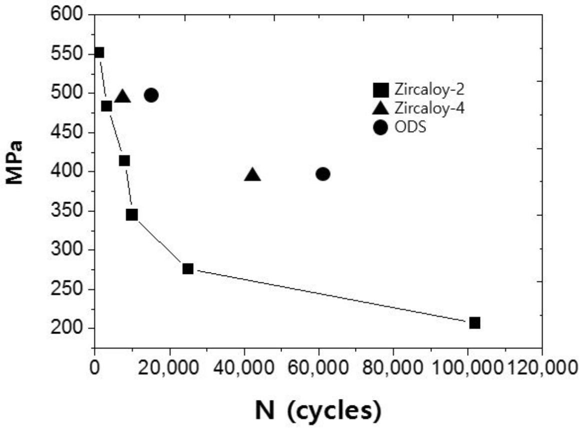

Fig. 2 Fatigue data of Zircaloy-4 and ODS treated Zircaloy-4. For comparison, data of Zircaloy-2 were taken from IZNA-1 [6].

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