Modification of the Strength Anisotropy in an Austenitic ODS Steel

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1. Introduction

Among many candidate alloys for Gen IV reactors, the oxide dispersion strengthened (ODS) alloy is widely considered as a good candidate material for the in-reactor component, like cladding tube. The ODS alloy is well known due to its good high temperature strength, and excellent irradiation resistance [1-3]. For the previous two decades in the nuclear community, the ODS alloy developments have been mostly focused on the ferritic-martensitic (F-M) steel-based ones. On the other hand, the austenitic stainless steels (e.g. 316L or 316LN) have been used as a structural material due to its good high temperature strength and a good compatibility with a media. However, the austenitic stainless steel showed unfavorable characteristics in the dimensional stability under neutron irradiation and cracking behavior with the media. It is thus expected that the austenitic ODS steels restrain the dimension stability under neutron irradiation.

However, the ODS alloys usually reveal the anisotropic characteristic in mechanical strength in the hoop and longitudinal directions, which is attributed to the grain morphology strongly developed parallel to the rolling direction with a high aspect ratio [4-6]. This study focuses on a modification of the strength anisotropy of an austenitic ODS alloy by a recrystallization heat treatment.

2. Methods and Results

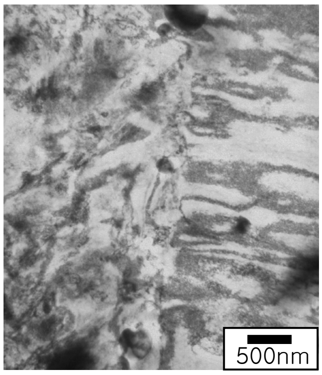
2.1 Experimental procedure

An ODS alloy composed of 99.4 wt% 316L stainless steel, 0.3 wt% Ti and 0.3wt% Y_2O_3 was fabricated by mechanical alloying, canning, degassing and hot isostatic pressing processes. The alloy sample was hot rolled to 4 mm in thickness followed by an annealing at 1150℃ for 1 h. And then, the hot rolled plate was cold rolled to 1 mm in thickness followed by the recrystallization heat treatment at 1200℃ for 1 h.

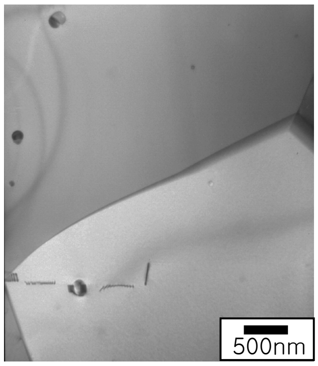
The microstructures of the cold rolled and heat treated specimens were observed by using a TEM (transmission electron microscope). The specimens were prepared in the longitudinal and transverse directions of the alloy sheet, and tensile tests were carried out at room temperature and 700°C.

2.2 Microstructure

Figure 1 shows the microstructures of the ODS alloy sheet based on 316L stainless steels. The cold rolled ODS steel sheet showed a high density of dislocations formed during the cold rolling process (Fig. 1a). After a heat treatment at 1200°C for 1 hour, most of the dislocations had disappeared, and equiaxed and recrystallized grain structure with an average grain size of about 3 μm (Fig. 1b) was observed. Spherical shaped Y_2O_3 particles with a size range less than 100 nm were also observed in the grains.



(a)

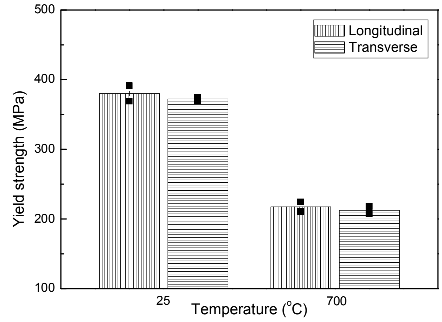


(b)

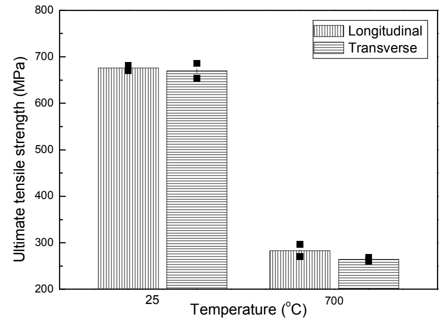
Figure 1. Bright field TEM images of ODS alloy sheets; (a) as cold rolled and (b) heat treated at 1200°C for 1 hour.

2.3 Strength anisotropy

Fig. 2 shows the results of the tensile test for the longitudinal and transverse directions of the recrystallized specimens at room temperature and 700°C. It was apparent that the yield and tensile strengths revealed similar values in the longitudinal and transverse directions of the recrystallized specimens at room temperature as well as 700°C (Fig. 2ab). In addition, the elongation revealed similar values in the longitudinal and transverse directions of the recrystallized specimens. These results mean that a recrystallization heat treatment is much more effective for a modification of a strength anisotropy. It is thus suggested that the strength anisotropy of an ODS alloy sheet could be eliminated by a transformation from elongated to equiaxed grains, which can be obtained by a recrystallization heat treatment.



(a)



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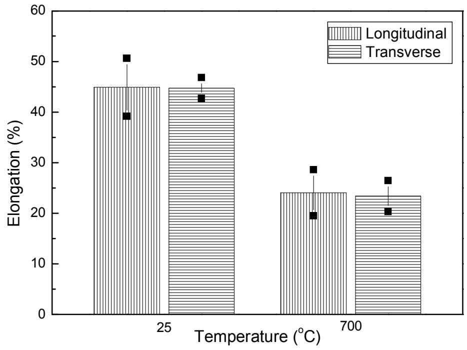

(c)

Figure 2. Tensile test results of the austenitic ODS alloy specimens at room temperature and 700℃; (a) yield strength, (b) ultimate tensile strength and (c) elongation.

3. Conclusion

The effects of a recrystallization heat treatment on the strength anisotropy of a ODS alloy sheet based on 316L stainless steel was evaluated. After a recrystallization heat treatment at 1200℃ for 1 h, most of the dislocations had disappeared, and a strength anisotropy was not found in the longitudinal and transverse directions of the ODS alloy sheet. It is thus suggested that the equiaxed grains which can be obtained by a recrystallization heat treatment would be much more effective for the modification of a strength anisotropy of an ODS alloy sheet.

Acknowledgements

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