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Alloying Effects on High Temperature Tensile Property and SCW Corrosion Behavior of Austenitic ODS Alloy

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1. Introduction

Austenitic stainless steels, e.g. type 304L , 316L, etc., have been used as structural materials for the in-reactor components of fission or fusion reactors. Although these austenitic stainless steels have demonstrated a relatively fair extent of high temperature strengths and compatibility with a coolant, these alloys suffered cracking behavior in water environments and irradiation swelling[1,2]. On the other hand fine and stable oxide particles in the metal matrix are widely known to enhance the irradiation resistance to swelling as well as to the cracking behavior [3,4] Since late 1980's oxide dispersion strengthened (ODS) alloys have been developed to be used as a fuel cladding materials for fast reactors, all these activities focused on ferritic-martensitic (F-M) steel-based ones [1, 2, 5]

In this study a series of austenitic ODS alloys have been prepared and their characteristics, including the high temperature tensile behavior and the corrosion property in a supercritical water condition have been investigated.

2. Experimental

2.1 Sample Preparation

In this study type 316L stainless steel powders of -325 mesh were mechanically alloyed with various portion of Y_2O_3 powders of 20 to 30 nm in diameter, and Ti powders of less than 20 mm in size. Mechanical alloying process was carried out using a planetary ball mill with 15:1 of ball to powder ratio under Ar atmosphere. Mechanically alloyed powders were vacuum sealed in a 304L stainless steel can, and hot isostatically pressed (HIP) at 1150^{o}C under 15,000 psi. After HIP process samples were hot rolled at 1150^{o}C with reduction ratio of 8:1 and then solution annealed at 1150^{o}C for 1 hr. The nominal composition of the specimen is shown in table 1. Specimen 1 is prepared by a mechanical alloying with type 316L stainless steel powders only, without the addition of any other particles or element powder. Specimens 2 and 3 are prepared by mechanical alloying the 316 L powders with two different concentration of yttria powder. And specimens 4 and 5 contain 0.2 wt% of Ti at the previous two different content of yttria.

Table 1. Nominal composition of the ODS alloy specimens

Specimen	Nominal Composition (wt%)
1	MA 316L
2	316L - 0.25 Y_2O_3
3	316L - 0.50 Y_2O_3
4	316L - 0.25 Y_2O_3 - 0.2Ti
5	316L - 0.50 Y_2O_3 - 0.2Ti

2.2 Mechanical and Corrosion Tests

Sub-size tensile specimens were prepared according to ASTM E8 using the hot rolled plate sample, and tensile tests were carried out at 600^{o}C under the atmosphere. Specimens were hold at the test temperature for 1 hr and then tensioned with the initial strain rate of $3*10^{-4}$/sec.

Corrosion tests were carried out in a deaerated supercritical water (SCW) of about 100 ppb of dissolved oxygen (D.O) at 500^{o}C and under 25 MPa. Specimen size was 10 by 10 by 2 mm. The specimen surfaces had been ground with # 600 SiC papers before the immersion tests were carried out. After the corrosion tests of the specimens in a SCW at 500 ^{o}C for 1,000 hrs, the weight changes of the specimens were measured, and the corrosion layers were examined using scanning electron microscope (S.E.M) with energy dispersive spectroscope (E.D.S).

3. Result

3.1 High Temperature tensile test

Figure 1 shows the stress-strain curves of the five ODS alloy specimens at 600^{o}C. Specimen 1, just mechanically alloyed 316 L stainless steel without any addition, showed a favorable behavior in the strength and the elongation. As the content of the strengthening dispersoid, Y_2O_3 increases (specimen 3 vs. 2; specimen 5 versus 4) the tensile strength increased. However the elongation change was reversed when dispersoid was added with 0.5 wt%. Also Ti addition effect appears remarkable. When the equivalent amount of Ti was added with yttria, the strength and the elongation were significantly improved (more than 100 MPa of tensile strength and 15% of elongation in the specimen 4 versus 2).

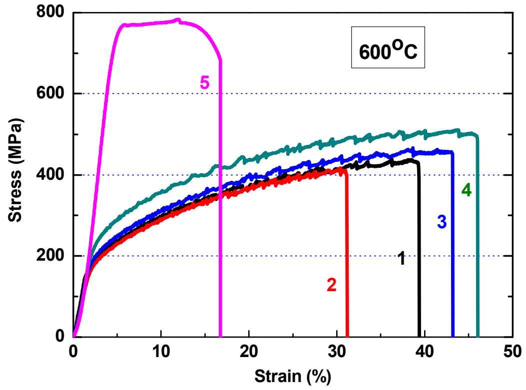

Figure 1. Stress-strain curves of five ODS alloy specimens (test temperature 600℃; strain rate $3*10^{-3}$ sec^{-1}).

However the specimen 5 which contains 0.5 wt% of yttria and 0.5 wt% of Ti showed drastic increase of strength, but very poor elongation (less than 20%). The effect of Ti is attributed to its role to change the dispersoid Y_2O_3 into much finer $Y_2Ti_2O_7$ or Y_2TiO_5 as previously reported [6].

3.2 SCW corrosion test

Figure 2 shows the weight change rate of five ODS alloy specimens after the immersion in a SCW at 500°C under 25 MPa for 1,000 hrs.

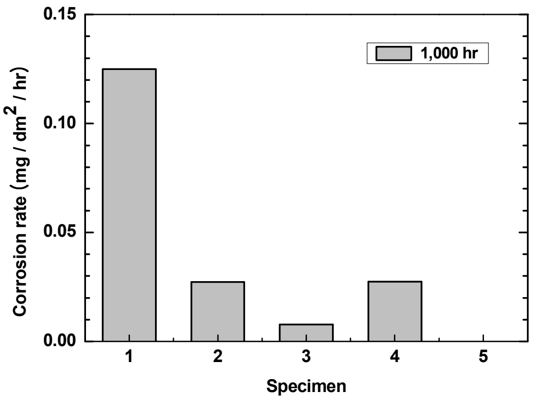

Figure 2. Corrosion rate of five ODS alloy specimens in a deaerated SCW (supercritical water) at 500°C for 1,000 hr

Compared with the specimen 1 which does not contain any additional element or dispersoid, all other ODS alloy specimens showed much better SCW corrosion resistances. As the Y_2O_3 dispersoid content increases the corrosion appears to become dull. As the dispersoid content increases from 0.25 to 0.5 wt% (specimen 3 versus 2; specimen 5 versus 4) the corrosion resistance increased by more than twofold. However, Ti addition, which appeared to significantly affect the mechanical behavior, did not change the corrosion resistance in a SCW. In case of 0.25wt% of Y_2O_3 addition (specimen 2 and 4) corrosion resistance was the same regardless of Ti addition. In case of 0.5 wt% Y_2O_3 (specimen 3 and 5) there seemed a small enhancement of corrosion resistance with Ti addition. However it is not clear whether the difference is significant or not because the measured data are in a very low range.

3. Conclusion

In this study five ODS alloy specimens using type 316 L powders with or without various amount of strengthening dispersoid, Y_2O_3 powders and Ti powders were fabricated by a mechanical alloying and hot isostatic pressing. With hot rolled plate specimens the mechanical properties at 600°C, and SCW corrosion resistance at 500°C for 1,000 hr were investigated.

The effects of the strengthening dispersoid, Y_2O_3 in ODS alloy specimens appeared significant; i.e. as the content of the strengthening dispersoid increases and especially the addition of Ti seemed very effective. The corrosion resistance in a SCW (supercritical water0 at 500°C under 25MPa was significantly improved by addition of the strengthening dispersoids, Y_2O_3, but the addition of Ti seemed negligible.

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