Influence of Normalizing Temperature on the Microstructure and Hardness of 9Cr-1Mo ODS Steel

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1. Introduction

Oxide dispersion strengthened(ODS) steel has superior high-temperature strength and creep properties because fine oxide particles having an excellent stability at high temperatures are uniformly distributed in the matrix. ODS steel has being developed for structure materials of sodium fast cooled reactor(SFR) because of its excellent irradiation resistance and mechanical properties[1]. In addition, it is expected to be applied to the gas turbine blade materials for thermal power plant and the fuel injector materials for automobile[2]. 9Cr-1Mo ODS steel has better high temperature strength and irradiation resistance than common 9Cr-1Mo steel because Y_2O_3 nano-sized particles which interrupt dislocation movement and grain boundary slip are uniformly dispersed in the martensite matrix[3]. The mechanical properties of the ODS steels are mainly determined by their microstructures, and the microstructure is considerably decided by the heat-treatment conditions.

This study focused on the effect of normalizing temperature on microstructure and hardness of 9Cr-1Mo martensitic ODS steel so as to optimize the heat-treatment condition.

2. Experimental Setup

2.1 Experimental procedure

The chemical composition of 9Cr-1Mo ODS martensitic steel used in this study is given in Table I.

Table I: The Chemical Composition of ODS steel(wt.%)

Fe	Cr	Mo	Y_2O_3
Bal.	9	1	0.2

The ODS steel sample was fabricated by mechanical alloying(MA), hot isostatic pressing(HIP) and hot rolling(HR). Fe, Cr, Mo and yttria powders were continuously collided in a high energy horizontal ball-mill apparatus, Simoloyer CM-20, under ultra-high purity argon atmosphere. The ball to powder weight ratio was 10:1 in this MA process. The HIP was performed at 1150℃ for 4 hours. After the HIP process, the HR process accomplished with a cross-section reduction ratio of 23%(Thickness: 15T) at 1150℃ for 2 hours. The Normalizing was performed at 950, 1075 and 1200℃ for an hour, respectively. After the normalizing, microstructures of 9Cr-1Mo ODS steel was observed using the transmission electron microscope (JEOL JEM-2100). The TEM samples of the ODS steel was prepared by mechanical grinding and electro-polishing. Mechanical property of ODS steel was investigated by hardness measurement.

3. Results and Discussion

3.1 Microstructure

Fig. 1 shows the TEM images of 9Cr-1Mo ODS steels after normalizing at 950, 1070 and 1200℃.

Typical martensitic structures consisting of prior austenitic grain, packet grain and lath were observed in all the samples. However, the lath width was different according to the normalizing temperature. The lath width were increased in proportional to the normalizing temperature. The value of lath width is shown in Fig. 2. After Normalizing at 950, 1070 and 1200℃, the lath widths were measured to be about 0.08, 0.15 and 0.32 ㎛, respectively. It is considered that the normalizing temperature affects the microstructure of 9Cr-1Mo ODS steel.

3.2 Hardness

Vickers microhardness of 9Cr-1Mo ODS steel is shown in Fig. 3. The hardness of ODS steel was continuously decreased with the increase of normalizing temperature. The hardness of specimen normalized at 950℃ was measured to be about 480 Hv and it decreased to 467 and 456 Hv for the specimens normalized at 1075 and 1200℃, respectively. It may be explained by Hall-Patch relationship. According to Hall-patch relationship, the yield strength decreases as the grain size increases. Therefore, the increase of grain size decreases the hardness and grain size is closely related with lath width. It is explained that lath width also have a significant effect on mechanical properties of 9Cr-1Mo ODS steel.

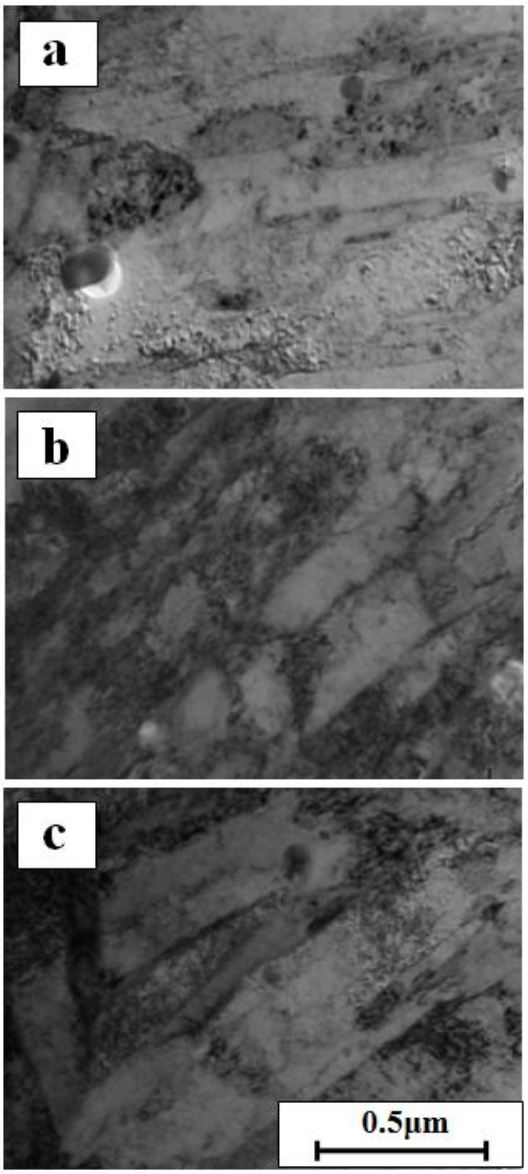

Fig. 1. TEM micrographs of 9Cr-1Mo ODS steel with different normalizing temperatures of (a) 950℃, (b) 1070℃ and (c) 1200℃

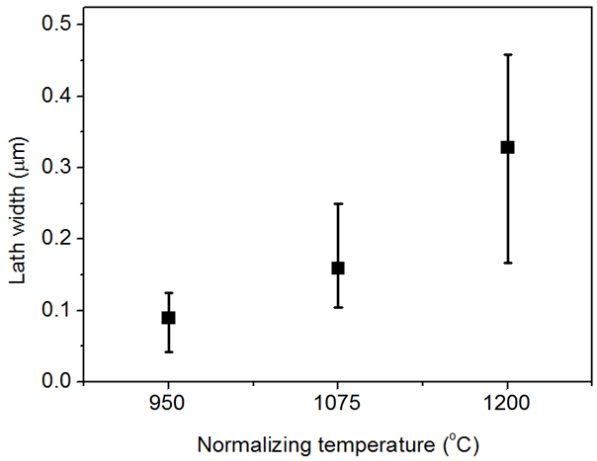

Fig. 2. Lath width of 9Cr-1Mo ODS steel with different normalizing temperatures

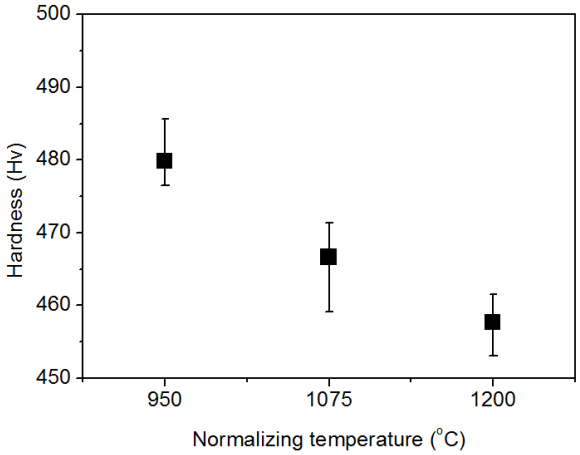

Fig. 3. Change of hardness with different normalizing temperature.

4. Conclusions

In this study, the effect of normalizing temperature on mechanical property and microstructures of 9Cr-1Mo martensitic ODS steel was investigated. It was shown that the microhardness was steadily increased with increasing of the normalizing temperature. According to TEM observation, mechanical property of 9Cr-1Mo ODS steel was significantly affected by lath width. These observations, could be useful to understand the relationship between normalizing temperature and microstructure.

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