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Effect of heat treatment condition on microstructure and mechanical properties of 2.5% Ni cast steels

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The effect of the cooling rate (WQ:Water-Quenching, AC: Air-Cooling and FC: Furnace-Cooling) after austenization on the microstructure and mechanical properties of 2.5%Ni cast steels was investigated. The WQ sample exhibited a fully bainite microstructure, while the AC and the FC samples exhibited a ferrite-bainite microstructure and ferrite-pearlite microstructure, respectively. The mechanical properties were significantly improved with increasing cooling rate after austenization. SEM fractography and EBSD measurement results showed that this improvement in mechanical properties was caused by grain refinement of the bainite microstructure.

Keywords: *austenization; cooling rate; bainite; grain refining; fracture appearance transition temperature (FATT);*

1. Introduction

JSW supplies large cast-steel products with heavy-sectioned parts for structural elements and power generation plants. Since the giant earthquakes in Kobe and the east coast of Japan, the expectations for higher strength and higher toughness of these products have increased. For example, ASTM A148 Grade 210-180 (JIS G5102, SCW620) is a high-strength cast steel with high toughness and high weldability. Although the microstructure and heat treatment condition must be optimized to ensure the mechanical properties of heavy sectioned casting parts made from ASTM A148 Grade 210-180, they have not previously been reported on. In the present study, the effect of the cooling rate after austenization on the microstructure and mechanical properties of 2.5%Ni cast steel with a similar composition to that of ASTM A 148 Grade 210-180 were therefore investigated.

2. Experimental procedures

Table 1 shows the chemical composition of the alloy ingot. The alloy ingot was melted by induction melting and cast in a sand mold in a vacuum. After stripping the mold, the following heat treatment was carried out.

・Annealing : 1323 K×18 hours⇒FC
・Austenization : 1163 K×22 hours
・Tempering : 888 K×18 hours ⇒FC
・Stress Relief annealing : 878 K×24 hours⇒FC

Three patterns (WQ, AC and FC) of cooling rate after austenization were tested. After the heat treatment, microstructural observation, a tensile test at room temperature, and the Charpy impact test were carried out. The microstructure was observed using an optical microscope and a field-emission scanning electron microscope (FE-SEM) with an electron back scatter diffraction (EBSD) analyzer.

Table 1 Chemical composition of alloy ingot (mass%)

C	Si	Mn	Ni	Cr	Mo	V	N
0.18	0.28	0.86	2.45	0.48	0.18	0.04	0.009

3. Results and Discussion

3.1. Microstructure

Figure 1 shows the optical micrographs of the samples after heat treatment. The WQ sample exhibits a fully bainite microstructure, while the AC and FC samples exhibit the ferrite-bainite microstructure and the ferrite-pearlite microstructure, respectively.

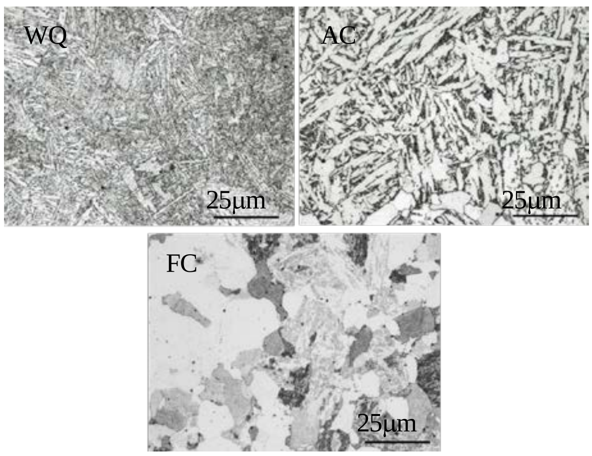


Fig.1 Optical micrographs of the samples after heat treatment.

3.2. Mechanical properties

Table 2 shows the tensile properties of the samples. The WQ sample showed the highest strength in all samples, and the strength decreased with decreasing cooling rate after austenization.

Figure 2 shows the temperature dependence of percent ductile fracture. The fracture appearance transition temperature (FATT) of the WQ sample shifted to a lower temperature than the AC and FC samples.

Table 2 Mechanical properties of the samples

	Tensile test result				Charpy test
	0.2%Y.S. /MPa	T.S. /MPa	EL/%	RA/%	FATT/K
WQ	613	718	22.9	63.5	213
AC	540	662	22.9	55.9	285
FC	436	583	30.3	65.3	287

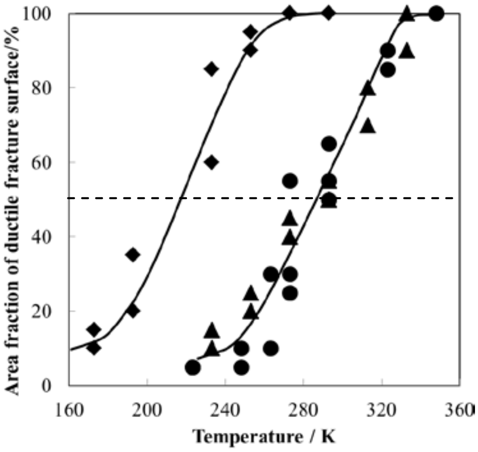


Fig. 2 Temperature dependence of percent ductile fracture.

3.3. SEM fractography and EBSD result

Figure 3 shows the SEM fractography of the samples. Although all samples exhibited a typical cleavage-like fracture surface, the size of fracture unit was significantly different among the samples. The fracture unit of the WQ sample was the smallest of all the samples.

Figure 4 shows the EBSD microstructure (inverse pole figure map) of the WQ and FC samples, where the black line shows the high angle grain boundary with misorientation larger than 15 degrees. It was found that the grain size of the bainite microstructure in the WQ sample was significantly smaller than that of the AC sample. It has been reported by Izumiya et al. [1] that the fracture unit in the Charpy impact test was almost the same as the average size of grain covered by the high angle boundary. The present result showed a tendency similar to their result [1]. Kadoya et al. reported that the bainite microstructure becomes smaller with decreasing Bs temperature [2]. In the present study, it was also confirmed that the transformation behavior and the distribution of precipitates change with increasing cooling rate after austenization. Therefore, it was concluded that refining the bainite microstructure by increasing the cooling rate after austenization is an effective means of improving mechanical properties of 2.5%Ni cast steels.

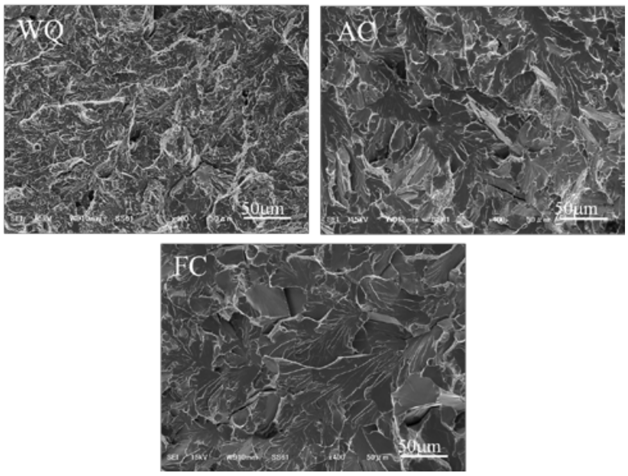
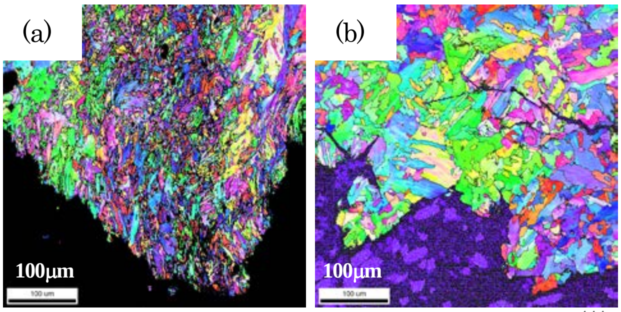


Fig. 3 Typical SEM fractgraphy of the samples



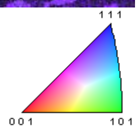


Fig. 4 EBSD microstructure near fracture surface of (a)WQ and (b) AC samples.

4. Conclusion

・The WQ sample exhibits the bainite microstructure. The AC sample exhibits the ferrite-bainite microstructure, and the FC sample exhibits the ferrite-pearlite microstructure.

・The mechanical properties of 2.5%Ni cast steel were improved by the refinement of the bainite microstructure with increased cooling rate after austenization.

References

[1] Y. Izumiyama et al. : Tetsu to Hagane, 100 (2014), 704-712.

[2] Y. Kadoya et al. : Tetsu to Hagane, 79 (1993), 980-987.