Evaluation of Modified 9Cr-2W steel on Microstructure and Mechanical Properties by heat treatment condition

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1. Introduction

As one of the future nuclear energy systems, a sodium-cooled fast reactor (SFR) uses liquid sodium as a coolant and causes nuclear fission by means of fast neutron. The cladding tubes of metallic fuels are designed to irradiate to a very high dose of up to 250dpa at a peak cladding temperature of 650℃. The fission gases from the metallic fuels are expected to become the source of an internal stress on the cladding tubes. Ferritic/martensitic (FM) steels are being primarily considered as materials for the cladding tubes due to their excellent irradiation resistance to a void swelling but are known to reveal an abrupt loss of their creep and tensile strengths at temperatures above 600℃. Hence, high temperature mechanical properties should be considerably improved for an application of these FM steels to the materials of SFR cladding tubes [1].

In order to increase the creep resistance and high temperature strength, many researches have been investigated on the manufacturing process and alloy design.

Boron added steels change its mechanical properties depending on cooling rate, heat treatment temperature, addition elements such as N, Al, Ti and addition amount [2].

In this paper, we are going to evaluate the workability of cold drawing for two kinds of modified 9Cr-2W steel with different contents of boron and nitrogen depending on normalizing and tempering temperature and time through ring compression test at room temperature, the effect of heat treatment on workability was investigated.

2. Methods and Results

2.1 Experiment material and heat treatment

The chemical composition of the different kinds of modified 9Cr-2W steel, named alloy B and alloy N, are shown in Table 1.

Table 1 Chemical compositions of modified 9Cr-2W steels (wt %).

	C	Cr	W	N	B	Fe
Alloy B	0.07	8.89	1.93	0.02	0.013	Bal.
Alloy N	0.063	9.09	2.019	0.0767	0.004	Bal.

As Drawn cladding tubes were normalized at 1038-1180℃ for 6 and 30minutes, followed by air cooling to room temperature. Normalized conditions was tempered at 760℃ for 40minutes, followed by air cooling to room temperature and only tempered specimen (760, 40minutes) followed by air cooling to room temperature. The compression test specimens were compressed at rate of 1mm/min for cladding with 19.05mm outer diameter and 1.24mm thickness and 10mm length.

2.2 Microstructure observation

Specimens for microstructure observations were prepared by grinding and polishing (up to 0.25 ㎛ powder size), followed by etching using an etchant of 95ml water + 3ml nitric acid + 2ml fluoric acid. Fig. 1 and 2 shows the alloy B and alloy N of optical microscope with heat treatment conditions.

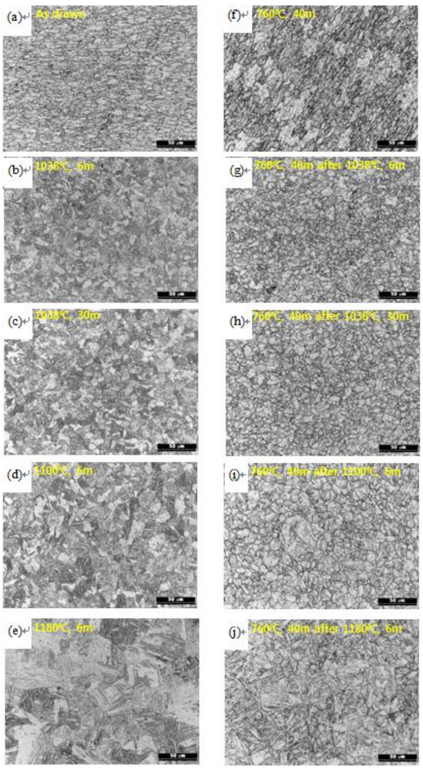


Fig. 1 optical micrographs of alloy B with heat treatment condition: (a) As drawn (b-e) normalized at 1038-1180℃ for

6 and 1038℃ for 30min (f) tempered at 760℃ for 40min (g-j) tempered at 760℃ for 40min after normalized.

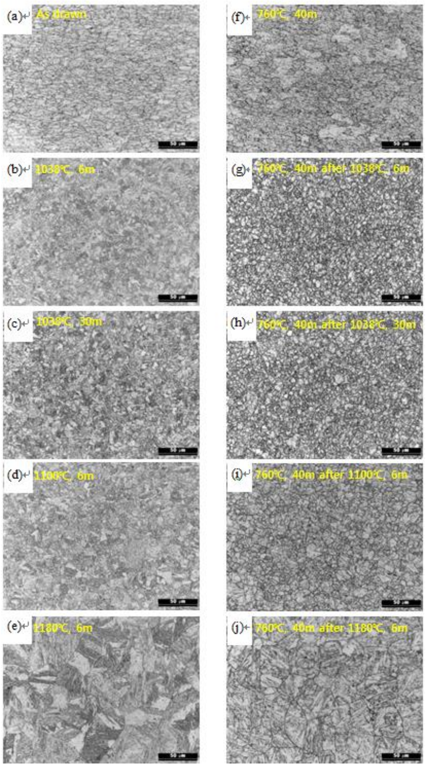


Fig. 2 optical micrographs of alloy N with heat treatment condition: (a) As drawn (b-e) normalized at 1038-1180℃ for 6 and 1038℃ for 30min (f) tempered at 760℃ for 40min (g-j) tempered at 760℃ for 40min after normalized.

Prior austenite grain boundary size was measured by line intercept method. Line intercept method is used to quantify the grain size for a given material by drawing a set of randomly positioned line segment on the micrographs, the counting number of times each line segment intersects grain boundary, and finding the ratio of intercepts to line length.

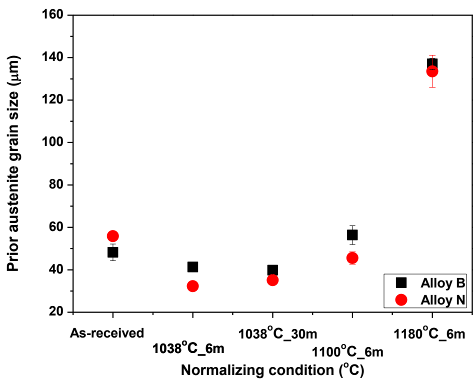


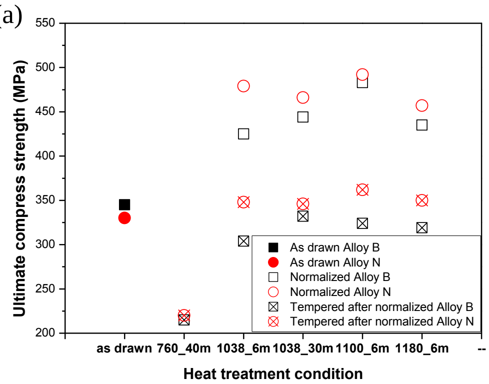
Fig. 3 variation of prior austenite grain size in alloy B and alloy N with normalizing conditions.

As drawn alloy B and alloy N, which are the initial conditions, have a prior austenite grain size of 48 and 55㎛ respectively. When the drawn specimen was normalized at 1038℃, the austenite transformation resulted in recrystallization of deformed microstructure and the increase of nucleation site, resulting in a smaller grain size. The grain size increases because the growth rate of the grain is faster than the rate at which the nucleation site occurs at the normalizing temperature above 1100°C. In particular, the prior austenite grain size at 1180°C increased more than twice the size of the prior austenite grain at 1038°C.

2.3 Experiment material and heat treatment

Fig. 3 shows the results of strength, through ring compression test at room temperature based on heat treatment conditions. Since the prior austenite grain size of alloy N is larger than alloy B, maximum compressive stress of alloy N has a small value by the hall-petch equation. The stress of alloy N has high value than alloy B after normalizing condition. Both alloys are austenitized by normalizing heat treatment and prior austenite grain size is less than that of as drawn before 1100°C. The prior austenite grain size is increased but higher than the stress of as drawn after 1100°C. During the normalizing heat treatment, carbide is solubilized in

(a)



(b)

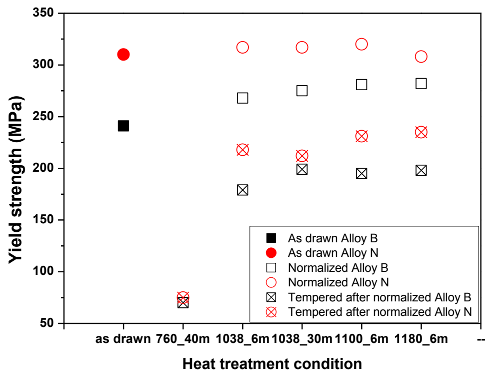


Fig. 3 Result of Alloy B and Alloy N of ring compression test with heat treatment (a) ultimate compressive strength (b) yield compressive strength

the matrix and has a low fraction of precipitate which increases the stress by carbon in the matrix. When as drawn conditions were tempered at 760℃ for 40min, stress decrease because the dislocation density decreased and solute atom in the matrix precipitated to precipitate which has a high fraction [3].

3. Conclusions

In this paper, we are going to evaluate mechanical properties of cold drawing for two kinds of modified 9Cr-2W steel with different contents of boron and nitrogen depending on normalizing and tempering temperature and time through ring compression test at room temperature, the effect of heat treatment on mechanical properties was investigated.

The normalizing heat treatment can change the prior austenite grain size by austenitization, and the prior austenite grain size increase as the normalizing temperature increase.

Alloy B and alloy N show other aspects after normalizing heat treatment.

REFERENCES

[1] T.K. Kim, S.H. Kim, Study on the cold working process for FM steel cladding tubes, J. Nucl. Mater. 411 (2011) 208–212.

[2] J. Lim, J. Kim, B. Park, J. Lee, J. Choi, Effects of Heat Treatment on the Micro-structures and the Mechanical, Kor. J. Mater. Res. 21 (2011) 303–308.

[3] D.R. Barbadikar, G.S. Deshmukh, L. Maddi, K. Laha, P. Parameswaran, a. R. Ballal, D.R. Peshwe, R.K. Paretkar, M. Nandagopal, M.D. Mathew, Effect of normalizing and tempering temperatures on microstructure and mechanical properties of P92 steel, Int. J. Press. Vessel. Pip. 132–133 (2015) 97–105.