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The Effect of High Temperature Liquid Sodium on Mechanical Properties and Microstructure of Ferritic-Martensitic Steel

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1. Introduction

A study was carried out to investigate the effect of liquid sodium on the microstructural and mechanical property of ferritic-martensitic steel used for cladding material of sodium-cooled fast reactor (SFR).

This study deals with the corrosion processes such as metal loss and selective leaching of metals and alloys that influence the mechanical behavior. Study was carried out to assess the microstructural and mechanical properties of ferritic-martensitic steel under a flow sodium environment. ASTM a192 Gr.92 steel was exposed to liquid sodium at 650 ℃ for 1583 h and 3095 h, and evaluations of the microstructure as well as the mechanical properties of the ring hoop tensile tests were conducted.

The objective of this study is to evaluate properties such as microstructure and mechanical property of the ferritic-martensitic steel which exposed to high temperature sodium environment. Ferritic-martensitic steel was exposed to the liquid sodium for a certain time and the ring hoop tensile test was then evaluated.

2. Experiments

A compatibility test facility was manufactured [1]. The facility was made as dynamic type to flow liquid sodium as natural circulation by temperature gradient. Detailed parameters regarding the facility have been published in [1]. A compatibility test of the ferritic-martensitic cladding tube was carried out. The test cladding tube was an ASTM A192 Gr.92 cladding tube, which has a 7 mm outer diameter and 0.6 mm thickness. The test ran in 650 ℃ liquid sodium for 3095 h at maximum, where the first cladding tube was exposed to sodium for 1583 h and was then interrupted to insert another cladding tube to continue for an additional 1512 h. In addition to the sodium compatibility test, the cladding specimen was aged for a comparison. The cladding tubes were aged in argon environment at 650 ℃ for 1601 h and 2973 h.

Table I. Chemical composition of the test material (in wt.%)

	C	Si	Mn	Cr	Ni	Mo	W	V
HT9	0.19	0.14	0.49	12.05	0.48	1.00	0.49	0.30

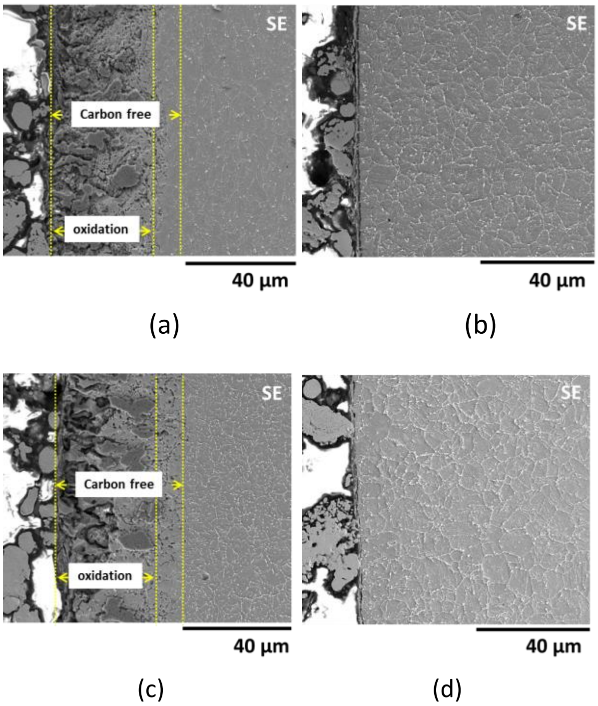

Fig. 1 SEM images of cross section of ring specimens exposed to (a) 650℃ sodium for 1583 h, (b) 650℃ Ar gas for 1601 h, (c) 650℃ sodium for 3095 h and (d) 650℃ Ar gas for 2973 h, respectively.

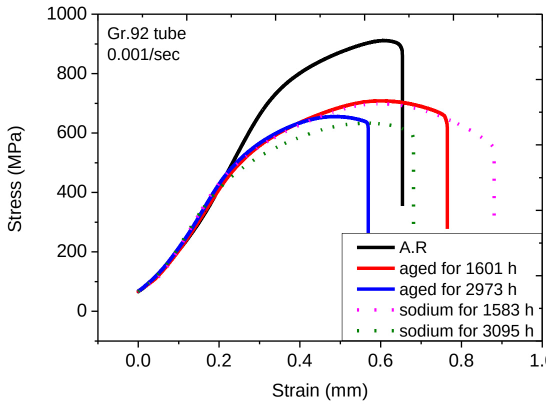

Fig. 2 Results of ring tensile tests at room temperature.

3. RESULTS

The cross-section image of ring specimens which exposed to sodium and aged at argon gas at 650 ℃ is shown in Fig. 1. Specimens exposed to sodium show surface oxidation with carbon free region, however argon aged specimens does not show any microstructural changes.

Fig. 2 shows the stress-stain curve of the ring specimens cut from the cladding tube from ring tensile tests at room temperature. All Ar-aged specimens and Na-exposed specimens show that the strength decreased as the aging process. Na-exposed specimen showed larger strain than Ar-aged specimen which have similar aging time compared with Na-exposed specimens.

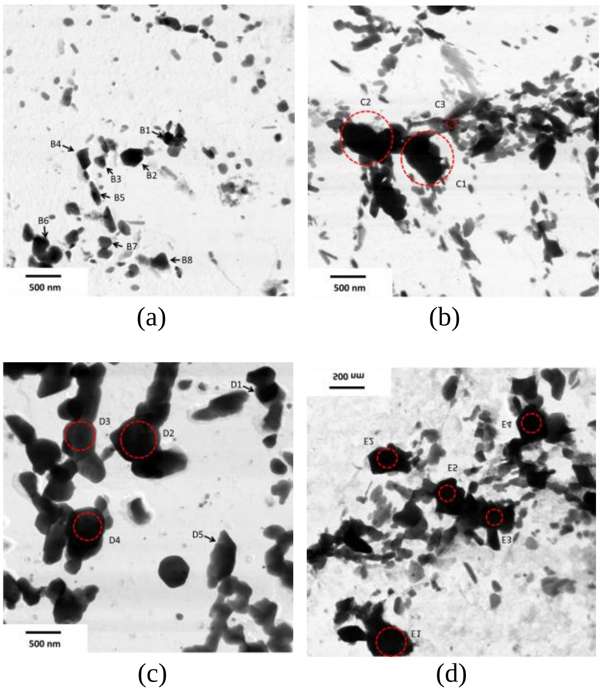

Fig. 3 7 TEM images of ring specimens exposed to (a) 650℃ sodium for 1583 h, (b) 650℃ Ar gas for 1601 h, (c) 650℃ sodium for 3095 h and (d) 650℃ Ar gas for 2973 h, respectively.

Fig. 3 shows TEM image each specimen to investigate the relationship between the mechanical property and the precipitates. The TEM-EDS analysis is shown in Table II. Specimens exposed to sodium showed precipitates with about 20Fe-60Cr-15W-3Mo and specimens aged at argon environment showed precipitates with about 30Fe-10Cr-50W-9Mo, respectively. In Argon environment, tungsten and molybdenum is agglomerated in the precipitates in this study.

The effect of precipitate on the mechanical properties is analyzed and now in process.

Table II. Representative compositions of the precipitates in the Gr. 92 specimen after exposed to sodium and aged at argon at 650℃ (in wt.%)

Precipitate	Fe	Cr	W	V	Mo	Mn
B1	19.29	58.97	16.18	0.84	3.46	0.95
B2	19.34	59.35	15.04	1.86	3.02	-
B3	17.38	57.03	16.35	4.34	2.57	-
B4	20.28	58.33	16.84	0.56	2.74	0.92
B5	19.58	61.01	13.94	0.62	3.36	-
B6	23.79	59.02	14.06	0.51	1.9	-
B7	20.89	57.23	14.32	2.78	2.64	-
B8	22.32	57.65	15.39	0.65	2.83	-
C1	29.26	6.85	53.37	-	8.88	0.47
C2	28.48	11.62	48.85	0.8	8.73	0.48
C3	16.53	48.96	12.17	14.69	1.92	-
D1	20.13	57.85	17.09	-	3.22	0.93
D2	18.79	59.65	16.69	0.39	3.02	1.08
D3	21.66	57.90	15.36	0.59	3.39	1.10
D4	20.24	58.41	15.99	1.51	2.64	0.73
D5	19.62	59.64	16.40	0.37	2.56	1.21
E1	30.12	5.51	53.86	-	9.69	0.55
E2	28.32	8.78	53.19	-	8.37	0.57
E3	25.89	23.51	40.09	1.59	7.39	0.86
E4	27.28	10.78	51.09	-	10.01	0.61
E5	28.26	5.55	57.40	-	8.70	-

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REFERENCES

[1] J.H. Kim, J.M. Kim, J.E. Cha, S.H. Kim, C.B. Lee, Kor. J. Met. Mater., Vol.48, p.410, 2010