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Corrosion Evaluation on Candidate Materials for SCWR

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1. INTRODUCTION

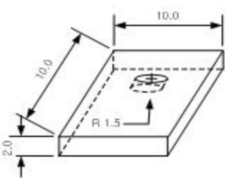
As one of the Generation IV nuclear reactors, Supercritical Water Cooled Reactor (SCWR) is considered as a candidate reactor due to its high thermal efficiency [1,2]. At above the supercritical condition of 374 ^{o}C, 22.1 MPa, the supercritical water does not change the phase through the reactor core outlet. Then the high temperature coolant is effectively used at on over 40 % thermal efficiency. A critical step for this good feature to be attainable is to choose the proper structural materials. For an application of the structural materials to a core internal, fuel cladding, the materials should be evaluated in terms of their high temperature tensile strength, creep strength, corrosion and stress corrosion cracking susceptibility, radiation resistance, weldability, etc. Among the qualification items, corrosion of F/M steels and high Ni alloys have been performed in supercritical water environment in this work.

This work aims at evaluating the corrosion behavior of F/M steels, high Ni alloys and an ODS alloy as the candidate materials for the SCWR.

2. EXPERIMENTAL

Three groups of materials such as F/M steels (T 91-I, T 91-II, T 92, T 122), high Ni alloys (Alloy 625, 690, Incoloy 800H) and an ODS alloy (MA 956, a commercial 20% Cr ODS alloy) were evaluated in a supercritical water environment. Table 1 shows the chemical composition of the test materials. Deionized water (~0.05 uS/cm) of below 10 ppb of dissolved oxygen and about a pH of 6.5 was used as a test solution. For a general corrosion rate measurement, coupons as shown in Table 2 were immersed in supercritical water environment. The cross sections of the corrosion coupons were analyzed with the SEM and Energy Dispersive X-ray Spectroscopy (EDS).

Table 2. Test materials and dimension of the coupon for the corrosion rate measurement

Alloy Class	Alloy	Shape
Ferritic-Martensitic Steels	T91- I, T91-II, T92, T122	
High Ni alloys (Superalloys)	Inconel625, Inconel690, Incoloy800H	
ODS alloy	MA956	

The corrosion test loop of a supercritical water environment designed for a 650 ^{o}C, 30 MPa operation. It consists of a pressure vessel of a 3.3 liter volume capacity made of Hastelloy C-276, a make up water control loop, a SSRT control unit, data acquisition module etc.

Table 1. Chemical compositions (wt%) of the tested alloys

Alloy	Fe	C	Si	Mn	P	S	Cr	Ni	Mo	–
	-	V	Nb	W	Ti	Al	N	O	Cu	others
T91- I	Bal	0.084	0.438	0.363	0.019	0.0008	**8.876**	0.102	0.928	–
	-	0.197	0.081			0.016	0.0351		0.081	
T91- II	Bal	0.1	0.28	0.45	0.01	0.003	**8.37**	0.21	0.9	–
	-	0.22	0.08			0.02	0.048		0.17	
T92	Bal	0.07		0.45			9		0.5	–
	-	0.2	0.05	1.8			0.06			
T122	Bal	0.1	0.27	0.58	0.017	0.002	**12.12**	0.35	0.35	–
	-	0.19	0.06	1.84		0.014	0.07		0.83	0.003B
MA956	Bal	0.02	0.04	0.1	0.01	0.008	19.4	0.05		–
	-				**0.32**	**4.8**	**0.022**	**0.23**	**0.02**	0.52 Y2O3
Inconel 625	4.52	0.02	0.17	0.1	0.01	<0.001	21.8	**60.04**	9.02	–
	-		3.62		0.27	0.2			0.08	0.20 Co
Inconel 690	10.7	0.002	0.39	0.28	0.01	0.002	29.8	**58.3**	0.01	–
	-				0.34	0.02	0.032		0.0l0	0.001 Ta
Incoloy 800H	**47.6**	0.07	0.4	0.74	0.01	<0.001	19.4	31.1		–
	–				0.32	0.23			0.1	0.05 Co

3. RESULTS and DISCUSSION

3.1Ccorrosion Rate Measurement

The F/M steels showed a higher corrosion rate than the Ni alloys at 500 ^{o}C as shown in Fig. 2.

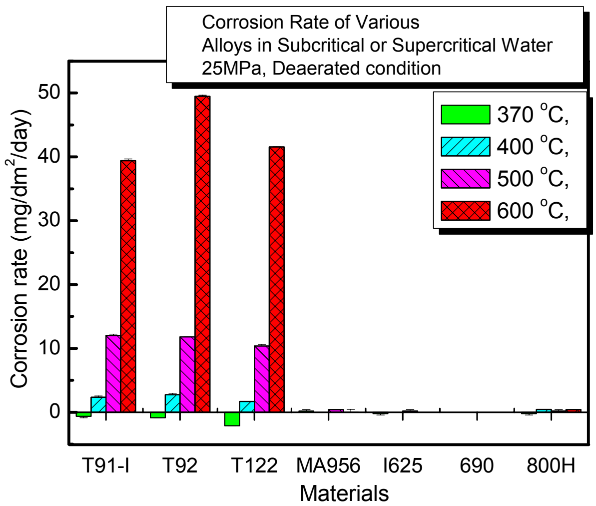


Fig. 2 Material dependence of corrosion rate of various alloys in deaerated subcritiacl or supercritical water

The big difference in the corrosion rates between the two groups (F/M steels and Ni alloys) seems to be from a dissolution behavior of the main alloying elements which are

Fe for the F/M steels, and Ni for the Ni alloys. The corrosion rates of the F/M steels at 550 °C were about three times larger than those at 500 °C. At the subcritical condition at 370 °C, the F/M steels showed a weight loss. Alloy MA 956, Incoloy 800H and the Ni base alloys showed a little weight change before and after the immersion test for the subcritical and supercritical water.

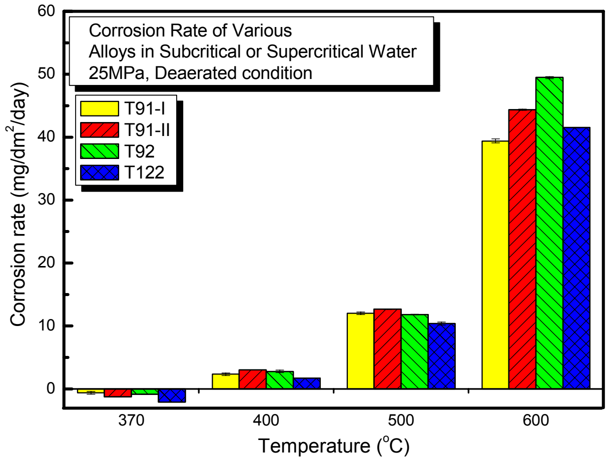


Fig. 3 Effect of test temperature on corrosion rate of the candidate alloys for SCWR.

A main factor for the general corrosion rate was the test temperature as shown in Fig. 3. The high Cr content of the Alloy 122 alloy seems to show a lower corrosion rate than that of the alloy T 91, but it is less effective than the test temperature.

There was little difference in the corrosion layer thickness or the corrosion rates of the T 92 and T 122 samples, which had different Cr contents (9 % and 12 % respectively)

3.2 Corrosion product analysis

Oxide of the alloy T 91 was composed mainly of three layers as shown in Fig. 4. There was a thin layer L3 between layer 2 and layer 4, which was enriched in Mo and Ni. A distinct element variation was measured in layer 2 and layer 3; depletion of Fe with an enrichment of Cr was shown in layer 2, depletion of Cr with an enrichment of Mo was detected in layer 4. Layer 3 enriched in Mo seems to retard an outward Cr diffusion. A source of the Mo in layer 3 seems to be the alloying element of T 91 and the test vessel material; Hastelloy C 276. An ion exchanger to purify the test solution was not installed for this corrosion test, so Mo from the test vessel is considered to be dissolved and deposited on to the corrosion product. Alloy T 92 and alloy T 122 showed a similar elemental profile as T 91.

On the surfaces of the alloy MA 956, alloy 625, alloy 690, and Incoloy 800H, thin oxides were formed. Little oxide was formed on the alloy 625 surface, so the main alloying elements did not change at the surface. Another research group has reported a similar result for the corrosion of alloy 625[3].

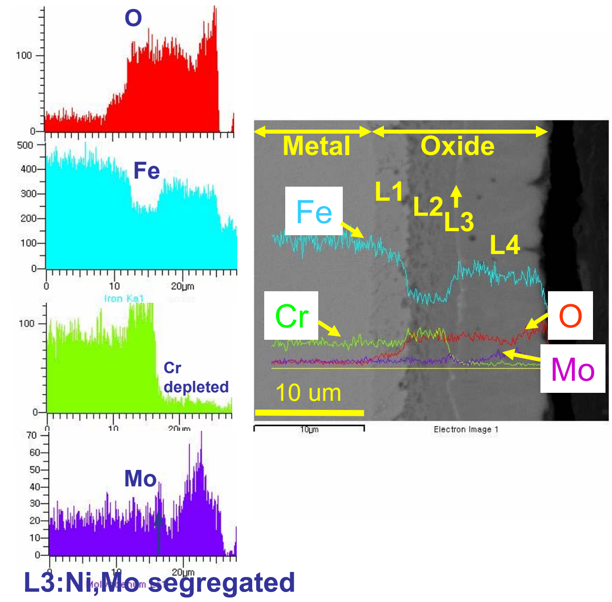


Fig. 4 Feature of the oxide of T 91 tested in SCW at 550 °C in 25.5 MPa, DO<10ppb.

4. CONCLUSIONS

-The F/M steels showed a high corrosion rate whereas the Ni base alloys showed a little corrosion at 500 °C and 550 °C.
-Corrosion rate of the 550 °C was as much as three times larger than that of the 500 °C for the F/M steels.
- A thin layer composed of Mo and Ni seems to retard the Cr diffusion into the out layer of the corrosion product of T 92 and T 122.

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