

Accelerated corrosion of reduced activation ferritic martensitic steel in non-isothermal Pb-17Li system

非等温鉛リチウム場における低放射化フェライト鋼の腐食の加速に関する研究

Masatoshi Kondo ¹⁾, Masaomi Ishii¹⁾, Takeo Muroga²⁾
 近藤正聡¹⁾, 石井政臣¹⁾, 室賀健夫²⁾,

1) Department of Nuclear Engineering, School of Engineering, Tokai University,
 4-1-1 Kitakaname, Hiratsuka-shi, Kanagawa 259-1292, Japan

2) National Institute for Fusion Science, Toki, Gifu 502-5292, Japan

Corresponding author: Masatoshi KONDO, kondo.masatoshi@tokai-u.jp

1. Background

The compatibility of the reduced activation ferritic steel, JLF-1(Fe-9Cr-2W-0.1C), with liquid lead lithium alloy (Pb-17Li) is one of the critical issues for the development of Pb-17Li type blanket systems. The compatibility depends on the purity of Pb-17Li, the flowing condition, the temperature and the temperature gradient in the blanket system. The previous studies made it clear that the corrosion of the steels in Pb-17Li was caused by the dissolution of metal elements such as Fe and Cr from the steel surface into the melt [1]. The corrosion is more intensive at higher temperature, since the solubility of the metal elements in the melt is larger at higher temperature. The corrosion must be accelerated in non-isothermal conditions by the mass transfer of metal elements. The previous studies indicated that the possibility of erosion-corrosion occurrence at the flowing condition. However, the information on these effects on the corrosion is still limited. The precipitation behavior of the dissolved element in a low temperature region of the non-isothermal system is not made clear so far. In the present work, the mixing tank type corrosion test apparatus having a small temperature gradient was developed. The corrosion and the mass transfer behavior in the non-isothermal condition were investigated.

2. Experimental conditions

A series of corrosion tests was performed by a static tank and mixing tanks with and without temperature gradient. The corrosion test conditions were summarized in Table 1. The detail of the isothermal type mixing test tank and the conditions of the tests (A, B and D) were reported in the previous literature [1]. Figure 1 shows the non-isothermal type test apparatus used in the test (E). Four specimens were fixed to the test vessel and exposed to flowing Pb-17Li, which was induced by the rotating impeller. The width of the impeller was 35mm. The temperature gradient was made by local heating and cooling in the mixing tank. A heater was installed on one side of the test vessel. Another side of the vessel was cooled by a flowing air. A wire mesh plate made of Fe-12Cr was inserted into the cooling region of the vessel to trap the dissolved metal elements by the corrosion. The temperature difference in this system was estimated as 11K. The solubility of metal elements in liquid Pb and Pb alloys was summarized in Fig. 2. The

temperature dependence of the solubility was relatively large. Then, the temperature difference of app. 10K can have sufficient effect as the temperature gradient, and the difference of the concentration in the system accelerates the corrosion.

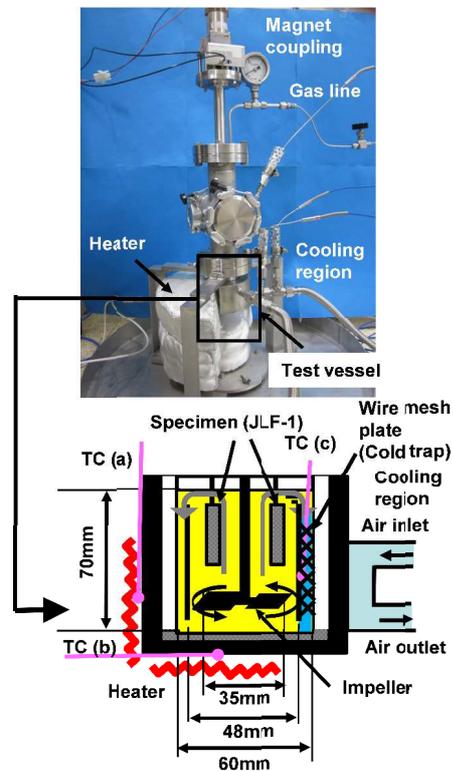


Fig. 1 Non-isothermal type mixing test tank

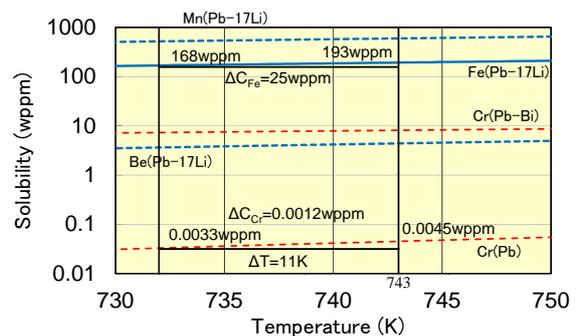


Fig.2 Solubility of metal elements in Pb and Pb alloys

Table 1 Experimental conditions

Test ID		Temp. [K]	Rotational speed of impeller [rpm]	Inventory [cc]	Specimen number	Vessel	Time [hour]
(A)	Static [1]	873	-	3	JLF-1 x 1	JLF-1	500,
(B)	Static [1]	873	-	3	JLF-1 x 1	JLF-1	750
(C)	Flow (Isothermal)	773	50	75	JLF-1 x 4	Mo	253
(D)	Flow [1] (Isothermal)	873	100	65	JLF-1 x 4	Fe-12Cr	300
(E)	Flow (Non-isothermal)	743 732	50	150	JLF-1 x 4	SUS316	502

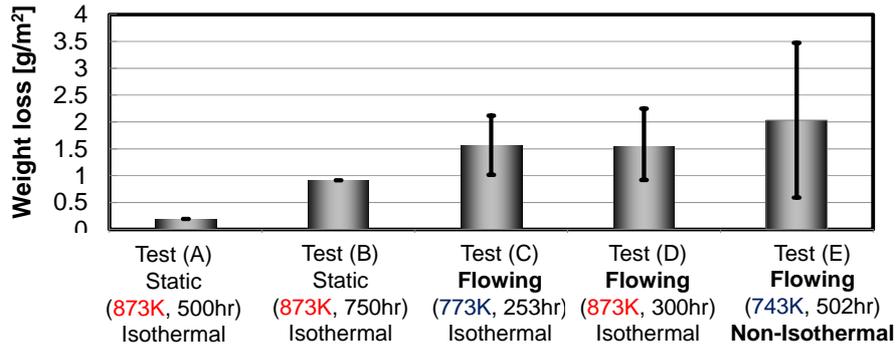


Fig. 3 Weight losses of specimens by corrosion in Pb-17Li

After the corrosion tests, the specimens were removed from the melt. Two of the four specimens in the tests (C, D and E) were cleaned using liquid Li, and their weight change due to the corrosion was measured by an electro reading balance with an accuracy of 0.1mg. The other two specimens were cut at span wise center and the surface cross section was metallurgically analyzed by electron probe micro analyzer (EPMA).

3. Results and discussions

Figure 3 shows the weight losses of the specimen. The weight losses of the specimen exposed in the impeller induced flow was larger than that in the static conditions. The impeller induced flow could accelerate the corrosion. Then, the effect of the temperature and the Re number for mixing did not seriously influence on the corrosion in the isothermal condition. Figure 4 shows the results of EPMA mapping analysis on the surface cross section of JLF-1 specimen tested in test (D). The depletion of Fe on the steel surface was caused by the corrosion. The corroded surface was eroded by the impeller induced flow. The occurrence of erosion- corrosion was the reason for the large weight losses of the specimens.

The weight loss of the specimens tested in the non-isothermal condition was larger than that in the isothermal condition. Figure 5 shows the results of EPMA mapping analysis for Fe and Pb on the cross section of the wire mesh plate placed at the low temperature region in the non-isothermal type mixing tank. The precipitation of Fe and Cr on the surface of wire mesh was detected. The concentration of Fe and Cr in the flowing Pb-17Li around the specimens could be kept at a lower level than their saturation. These results indicated the temperature gradient in the flowing system accelerated the corrosion.

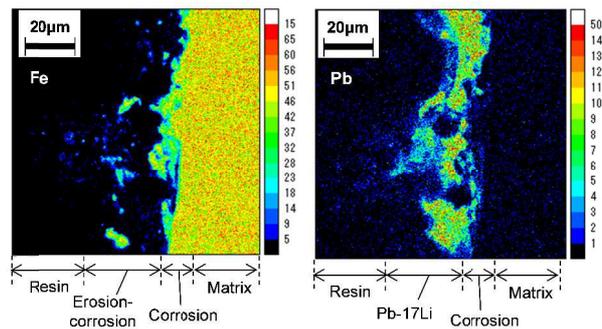


Fig.4 Results of EPMA mapping analysis of Fe and Pb on surface cross section of JLF-1 specimen tested in test (C).

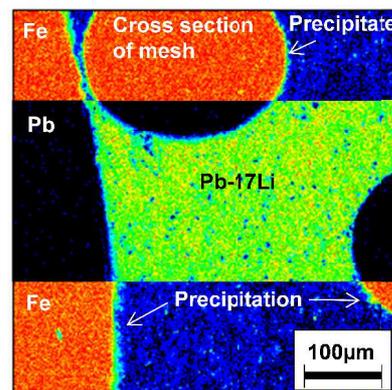


Fig. 5 EPMA mapping analysis for Fe and Pb for cross section of wire mesh plate placed at low temperature region of mixing tank

Reference

[1] M. Kondo, M. Takahashi, T. Tanaka, V. Tsisar, T. Muroga, Fus. Eng. Des., 87, 1777–1787 (2012).