Corrosion test using commercial FMS and developed ARAA in the Experimental loop for liquid breeder

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1. Introduction

The major objectives of the ITER project are to develop next-generation technologies of neutronics, a blanket module, tritium treatment, and plasma, and to investigate the heat extraction from the blanket module of a fusion reactor and tritium extraction experiments. [1-3]. Korea plans to test a Helium Cooled Ceramic Reflector (HCCR) Test Blanket Module (TBM) in the ITER [4]. A ferritic-martensitic steel (FMS) was considered as a structural material and the commercial-scale Advanced Reduced Activation Alloy (ARAA) is developed as a HCCR TBM structural material. A liquid-type TBM, a Helium Cooled Molten Lithium (HCML) TBM, is one of candidate TBM for KO Demos. In this concept, helium (He) and liquid lithium (Li) were used as a coolant and a breeder, respectively. However, according to our strategy for developing the liquid breeder TBM and its more relevant DEMO concept, liquid breeders not only considered liquid lithium but also lead-lithium (PbLi). An Experimental Loop for Liquid breeder (ELLI) was constructed for the purpose of validating the electromagnetic (EM) pump design, which designed and fabricated by ourselves; testing the effects of magneto-hydro-dynamics (MHD); and investigating the compatibility of PbLi using structural materials such as ferritic martensitic steel. The picture of the experimental loop is shown in Fig. 1. The performance test on each component such as heaters, the control systems for heating the loop were performed and the characteristic tests with a magnet and the EM pump were carried out [5-8]. A corrosion tests using ELLI were performed with grade 91 FMS steel and ARAA during 250 hours. The corrosion tests specimens using developed commercial-scale ARAA-1 will be carried out in the ELLI loop using EM pump to investigate the corrosion behavior of ARAA-1, and the test results will be compared the previous corrosion tests of FMS corrosion specimens.

2. Corrosion Test in the ELLI

A commercial FMS with grade 91(Gr.91) and developed ARAA steel was used for corrosion test-specimens. The corrosion tests for the Gr.91 and ARAA were performed to investigate the corrosion behavior in flowing PbLi. A 15mm length tubular-type, with a 10 mm diameter and 1 mm thickness, samples were fabricated for corrosion specimens. The fabricated tubular-type specimens were fixed at a post using wires as shown in Fig. 2. Three sets of the corrosion specimens were installed to three test pots as shown in Fig. 3. A series corrosion tests were carried out during two separate experiments. The experiments were performed at 150 h, and 100 h for each test, respectively. After first corrosion test experiments with a duration of 150 h, some of specimens were replaced to compare the corrosion status for exposed times of the specimens. The replaced specimens were test-pot 1(#1 : Gr.91, #2 : ARAA) with same material and test-pot 2(#3 : Gr.91, #4 : Gr.91) with different type ARAA(#3 : coated-1 ARAA, #4 : coated-2 ARAA). After installing the specimens into the loop, a corrosion test was performed while the EM pump was operating with a 0.16 m/s flow rate at 340 ℃ for 250 h for all two experiments. After corrosion test in the flowing PbLi at 340 ℃ for 250 h, the weigh losses of the tubular type samples at test-pot 1 (TP-1), test-pot 2 (TP-2) and test-pot 3 (TP-3) were measured. The initial masses were 3.31847 g for the ARAA-sample and 3.33993 g for Gr.91-sample at TP-3, respectively. Then, the masses after the corrosion test were obtained as 3.31827 g for the ARAA-sample and 3.39985 g for Gr.91-sample at TP-3, respectively. Mass of samples was decreased about 0.006% for ARAA-sample and 0.009% for Gr.91-sample, which corresponded to 0.22 g/m2 and 0.34 g/m2 of a corrosion attack, respectively. The mass change during corrosion test was shown in Fig. 4. Fig. 5 demonstrates the elemental distribution at the corroded surface. EDS line-scan analyses on cross sections were performed from the surface. The concentration profiles of Fe, W, and Cr for ARAA-sample and Fe, Mo, and Cr for Gr.91-sample at the surface had not changed within the resolution limit in 250 h of exposure and 340 ℃ of temperature.

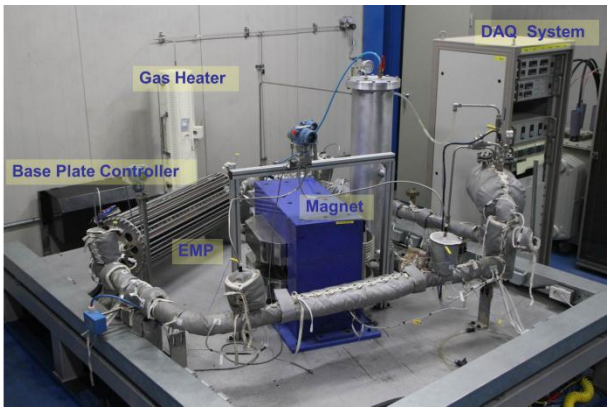

Fig. 1. A photo of the experimental loop.

Fig. 2. Photograph of the corrosion specimen.

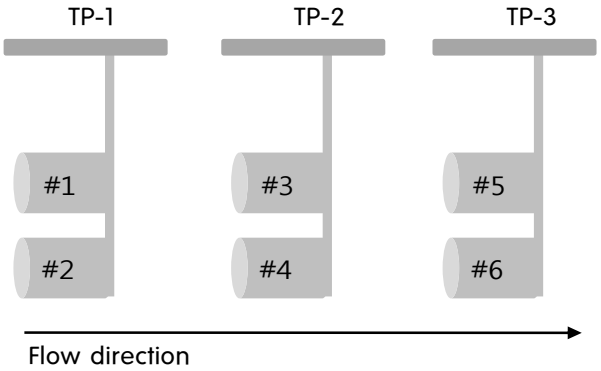

Fig. 3. Schematic diagram of specimens of the test pots.

ID	Before [g_0]	After [g]	Δg/g_0 [%]	Δg/A [g/m2]
ARaa - 100 h	3.28534	3.28519	0.00456574	0.165870488
ARaa - 150 h	3.35819	3.35791	0.00833782	0.309624912
ARaa - 250 h	3.31847	3.31827	0.00602687	0.221160651
Gr.91 - 100 h	3.43198	3.43186	0.00349652	0.132696391
Gr.91 - 150 h	3.33993	3.33965	0.00838341	0.309624912
Gr.91 - 250 h	3.40016	3.39985	0.00911722	0.342799009
Gr.91/Al2O3 - 100 h	3.31641	3.31611	0.00904593	0.331740977
Gr.91/Al2O3 - 150 h	3.30974	3.30955	0.00574063	0.210102619
Gr.91/ZrO2 - 150 h	3.30723	3.30700	0.00695446	0.254334749
Gr.91/Ta2O5 - 100 h	3.28662	3.28651	0.0033469	0.121638358

Fig. 4. Mass change after corrosion test.

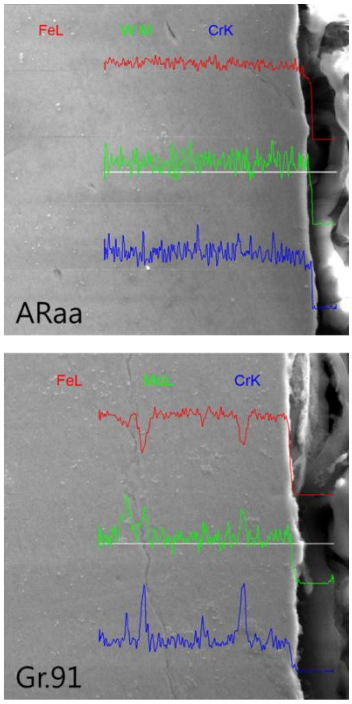

Fig. 5. Elemental distribution at the corroded surface.

3. Conclusions

A commercial FMS with grade 91 and developed ARAA steel was used for corrosion test-specimens to compare the corrosion characteristics in the flowing Pbli loop. Long term operation performance of the ELLI loop was conformed during 250 h corrosion tests. During the two separate experiments, an EM pump was operated for 250 h with a speed of 0.16 m/s (0.95 Kg/s) for corrosion tests. Mass of samples was decreased about 0.006% for ARAA-sample and 0.009% for Gr.91-sample, which corresponded to 0.22 g/m2 and 0.34 g/m2 of a corrosion attack, respectively. Unfortunately, it was unavailable to compare these weight losses with previous reports because of the relative low corrosion temperature (340 ℃) and short exposure time (250 h). A micro structural observation on the ARAA-sample and Gr.91-sample specimen surface and elemental analysis were done using a scanning electron microscope (SEM). The concentration profiles of Fe, W, and Cr for ARAA-sample and Fe, Mo, and Cr for Gr.91-sample at the surface had not changed within the resolution limit in 250 h of exposure and 340 ℃ of temperature.

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