The Installation of Corrosion-Loop for Lead-Bismuth Eutectic

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1. Introduction

Lead-Bismuth Eutectic (LBE) corrosion has been considered as an important design factor which limits the temperature and velocity of the accelerator driven transmutation system. KAERI has systematically conducted a series of corrosion test under several stagnant conditions since 2003 September. Corrosion tests using a liquid metal loop are also necessary to estimate the corrosion and erosion behavior in the LBE flow. KAERI recently finished the piping work of a dynamic corrosion loop according to the preliminary design concept [1] and started a finishing process to conduct the corrosion test under the flowing condition of LBE by the fall of 2005.

For the corrosion loop, we shortly describe the general design concept and the status-of-the-art for the installation at KAERI.

2. Installation of the LBE Corrosion Loop

Recently, LBE has been widely studied as a core coolant and target material of the ADS in various countries. However, LBE and Lead are more corrosive than sodium because the solubility of Ni, Cr and Fe is high. Thus, LBE corrosion has been considered as an important design-factor which limits the temperature and velocity of the ADS system [2].

Several methods have been considered to prevent the corrosion problem in LBE. In the research on the LBE technology, it has been made clear that the corrosion behavior is controlled by the oxygen concentration in the liquid LBE. Thus, one method is to form a stable oxide layer on the material surface through an oxygen level control in the LBE. Another one is to modify the material compositions or the surface of the material.

Fig. 1 and Fig. 2 show the schematics and the photo of the dynamic corrosion loop installed at KAERI, respectively. The LBE loop was designed to conduct a test in the isothermal condition. The flow velocity in the test section was also designed to be around 2m/s in the range of 400~550^{o}C and the charging volume of the LBE is around 0.03 m^3 in the circulation loop. A total of 0.08 m^3 of LBE is stored in the sump tank before charging it into the test loop. Test samples are installed in the test-section with an annular cross section. In order to treat the test samples in a regulated oxygen environment, the upper part of the test-section was installed inside the glove box.

The LBE loop is mainly composed of a main test-loop, bypass-loop for filtering the LBE and a mixture-gas supplying system. The liquid metal in the main test loop circulates in the following order: EM-pump – EM flow meter – oxygen controller – test-section – magnetic filter – EM pump. From the analysis of the pressure drop, the specification of the piping system was determined as a 1.5-inch pipe to reduce the pressure drop by a high mean fluid velocity.

The LBE is circulated with an electromagnetic pump, which was designed by an equivalent electric-circuit and manufactured to be operated for the corrosive LBE circulation under a high temperature of around 500^{o}C. The flow rate is measured with electromagnetic flow meters based on Faraday's induction law [3]. The performance of every EM flow meter can be calibrated with a calibration tank in the loop.

Most parts of the piping system were made of stainless steel pipe with 1.5 inch in inner diameter (SUS316L, 1.5 inch schedule 40) and were assembled by the welding and the metal gasket for the prevention of a leakage of the LBE. The valve was especially manufactured for the LBE environment, which took into consideration the temperature of the seal and did not include any bellows.

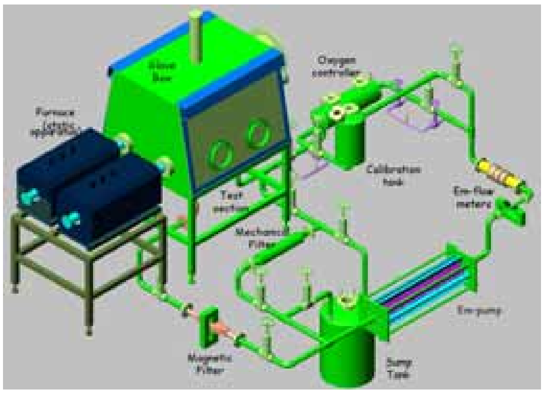

Fig. 1. The schematics of the LBE corrosion loop.


Fig. 2. The photo of the LBE corrosion loop.

The oxygen concentration in the range of 10^{-7}wt% ~ 10^{-5}wt% is controlled by the chemical equilibrium between the mixture gas of hydrogen-argon and the water vapor. At present, the oxygen concentration in the LBE and the mixture gas is measured with an oxygen sensor made of Yttria Stabilized Zirconia as a solid electrolyte cell and Pt/air as a reference system. Fig. 3 shows the prototype of the oxygen sensor to measure the oxygen activity in the liquid LBE. The electric potential between the LBE flow and the reference electrode is measured by a voltmeter with a high input impedance to maintain the difference of the oxygen concentration. The oxygen partial pressure is determined by the Nernst's equation.

Fig. 4 is the oxygen-control system which has been used to control and to measure the oxygen concentration and the humidity in the flowing mixture gas. In case of the highest purity gas (99.999% Argon), the device could control the oxygen concentration up to 1~10 ppmv. If we used the highest purity mixture-gas (argon-hydrogen 5%), the device could control the oxygen concentration up to 10^{-22} ppmv.

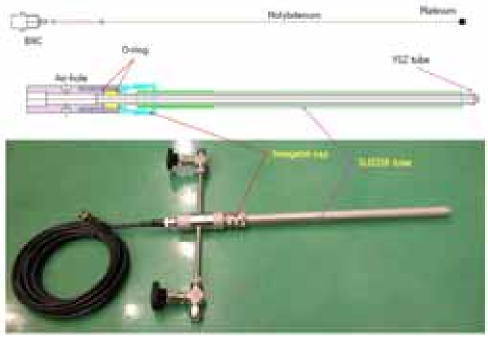

Fig. 3. The prototype of oxygen sensor (Pt-Air).

Fig. 4. The oxygen-control system for the oxygen-sensor test apparatus.

The oxygen controller was installed to control the level of the oxygen concentration in the loop and expand the liquid LBE during the test. Direct control of the oxygen concentration is not easy since the required oxygen level is very low. However, the oxygen partial pressure P_{O2} can be chemically controlled with the ratio of the other gases involved, e.g. the $H_2/O_2/H_2O$. In order to control the oxygen level in the loop, a mixture gas of argon, hydrogen and water vapor is continuously injected into the LBE flow in the oxygen controller.

$$C_o = C_{o,S}\ (\frac{P_{O_2}}{P_{O_2,s}})^2 \quad [wt\%] \tag{1}$$

$$P_{O_2} = (\frac{P_{H_2O}}{P_{H_2}})^2 \exp(\frac{2\Delta G^o_{H_2O}}{RT}) \quad [bar] \tag{2}$$

where C_0 is the oxygen concentration, $C_{0,S}$ is the solubility of the oxygen in the LBE and P_{H2O} and P_{H2} are the partial pressures of the H_2O and H_2, respectively and $\Delta G^o_{H_2O}$ is the oxygen potential of the water vapor.

Fig. 5 shows the performance of the EM-pump measured with one-component dynamometer. The pressure head of the revised pump was largely enhanced after changing the structure of the inner-core and the intercore gap between the inner-core and the outer-core. From this test, we confirmed that the EM-pump could operate at more than around 500°C and pumped the LBE at more than 2.5bar.

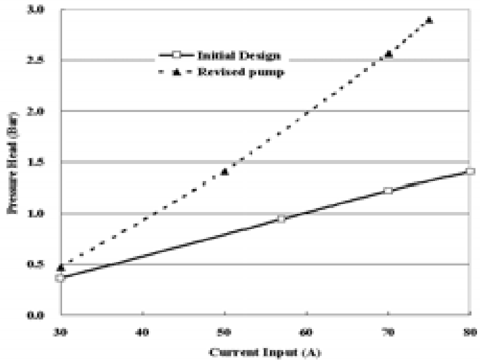

Fig. 5. Pumping power of EM-pump with current input.

3. Conclusion

KAERI finished the setup of the LBE static corrosion facility and has systematically conducted a series of corrosion test under several stagnant conditions since 2003 September.

KAERI recently finished the piping work of a dynamic corrosion loop and started a finishing process to conduct the corrosion test under the flowing condition of LBE by the fall of 2005. From the EM-pump test, we confirmed that the EM-pump could operate at more than around 500°C and pumped the LBE at more than 2.5bar.

REFERENCES

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