Development of High-Temperature Sodium Loop System for Materials Compatibility Test for Ultra-long Cycle Fast Reactor (UCFR)

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1. Introduction

Sodium is a candidate for fast reactor coolants that has been believed to have favorable compatibility with structural materials. However, recent studies showed results which need for a more careful attention at this previous belief [1, 2]. For prolonging the service life time of cladding and structural materials in contact with liquid sodium, more detail analysis methods are needed to examine this material compatibility issue with sodium.

As a candidate of liquid metals coolants of Ultra-long Cycle Fast Reactor (UCFR), the compatibility of sodium with cladding materials has to be investigated in detail with long term exposure time.

It is known that corrosion promotes corrosion in two ways. One is corrosion produced by dissolution of alloy elements into sodium and the other is corrosion produced through a chemical reaction with impurities in sodium, especially dissolved oxygen [3].

The use of the technique of impedance spectroscopy to measure the electrical impedance response of any oxide layers may be a good experimental tool to this monitoring system [4].

The motivation of current study is to investigate the relationship between the electrochemical behaviors of oxide scales on ferritic-martensitic (FM) steel and austenitic steels (as shown in Table I) and their corrosion rates in liquid sodium environment.

2. Experiments

The sodium loop system mainly consists of molybdenum crucible, corrosion cell, electromagnetic pump, cold trap, hot trap, sodium valve, oxygen sensor and storage tank in glove box as shown in Fig. 1. The reason that all main parts are installed in glove box is to keep in control of inert gas environment in glove box for preventing sodium-air or sodium-moisture reaction.

The characteristics of experimental system are summarized in Table II. To investigate materials compatibility with sodium except other impurities effects, corrosion test will be conducted in molybdenum crucible which is inert materials in sodium environment as shown in Fig. 2. Corrosion cell is also designed to conduct material compatibility test with sodium at high temperature. At cold trap, sodium will be oversaturated and impurities will be extracted on the surface of mesh installed in cold trap. The temperature of sodium in cold trap is controlled by the chiller system using synthetic oil coolant. At hot trap, $Zr_{0.87}$-$Ti_{0.13}$ alloy scraps are used and the capacity of the alloy for getting oxygen is 0.234g(O)/g(alloy) [6]. The electromagnetic pump is designed to overcome the pressure drop through the sodium loop, and it gives forced circulation of sodium in the loop.

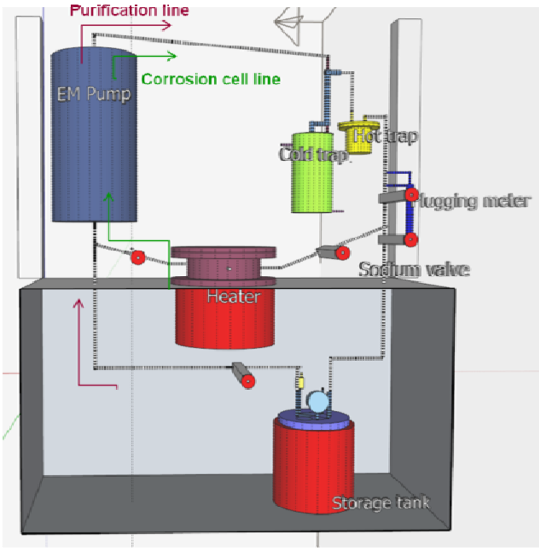

Fig. 1. Schematic of sodium loop

Table II. The characteristics of experimental system

Main tube diameter	3/8 inch
Sodium velocity	2 m/s
Mass flow rate	0.1038 kg/sec (8.54 liter/min)
Total sodium weight	9.8kg
Total pressure drop	4.2 bar
Temperature at test section	550°C
Oxygen concentration	< 10 wppm

Table I. Chemical composition (wt.%) of specimens.

	C	Si	Mn	P	S	Ni	Cr	Mo	Cu	Al	V	W	Nb
HT9	0.184	0.252	0.624	0.005	0.01	0.592	11.961	1.003		0.0246	0.332	0.541	0.008
Gr.92	0.087	0.205	0.412	0.0117	0.0018	0.126	8.686	0.381	0.104	0.0057	0.184	1.618	0.002
316L	0.025	0.66	1.02	0.035	0.001	10.05	16.43	2.02	-	-	-	-	-

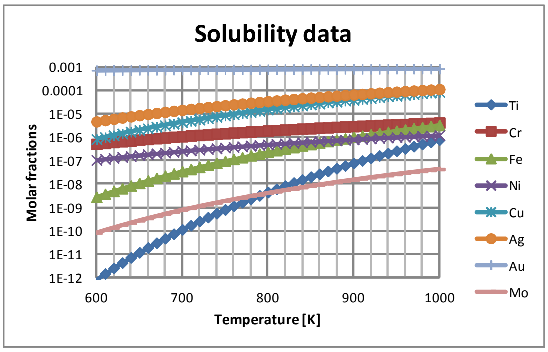

Fig. 2. Solubility data of few elements [5].

For the operation sodium loop with two different objectives, sodium valves are installed on the main tube.

The one is corrosion cell line with mini-loop, the other is sodium purification line as shown in Fig. 1.

For monitoring the concentration of dissolved oxygen in sodium, GDC (galoinia doped ceria) electrolyte based oxygen sensor is now under development.

For the storage of sodium, tank also has been manufactured, and level gauge is installed in the tank to check sodium level.

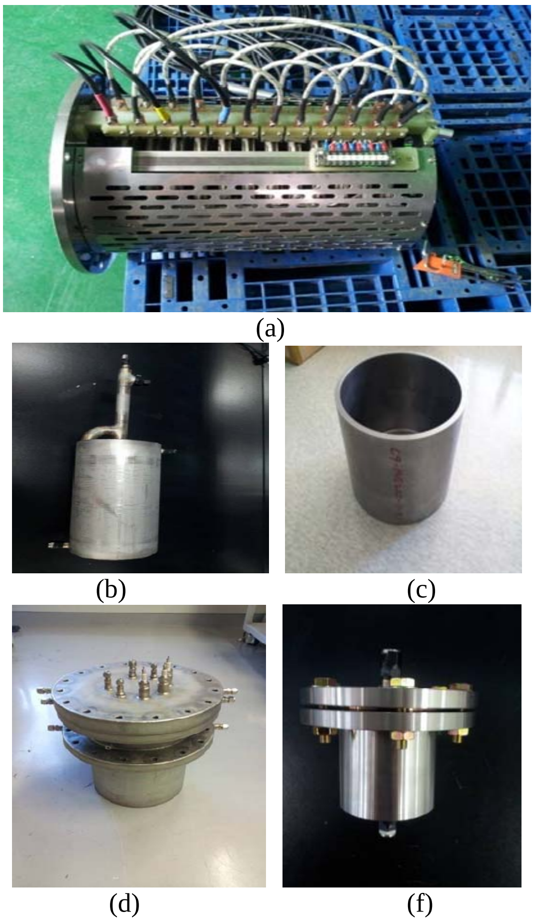

Fig. 3. The figures of (a) electromagnetic pump (b) cold trap (c) molybdenum crucible (d) corrosion cell and (f) hot trap, respectively.

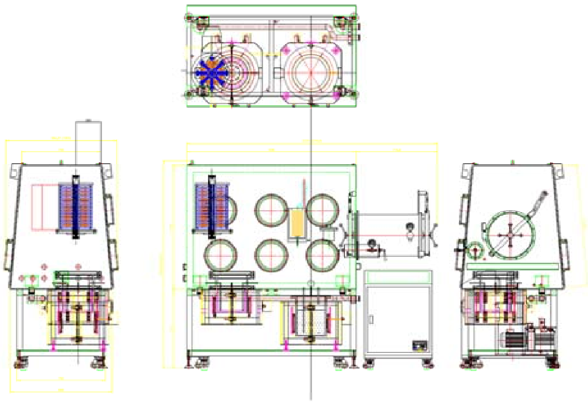

Fig. 4. The design of material compatibility test system.

3. Summary

The compatibility of ferritic-martensitic(FM) steel and austenitic steel with sodium will be investigated in this system. Electrochemical investigation, especially impedance spectroscopy, will be applied to corrosion cell to characterize corrosion behavior of those specimens in sodium environment. And also oxygen concentration is controlled and monitored by oxygen sensor and traps, respectively.

To assemble the elements (as shown in Fig. 3) of material compatibility experimental systems in glove box as shown in Fig. 4, is now in process.

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