

Corrosion experiment for CLAM and SS316L in liquid LiPb loop of China

Zhang Maolian^{a,b,*}, FDS Team^a Anhui Science and Technology University, Fengyang, Anhui 233100, China^b Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, Hefei, Anhui 230031, China

ARTICLE INFO

Article history:

Received 29 June 2014

Received in revised form 9 February 2015

Accepted 9 February 2015

Available online 2 March 2015

Keywords:

LiPb loop

CLAM

SS316L

Corrosion

Experiment

ABSTRACT

The liquid metal LiPb blanket design is one of the most promising designs for future fusion power reactors and under wide research in the world. LiPb loops are indispensable to research on characteristics of liquid LiPb such as its corrosive effect on structural materials on the blankets and so on, and have been built in China. Corrosion experiments using flowing LiPb with a speed of 0.08 m/s at 480 °C for 2500 h were carried out on CLAM steel and on 316L stainless steel for comparison. The exposed samples were observed and analyzed by metallography and Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy after 500, 1000, 1500, 2000, and 2500 h corrosion experiments. The results show that the corrosion of CLAM steel is non-uniform and the weight loss was about 0.38 mg/cm² after 2500 h of exposure, while that for 316L was visible and very serious and the weight loss was about 35.7 mg/cm² after 2500 h of exposure.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The liquid metal LiPb blanket design is one of the most promising designs for future fusion power reactors and under wide research in the world. China, EU, USA, and the other members of ITER (International Thermonuclear Experimental Reactor) all pay much attention to the R&D of the liquid LiPb blankets.

As demonstrated (Wu et al., 2006, 2007a,b,c), the activities of FDS series fusion reactors designs with liquid tritium breeder blankets have been performed at ASINEST (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences) for years. In the designs, CLAM (China Low Activation Martensitic steel), as demonstrated (Huang et al., 2007a,b), is considered as the primary candidate structural material and LiPb eutectic as both tritium breeder and coolant of the blankets. So compatibility of candidate structural materials for fusion reactors such as RAFMs etc., flowing characteristics of LiPb and Magnetohydrodynamic (MHD) effect are essential to researches of liquid LiPb blankets.

The LiPb experimental loop is indispensable to study the compatibility of liquid metal LiPb with structural materials, the fluent characteristics of liquid LiPb, MHD effect of LiPb and so on. Great attention had been paid to it in the world. As demonstrated (Antipenkov et al., 1991; Barbier, 1997; Barbier et al., 2002; Benamati et al., 2002; Borgstedt et al., 1988; Broc et al., 1986;

Sannier et al., 1991; TAS et al., 1986; Tortorelli et al., 1986), researches on LiPb experimental loop were carried out in Europe, America and Japan since 1980s. However, the loops were all shut-down for their life limit except PICOLO LiPb loop of Germany, as demonstrated (Konys et al., 2004, 2007a,b). In China, there was no research on LiPb loop and related experiments several years ago.

A lot of work has been done at ASINEST on design, manufacture and experiments for the series LiPb experimental loops recent years. The first liquid metal LiPb loop of China, i.e. DRAGON-1, as demonstrated (Huang et al., 2007c), was built in 2005 at ASINEST, and CLAM and austenitic stainless steel 316L were exposed to the flowing LiPb at 480 °C in flowing LiPb at 0.08 m/s for 2500hrs in DRAGON-1. The purpose of these corrosion tests is to provide a database on corrosion of CLAM and austenitic stainless steel 316L in liquid metal LiPb.

2. Experimental

2.1. Specimens

The experimental specimens of martensitic steel CLAM and austenitic steel 316L with sizes of $\Phi 10 \times 15$ mm were prepared. The chemical compositions of them are listed in Table 1. The austenitization conditions of the CLAM bar materials were 980 °C, 27 min and cooling in air, and tempering at 760 °C for 90 min with subsequent air cooling. All samples showed a bright metallic surface. The average roughness was measured to be about $R_a = 0.5 \mu\text{m}$, maximal value in roughness was $R_z = 2.4 \mu\text{m}$.

* Corresponding author at: Anhui Science and Technology University, Fengyang, Anhui 233100, China, and Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, Hefei, Anhui 230031, China.

E-mail address: maolianzhang@163.com

Table 1

Chemical compositions of the two steels (wt%).

	Cr	Ni	Mn	C	S	Si	W	V	Ta	Mo	N	P	Fe
CLAM	8.91	–	0.49	0.12	0.003	–	1.44	0.20	0.15	–	0.0084	–	Bal.
316L ss	17.4	11.1	1.11	0.018	0.001	0.53	–	–	–	2.16	0.04	0.026	Bal.

2.2. Experimental conditions

DRAGON-I loop is a 0.5 m × 0.5 m thermal convection loop made of SS316L tube with a internal diameter of 22 mm. It consists of a hot leg and a cold leg. The cylindrical specimens were immersed in the vertical isothermal hot leg. The operating conditions of the tests are summarized in Table 2. The chemical composition of LiPb alloy used for the experiment is listed in Table 3.

After experiment, the corrosion specimens were taken out of the loop and some were cleaned with a solution made by CH₃COOH, H₂O₂ and C₂H₅OH in a ratio of 1:1:1 until the weight of the specimen remained constant, and the weight loss of post-test specimens were tested after cleaning. While the other corrosion specimens used for metallurgical analysis, were not treated with the cleaning solution. The metallurgical analysis was performed with the aid of an optical microscope and Scanning Electron Microscope (SEM). The chemical compositions of the corroded layers were evaluated by Energy Dispersive X-ray Spectroscopy (EDX).

3. Results

3.1. Weight change

After exposed to the flowing LiPb at 480 °C for 500 and 2500 h, respectively, the specimen weights were measured and the weight losses of the specimens were calculated respectively. The weight loss for CLAM specimen was measured about 0.17 mg/cm² and 0.38 mg/cm². While the 316L specimen exhibited obvious differences in weight changes, i.e. the weight loss of it was about 1.7 mg/cm² and 35.7 mg/cm², which was 10 times higher than that of CLAM specimen. So the corrosion of 316L in liquid LiPb was much more serious than that of CLAM.

3.2. Surface investigation

The cross-section morphologies of the specimens' interface between liquid metal and base materials after 2500 h' exposure for CLAM and 316L were cleaned and observed by SEM as shown in Figs. 1 and 2, respectively. It is clear that the surface defects on the corroded layer of CLAM specimen were much more shallow compared with that of 316L specimen, and most area of the surface kept unaffected. But the 316L specimen was corroded much more seriously.

In addition, the compositions of the surface layers for CLAM and 316L specimens, which were not washed with the chemical mixture after experiments in order to avoid destroying the specimen surfaces, were achieved by EDX line-scan analysis on the cross sections of the specimens as shown in Figs. 3 and 4, respectively. In Fig. 3, the CLAM specimen surface did not show changes in the concentration profiles of Cr, Fe, V after 500hrs of exposure. After

Table 2

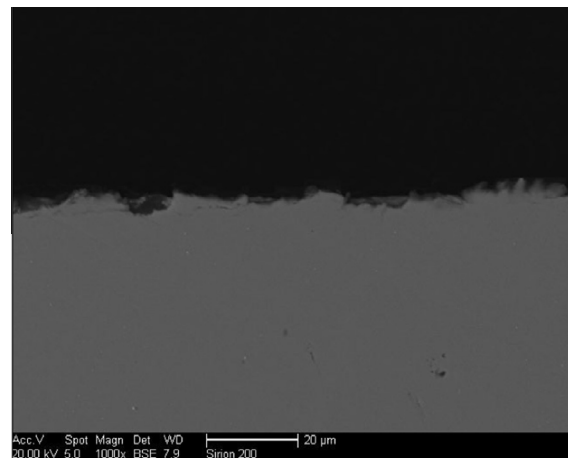
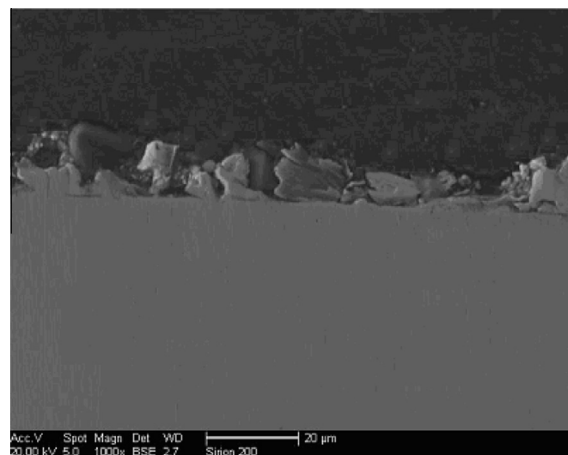
Operating conditions of the experiment.

Temperature at hot leg (°C)	Temperature at cold leg (°C)	Test duration (h)	Velocity of LiPb (m/s)
480	420	500/1000/1500 /2000/2500	0.08

Table 3

The chemical composition of LiPb eutectic (Li 0.71 wt%).

Element	Al	Cd	Cr	Cu	Fe	Hg	Mg	Others
wppm	40	3	5	13	284	37	105	<3

**Fig. 1.** Cross section of CLAM after exposure for 2500 h at 480 °C (cleaned).**Fig. 2.** Cross section of 316L after exposure or 2500 h at 480 °C (cleaned).

2500 h' exposure, a local decrease of Cr and Fe contents were observed near the surface. The thickness of depleted layers was around a few microns as was evaluated from the EDX line scan result in the 10 μm range.

As to the corrosion layers of 316L specimen in Fig. 4, the thickness of corrosion layers for 316L was about 7 μm by EDX after 500 h' exposure. The concentration of chromium changed from the normal level as the base material to low value, and nickel existed with very low content in the porous layer, while iron decreased apparently compared with the base material. After 2500 h' exposure, obvious decreases of Ni, Cr and Fe contents were observed near the surface. The thickness of depleted layers was around a

Download English Version:

<https://daneshyari.com/en/article/8068769>

Download Persian Version:

<https://daneshyari.com/article/8068769>

[Daneshyari.com](https://daneshyari.com)