3 - 4 Compatibility Tests of SIMP and T91 Steels in Static LBE

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Because of their good mechanical properties under irradiation up to 500 °C, ferritic/martensitic steels are considered to be the promising structural materials for advanced nuclear reactors. However, severe corrosion of structural materials occurs in the presence of LBE in advanced nuclear reactors, especially at high temperature[1]. Therefore, the selection of the structural material exposed to LBE is an extremely complex problem and compatibility tests are required.

The compatibility tests of SIMP and T91 steel specimens were conducted at 450 °C with saturated oxygen for 500, 1 000, 2 000 and 8 000 h, respectively. The specimens without removing the adhered lead-bismuth were cut and polished for cross section examination by scanning electron microscopy (SEM) with energy dispersion X-ray (EDX). SEM micrograph of cross-sections of SIMP and T91 steels after exposing to LBE are shown in Fig. 1. The thickness of the corrosion layer of both SIMP and T91 specimens increase with increasing corrosion time and the growth rate of the corrosion layer is more and more slowly. Moreover, double corrosion layers are clearly observed at both SIMP and T91 specimens exposing to LBE for more than 2 000 h and the thicknesses of outer and inner corrosion layers are nearly the same. Clearly, SIMP steel has a thinner corrosion layer than T91 steel in the same condition corrosion experiments. When corrosion time is 8 000 h, the corrosion layer of both SIMP and T91 steels has a maximum. The measured depth of the corrosion layer for SIMP steel is about 6.5 μm and T91, made in Japan, reaches 11 μm.

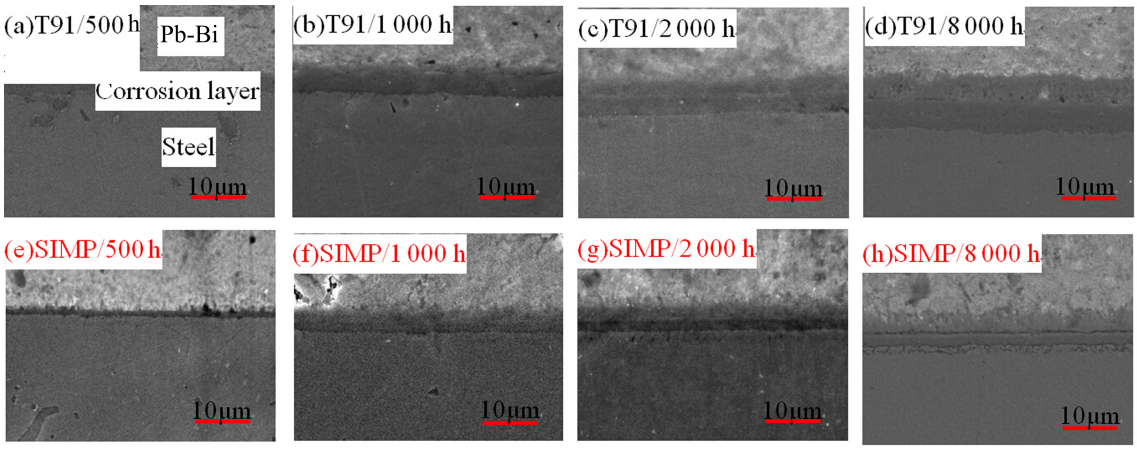

Fig. 1 (color online) SEM micrograph of cross-sections of SIMP and T91 steels after exposing to LBE at 450 °C for different time.

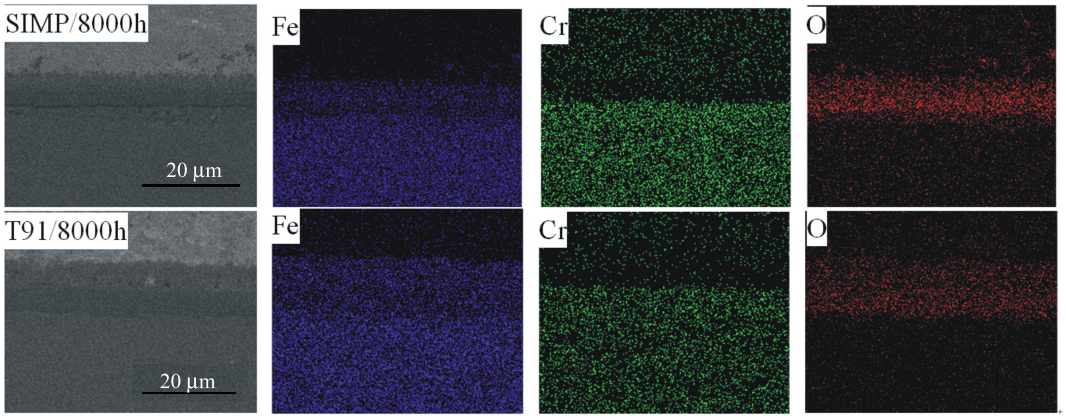

Fig. 2 (color online) EDX analysis of the cross-section of SIMP and T91 steels after exposing to LBE at 450 °C for 8 000 h.

From the results of EDX analysis for SIMP and T91 steels after corrosion at 450 °C, it is found that double

corrosion layers containing different element is formed. Fe and O were observed in the outer corrosion layer and, Fe, Cr and O were observed in the inner corrosion layer. The results of element mapping for the cross-section of SIMP and T91 steels after corrosion at 450 °C for 8 000 h are shown in Fig. 2. In Fig. 3, XRD analysis indicates that a new phase M_3O_4 appeared in both SIMP and T91 steels after corrosion. It agrees with the result of outer magnetite and inner Fe–Cr spinel formed during ferritic/martensitic steels corrosion in LBE[2−4].

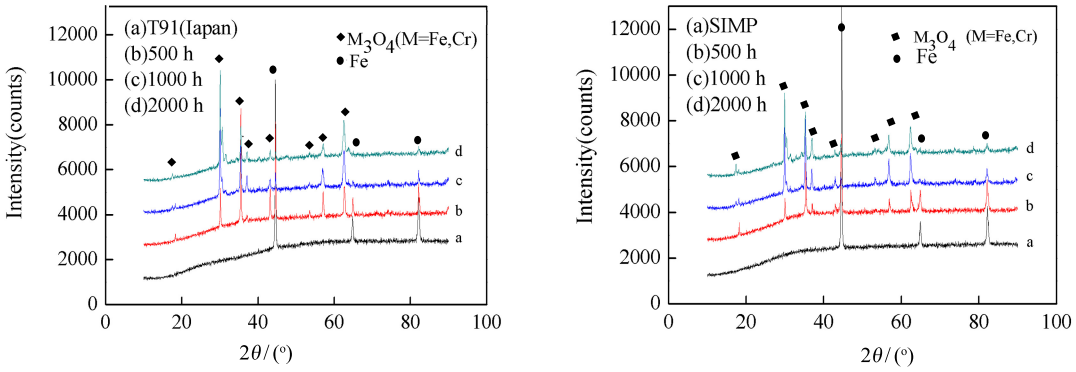

Fig. 3 (color online) XRD analysis of SIMP and T91 steels after exposing to LBE at 450 °C for different time.

It is clearly observed in Fig. 4 that the surfaces of SIMP and T91 steels after exposing to LBE at 450 °C for 500 h are different. EDX analysis of the surfaces of SIMP and T91 steels after exposing to LBE at 450 °C for 500 and 2 000 h are shown in Table 1. From the result, it is found that the white particle of the surface of SIMP and T91 steels after exposing to LBE for 500 h are magnetite and the black substrate is Fe–Cr spinel. Now there is a hypothesis of corrosion mechanism of SIMP and T91 steels under LBE. As the corrosion time increases, on the one hand, the oxygen anions diffuse inward, and hence the growth of the Fe-Cr spinel continues towards the interior of the steel substrate, on the other hand, the iron anions flux outward, this produces the magnetite growth on the Fe-Cr spinel layer and contines towards the exterior of it.

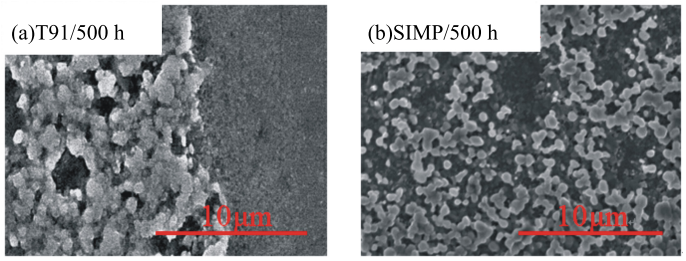

Fig. 4 (color online) SEM micrograph of the surface of SIMP and T91 steels after exposing to LBE at 450 °C for 500 h.

Table 1 EDX analysis of the surface of SIMP and T91 steels after exposing to LBE at 450 °C for different time. (atom%)

Element	T91/500 h	SIMP/500 h	T91/2 000 h	SIMP/2 000 h
C	13.19	11.18	6.80	6.83
Fe	23.62	30.27	33.64	33.84
Cr	6.95	3.40		
Pb			4.60	4.34
O	54.31	53.93	54.96	55.02

References

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