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A comparative study on atmospheric oxidation of reduced activation ferritic martensitic steel and grade 91 steel

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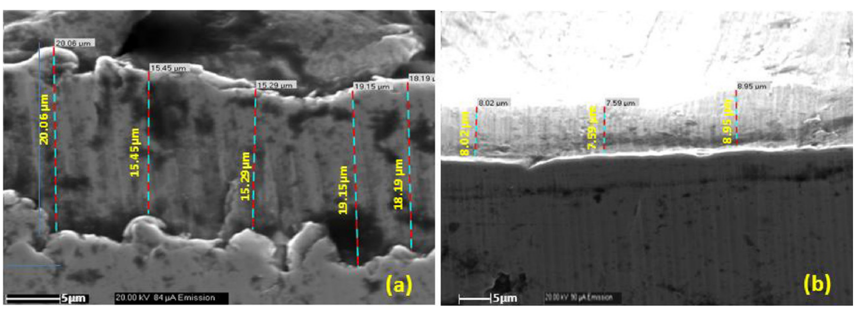
GRAPHICAL ABSTRACT

SEM micrographs showing the thickness of oxide film at a location with less spallation after ~ 8 months of atmospheric exposure for (a) RAFM Steel and (b) P91Steel.



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ABSTRACT

Oxidation behaviour of Reduced Activation Ferritic Martensitic Steel (RAFMS), the structural material for fusion reactors, exposed to atmosphere for ~2 years has been studied giving special emphasis on the morphology and chemistry of the oxides formed. The results obtained are compared with those of Grade 91(P91) steel, the composition of which was modified to develop RAFM steel; replacing Mo and Nb with W and Ta respectively. The oxidation products formed on RAFMS and P91 steel plates exposed to atmosphere were analyzed using of different material characterization techniques includes confocal microscopy, scanning electron microscopy, energy dispersive spectroscopy, X-ray photo electron spectroscopy and laser Raman spectroscopy. It is found that rate of oxidation in RAFM steel is faster than in P91 steel. The chloride ions in the environment and difference in surface oxide chemistry play roles in deteriorating the oxidation resistance of RAFM steel. Oxides formed on RAFM steel contain W while those formed on P91 steel contain Mo and difference in the oxide layers seems to affect their adherence to the substrate. Electrochemical corrosion studies on these steels using impedance spectroscopy showed corrosion resistance of RAFM steel in chloride containing acidic medium is lower than that of P91steel.

1. Introduction

Reduced Activation Ferritic Martensitic Steel (RAFMS) is one of the candidate structural materials for future fusion reactors. This steel is developed by replacing Mo and Nb with W and Ta respectively in widely used Grade 91 (modified 9Cr-1Mo/P91) steel and limiting elements that can produce radioactive isotopes in a reactor environment at very low levels [1,2]. However, this steel appears to oxidize faster than

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Table 1
Chemical composition of P91 and RAFM steels (Wt %).

Element	P91	RAFM
Fe	Bal.	Bal.
Cr	8.838	9.150
Mo	0.860	< 0.002
C	0.114	0.078
V	0.207	0.240
Nb	0.080	–
N	0.054	0.021
Mn	0.403	0.530
Si	0.309	0.026
Al	0.013	0.004
Ni	0.220	0.004
P	0.014	< 0.003
S	0.001	0.002
W	–	1.37
Ta	–	0.080
B	–	0.001
Ti	0.004	0.002
Cu	0.052	0.002
Co	–	0.003

P91 steel when exposed to open atmosphere. It is noticed that oxidation of RAFM filler wires developed for welding is so high that wire feeding is found to be difficult due to presence of oxides on the surface; but such difficulties are not encountered for P91 filler wires. Though information on oxidation behaviour of P91 steel and its variant P92 steel is available in open literature [3–6], similar information on recently developed RAFM steel is sparse. Hence, a comparative study on the oxidation behaviour of the two steels in open atmosphere was undertaken. This paper presents the results from the oxidation as well as electrochemical corrosion studies carried out on RAFM steel and P91 steel using different material characterization techniques and discusses the possible reasons for the difference in the oxidation behaviour of these two steels.

2. Materials and methods

RAFM steel and P91 steel (with chemical composition as given in Table 1) plates in the normalized and tempered conditions (hardness:190-196 HV and 218–226 HV respectively for 0.5Kg load) of dimensions 150 × 100 × 12 mm^3 were kept in open environment where temperature and humidity varied in the range 26 °C–35 °C and 50%–80% respectively for a period of ~two years. These plates were in the machined condition and their surface roughness was measured

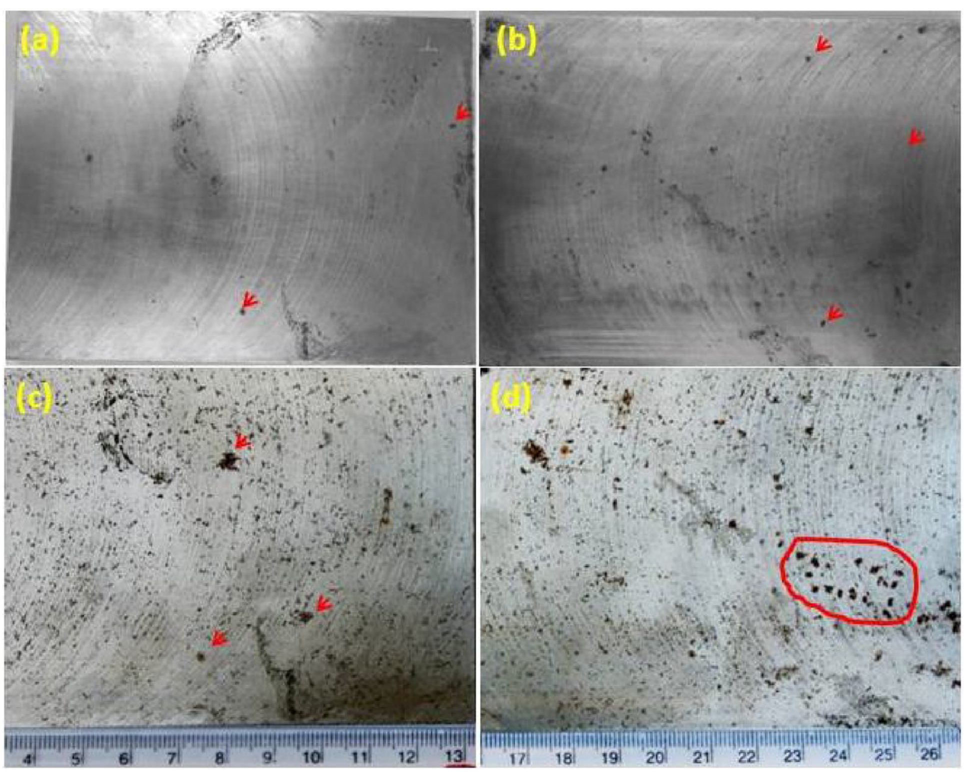

Fig. 1. Photographs of alloy plates exposed to open environment (a) P91 steel-8months, (b) RAFM steel-8months, (c) P91 steel-2years, (d) RAFM steel-2years.

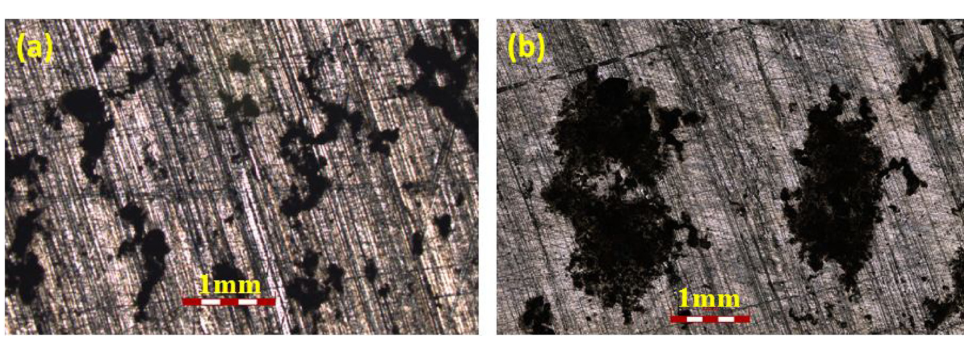

Fig. 2. Confocal 2D micrographs for the oxides formed on the surface of (a) P91 steel and (b) RAFM steel after ~ two years exposure to atmosphere.