# Corrosion Mechanisms of T91 (Fe-9Cr) Steel in Pb-Bi Eutectic Alloy aided by Thermodynamic Calculations: Effect of Oxygen

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In the framework of the new generation IV nuclear fast reactor projects, lead alloys and particularly lead bismuth eutectic (LBE) are candidates as coolant materials for the primary or intermediary circuit. However, the compatibility of this liquid alloy with the structural materials is a key issue.

The Fe-9Cr steel, is one of the steel considered for structural material in contact with LBE. It exhibits severe damages when exposed to this heavy liquid at high temperatures. According to the literature, the oxidation of martensitic steels in LBE is always characterized by the growth of a duplex Cr-Fe spinel oxide scale for the temperature range from 400°C to 620°C. Some studies showed that above 540°C, a change in the oxide scale microstructure occurs to form a Fe-Pb-O plumboferrite phase. The formation of this plumboferrite scale follows the formation of the $(Fe_{-x}Cr)_3O_4$ spinel duplex scale between 470°C and 600°C.

In accidental case for which oxygen leak leads oxygen to reach locally the saturation level, a plumboferrite phase can appear. In the aim of understanding the conditions of formation of plumboferrite, kinetics and thermodynamics investigations are carried out. Some experiments were performed up to 3000 h at 630°C in oxygen saturated liquid alloy under argon. The oxidation kinetic follows several successive parabolic shape which indicates several kinetic breakaways linked to a change in oxide nature. Analyses of this layer has been performed at various oxidation times. From these corrosion layers and samples studies, a mechanism is proposed. Previous studies on oxidation of a T91 Fe-9Cr steel allowed the elaboration of an oxidation mechanism in the case of the formation of the usual spinel/magnetite duplex layer formation. The simulation of the oxidation kinetics, is in good agreement with the first experimental points of this study but due to a change in oxidation mechanism induced by lead incorporation within the oxide layer, the kinetic modelling is revisited.

Furthermore, the thermodynamics of steel/LBE interactions was investigated using the Calphad method. A first database was developed to assess the interaction between the main elements of the alloys and LBE. Recently, an updated version of the database was implemented to consider the effect of the oxygen potential. The current thermodynamic data on the Cr-Fe-Ni + Bi-Pb + O system was assessed to model Fe-Cr-Ni and O solubilities in the liquid alloy . Using this database, the liquid alloy composition and the oxygen solubility can be modelled as a function of temperature to better determine the equilibrium temperature and $p(O_2)$ where complex oxide phases can form.

This new thermo-kinetic coupling modelling permitted to forecast the regions in terms of temperature/oxygen concentration within the liquid for which the breakaway kinetic can appear. This cartography has to be taken into account for safety scenario in order to avoid catastrophic oxidation of the steels.