MATERIAL COOLANT INTERACTION - CORROSION, MECHANICAL PROPERTY DEGRADATION AND OXYGEN CONTROL FOR Pb-ALLOY COOLED TRANSMUTATION DEVICES

Alfons Weisenburger, Georg Müller, Renate Fetzer, Annette Heinzel, Adrian Jianu
Karlsruhe Institute of Technology, Institute for Pulsed Power and Microwave Technology, Germany

Abstract

Beside general requirements for material properties that are common for all planned transmutation devices, specific issues arise from material coolant interaction. Pb- alloys are especially regarding safety aspect one of the most promising coolants investigated at time. But, the high solubility of steel alloying elements in liquid Pb-alloys at reactor relevant temperatures is clearly detrimental. Therefore, all steels that are considered as structural materials have to be protected by dissolution barriers. The most common barriers for steels under consideration are oxide scales that are formed in situ during operation. However, increasing the temperature above 500 °C will result either in dissolution attack or enhanced oxidation. For higher temperatures additional barriers like alumina forming surface alloys are discussed and investigated. Mechanical loads like creep stress and fretting will act on the steels. These mechanical loads will interact with the coolant and can increase the negative effects. Therefore, clear safety margins have to be respected by design. All corrosion barriers require well-defined oxygen contents in the liquid Pb- alloy to be maintained. Oxygen control therefore needs to consider always oxygen consumption by corrosion barrier formation.

Several design studies of transmutation devices like the EFIT (European Facility for Industrial Transmutation) and MYHRRA (Multi-purpose HYbrid Research Reactor for high-tech applications) consider the austenitic steels (316L-type) and the ferritic/martensitic steel T91 for most in core components. Surface alloying with alumina forming alloys is considered to assure material functionality at higher temperatures and is therefore proposed for fuel cladding and the heat exchanger tubes of the EFIT. This presentation will give an overview on the selected materials for innovative Pb alloy cooled transmutation devices considering, beside pure compatibility, the influence of mechanical interaction like creep and fretting. The compatibility of the steels in reactor systems with liquid lead alloys can only be maintained if the oxygen consumed by the growing oxide scales is replaced. Calculation of the oxygen consumed is performed on the basis of experiments on the oxide scale growth on steels in liquid Pb alloys. These calculations consider also the change in surface temperature caused by the growth of the oxide scales. The design data of EFIT and a realistic start-up scenario for such a system was used in the investigation. The oxygen consumption is very high in the beginning, when the metals get into contact with the lead alloy. It is a great advantage to employ structures that have already protective oxide scales or can form those during a commissioning phase at 400°C inside the reactor. Otherwise, the oxygen consumption rate would be difficult to handle. A further great improvement would be to alloy the surface of heavy loaded structure parts like the high temperature parts of fuel pins and the heat exchanger tubes with aluminum to form thin stable oxide

films, which, furthermore, have the advantage of a low thermal resistance. This surface treatment would cut down the overall oxygen consumption to less than the half of it.