Chapter 1

Executive summary

As the energy demand worldwide continues to increase, it is extremely important to decrease its CO_2 footprint, if we want to meet the *Green Deal* goals by 2050. Thanks to its load factor (80% on average), and very limited GHG emissions, the nuclear power generation industry could replace fossil fuels and be supported by renewable sources, ensuring energy production with minimal impact on the global warming crisis.

The current nuclear fleet consists of Gen I to III fission reactors, with some units of Gen III+. In the future, Generation IV reactors will have their share of adoption, as will fusion reactors; among the Generation IV designs, one of the most competitive, with the highest TRL, is the LFR. However, it presents some problems that require further investigation: for example, the corrosion resistance of structural materials at temperatures above 500 °C, therefore, significant effort is required in the R&D activities for new alloys and coating characterized by superior corrosion resistance in HLM environment. A crucial role in the corrosion resistance of materials is played by the oxygen content within the HLM system: it is therefore of major importance to investigate technologies to monitor and control it. As far as fusion reactors are concerned, one promising option is compact reactors, which will be cheaper and ready in a more reasonable timeframe than larger ones. The adoption of HTS in TF coils has made it possible to design high magnetic field fusion reactors that are smaller in size while being able to produce similar power; however, concerns have been raised about radiation damage.

This Ph.D. thesis concerns research activities related to three main objectives:

- The development of a neutron model aimed to estimate the radiation damage using a Monte Carlo code and an activation analysis tool. An operating time interval of 12.5 years was also assumed. The results showed values of dpa, KERMA rates, H and He that could compromise the superconducting properties of REBCO. Further investigations would be necessary to quantify the actual impact of such radiation damage.
- An investigation was conducted into the corrosion resistance of advanced materials in an oxygen-controlled HLM environment at T > 500 °C was carried out: two experimental campaigns in stagnant Pb and one in flowing Pb were followed. Results have shown that AFA steels and a Kanthal AF had good corrosion resistance at 650 °C and 750 °C, respectively: sporadic spots of local corrosion damage were found on these alloys, which otherwise, showed corrosion resistance via alumina formation. Pack cementation diffusion coatings have been tested in stagnant Pb at 650 °C and in flowing Pb at 550 °C: during the stagnant exposure, coating by Diffusion Alloy and Lincotek experienced Pb penetration and oxidation within the first µm of the external layer of the coating; their internal layer resulted almost unaffected, and free of Pb. The exposure in flowing Pb of two steel with Diffusion Alloy coating did not cause any corrosion damage on the coatings, which appeared almost unaffected. An austenitic 316H steel, exposed at 550 °C in flowing conditions has shown remarkable corrosion resistance through the formation of Fe-Cr passivation.
- Development of an experimental oxygen sensor where gas tightness between the zirconia probe and steel body is ensured via graphite seal fitting. Laboratory experiments on gas-tightness in dry and liquid Pb atmospheres and calibration with the theoretical electrical potential were successful. Scalability in larger structures should require minimal adjustments mainly related to the thickness of the steel body designed to absorb thermomechanical loads.