Experimental Insights into a New Generation Irradiation Resistance Fe-30Mn-5Al-1C-3Mo based alloys

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Advanced nuclear reactor concepts require novel alloy designs to circumvent irradiation-induced degradation in existing materials. Although Fe-Ni-Cr-based austenitic steels (ρ: 7.85 g-cc^{-1}) are widely adopted for various reactor core structural applications, they are susceptible to radiation-induced phase instabilities, such as void swelling, embrittlement, and irradiation-assisted stress-corrosion cracking. The present investigation explores a Ni-free alloy design in the form of a lightweight austenitic steel (Fe-30Mn-5Al-1C-3Mo, wt.%) with reduced density (~7 g-cc^{-1}), exhibiting deformation characteristics comparable to those of 316 LN at high temperatures. The defect evolution has been characterised using EBSD, ECCI, and TEM, revealing limited grain growth, the absence of the RIS effect, and network dislocations. The room-temperature and elevated-temperature mechanical properties of bulk material is evaluated using hardness (nanoindentation), uniaxial tensile, and creep tests at 650°C. The underlying mechanisms are established in post-deformed substructures using correlative microscopy and compared with SS 316 LN under similar conditions. The alloy has been subjected to 10 MeV Fe^{2+} ion irradiation at 300°C and doses up to ~8 dpa, mimicking the end of the material's lifetime under operating conditions, as shown by SDTrimSP simulations at a fluence of 5×10^{15} ions·cm^{-2}. The calculations incorporate temperature-dependent corrections, including thermally activated diffusion and dynamic target evolution, enabling a more realistic representation of high-temperature irradiation conditions. The key results of the investigation will be discussed in detail.

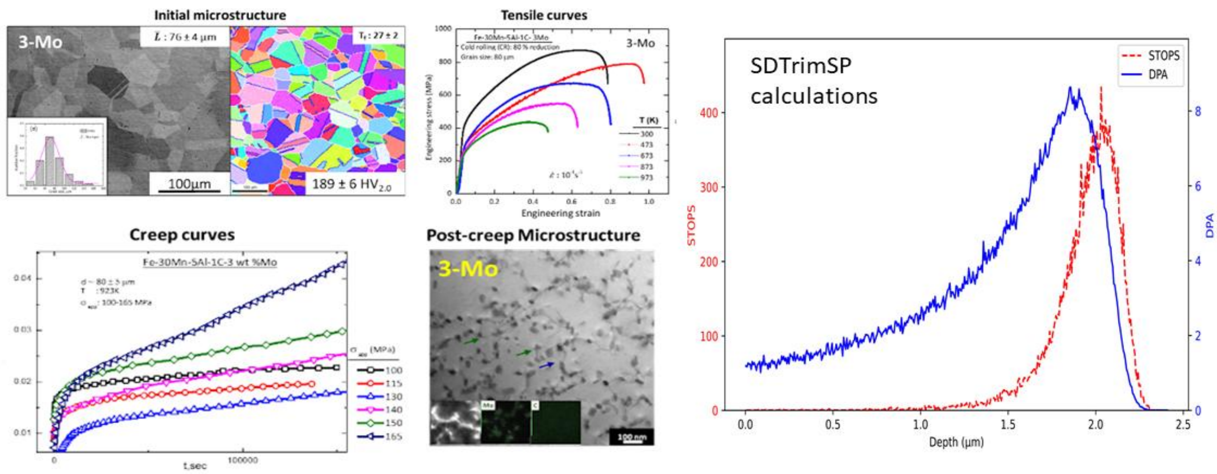

Figure 1. Initial microstructure with tensile and creep curves, and crept microstructure.

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