Effect of neutron irradiation on microstructure and mechanical properties of Eurofer-ODS alloy

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The development of new “reduced-activation materials” that decay faster than conventional alloys by several orders of magnitude is essential for the construction of future fusion power reactors. EUROFER 97 with 9 % Cr has become the European reference reduced-activation ferritic-martensitic (RAFM) steel for the fabrication of structural components for future fusion reactors. In order further to increase the operational temperature and thus the efficiency of advanced blanket concepts for fusion reactors, an oxide-dispersion-strengthened (ODS) variant of EUROFER with 0.5% Y_2O_3 was developed. The irradiation was carried out in the Petten High Flux Reactor (HFR) in the framework of the HFR Phase IIb (SPICE) irradiation project at a nominal dose of 16.3 dpa in the temperature range from 250°C to 450°C.

The EUROFER-ODS alloy demonstrated in the un-irradiated state a higher yield strength and hardness than EUROFER 97 [1]. The yield strength and hardness increases further after irradiation at 250°C, 300°C and 350°C. The material irradiated at 400°C shows in turn a lower yield strength and hardness then at 350°C, whereas their values after irradiation at 450°C remains unchanged compared to the unirradiated state.

The microstructure of neutron irradiated EUROFER–ODS with 0.5% Y_2O_3 material was characterized by TEM applying weak beam diffraction (WBDF) imaging with different ***g*** vectors to study the temperature dependent formation of radiation induced defects. The number density of radiation induced defects was found in general to be significantly lower than in EUROFER 97 irradiated at the same conditions. It was found that the appearance and extent of radiation damage strongly depend not only on the irradiation temperature but also on the local number density and size distribution of ODS particles. A higher number density of dislocation loops and voids was found in local areas with low number density of ODS particles.

Interstitial loops with Burgers vectors of ½<111> and <100> type were detected by imaging with different diffraction conditions. At 250°C ODS particles strongly suppress the formation of displacement damage clusters, whereas in specimens irradiated at 350°C both dislocation loops and cavities at the surface of ODS particles are observed. At 450°C irradiation temperature large dislocation loops with sizes >30nm were detected.

Reviewing all experimental results, it can be concluded that ODS materials have a higher radiation resistance than equivalent alloys without ODS particles. Moreover, the ODS materials with nanoclusters of high number density show a higher radiation resistance (i.e. lower defect density) at all temperatures than materials with low number density of ODS particles. The correlation of microstructure with tensile and fatigue properties will be discussed.

[1] E. Materna-Morris, R. Lindau, H.-C. Schneider, and A. Möslang Fusion Engineering and Design, **88-99** (2015) 2038

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