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FTP/P7-16: Research of Low Activation Structural Material for Fusion Reactor in SWIP

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Development of low activation structural materials is a critical path to fusion power plant. This paper briefly reviews the strategies for structural materials development in Southwestern Institute of Physics (SWIP) and the current status of the materials under investigation.
To provide material database for the China Helium-cooled ceramic breeder TBM, several 1000kg heats of CLF-1 RAFM steel have been produced with the chemical composition of Fe-8.5Cr-1.5W-0.25V-0.5Mn-0.1Ta-0.1C-0.03 N (wt. %). The material has a fully martensitic microstructure without either Laves phase or delta ferrite phases after an optimized normalizing and tempering heat treatment. A large number of material properties were evaluated, including mechanical properties and physical properties. Studies on the thermal ageing showed no obvious degradation in tensile properties even after ageing at 550℃ and 600℃ for 6000h. Various joining technologies were investigated, such as TIG welding, electron beam welding and hot isostatic pressing bonding. In addition, researches on the influence of magnetic fields on mechanical properties were carried out for understanding the applicability of the RAFM steel in fusion reactors.
A 30kg V-4Cr-4Ti alloy ingot and various Ti3SiC2 particle dispersion strengthened vanadium alloys (PDS) were developed. For SWIP-30 good control of impurities was achieved with the sum of C, N, and O less than 430wppm. Thermo-mechanical Treatment has been investigated, which increases the alloy's tensile strength significantly. The ultimate tensile strength can reach 562MPa with 7% total elongation at 700℃. Cold working before aging manifests better strengthening effect due to the strong interaction of dislocations and precipitations. PDS-vanadium alloys have much higher mechanical strength. After vacuum annealing at 1000-1200℃, the alloy can achieve 1108MPa in RT ultimate tensile strength, and total elongation of 16.8%. The alloy has ultra-fine grain of 0.5-1.5μm with <100nm dispersing Ti3SiC2 particle and ~50nm Y2O3 or YN.
A neutron irradiation campaign has been planned by SWIP for the CLF-1 steel and the irradiation will be performed. Post-irradiation properties and microstructure of the steel will be studied using miniature specimens. In 2013, the target dose level for the irradiation is up to 1dpa and the nominal irradiation temperature is 300℃.

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