Hydrogen Embrittlement Susceptibility of Conventional and Reduced Activation 9Cr-Steels

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Reduced activation ferritic/martensitic steels (RAF/MS) for DEMO structural components have been derived from the conventional 9-12Cr alloys by elemental substitution of Mo, Ni and Nb with W, V and Ta respectively for mitigating the high level waste issue. Further compositional adjustments for the purpose of improving their mechanical performances and irradiation damage resistance have led to the development of recent modified versions which actually are under characterisation within the frame of International Material Programmes.

One among other uncertainties to be solved for a safe and effective usage of RAF/MS concerns their potential susceptibility to embrittlement phenomena, due to their simultaneous exposure to thermal stresses and hydrogen generated from various sources in fusion reactor working scenarios. The nature and entity of hydrogen induced damage are well known to strongly depend on material factors, especially microstructural trap types, density and distribution, and thus may considerably differ from steel-to-steel of the same family.

The objective of this work was to compare the intrinsic propensity to hydrogen degradation of the conventional 9CrMoVNb steel, T91, to those of two 9CrWVTa RAF/MS: the experimental heat, VS3104, and Eurofer'97, which is the current reference alloy of the European strategy. For this purpose, constant extension rate tests were performed on tensile specimens pre-saturated with various amounts of hydrogen by electrochemical galvanostatic charging, and maintained at saturation during mechanical testing to avoid any hydrogen loss. Charged versus uncharged reductions of specimen areas at rupture were taken as the most suitable ductility parameters for quantifying the magnitude of hydrogen embrittlement. Immediately after testing, the specimens were subjected to a linearly increasing heating ramp in a furnace for hydrogen desorption and quantitative analysis by differential conductivity measurements. The very selective character of the extraction process gave an indirect indication of the number and strengths of the effective material defects for hydrogen trapping, while conclusions about their possible nature were drawn on the basis of microstructural assessments. Predictions concerning the implication of specific traps to the cracking process induced by hydrogen could be made with the support of scanning electron microscope fractographic analysis.