World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:11, No:04, 2017

Effect of Thermal Treatment on Mechanical Properties of Reduced Activation Ferritic/Martensitic Eurofer Steel Grade

Authors : Athina Puype, Lorenzo Malerba, Nico De Wispelaere, Roumen Petrov, Jilt Sietsma

Abstract : Reduced activation ferritic/martensitic (RAFM) steels like EUROFER97 are primary candidate structural materials for first wall application in the future demonstration (DEMO) fusion reactor. Existing steels of this type obtain their functional properties by a two-stage heat treatment, which consists of an annealing stage at 980°C for thirty minutes followed by quenching and an additional tempering stage at 750°C for two hours. This thermal quench and temper (Q&T) treatment creates a microstructure of tempered martensite with, as main precipitates, M23C6 carbides, with M = Fe, Cr and carbonitrides of MX type, e.g. TaC and VN. The resulting microstructure determines the mechanical properties of the steel. The ductility is largely determined by the tempered martensite matrix, while the resistance to mechanical degradation, determined by the spatial and size distribution of precipitates and the martensite crystals, plays a key role in the high temperature properties of the steel. Unfortunately, the high temperature response of EUROFER97 is currently insufficient for long term use in fusion reactors, due to instability of the matrix phase and coarsening of the precipitates at prolonged high temperature exposure. The objective of this study is to induce grain refinement by appropriate modifications of the processing route in order to increase the high temperature strength of a lab-cast EUROFER RAFM steel grade. The goal of the work is to obtain improved mechanical behavior at elevated temperatures with respect to conventionally heat treated EUROFER97. A dilatometric study was conducted to study the effect of the annealing temperature on the mechanical properties after a Q&T treatment. The microstructural features were investigated with scanning electron microscopy (SEM), electron back-scattered diffraction (EBSD) and transmission electron microscopy (TEM). Additionally, hardness measurements, tensile tests at elevated temperatures and Charpy V-notch impact testing of KLST-type MCVN specimens were performed to study the mechanical properties of the furnace-heated lab-cast EUROFER RAFM steel grade. A significant prior austenite grain (PAG) refinement was obtained by lowering the annealing temperature of the conventionally used Q&T treatment for EUROFER97. The reduction of the PAG results in finer martensitic constituents upon quenching, which offers more nucleation sites for carbide and carbonitride formation upon tempering. The ductile-to-brittle transition temperature (DBTT) was found to decrease with decreasing martensitic block size. Additionally, an increased resistance against high temperature degradation was accomplished in the fine grained martensitic materials with smallest precipitates obtained by tailoring the annealing temperature of the Q&T treatment. It is concluded that the microstructural refinement has a pronounced effect on the DBTT without significant loss of strength and ductility. Further investigation into the optimization of the processing route is recommended to improve the mechanical behavior of RAFM steels at elevated temperatures.

Keywords : ductile-to-brittle transition temperature (DBTT), EUROFER, reduced activation ferritic/martensitic (RAFM) steels, thermal treatments
Conference Title : ICMSNM 2017 : International Conference on Materials Science and Nuclear Metallurgy
Conference Location : London, United Kingdom
Conference Dates : April 24-25, 2017