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Helium Embrittlement of RAfm Steels

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Transmutation product helium generated in the structure materials of future fusion reactors is believed to strongly influence material embrittlement behaviour. To simulate helium effects in reduced activation ferritic/martensitic (RAFM) steels, experimental heats ADS2 (OPTIFER-VIII), ADS3 and ADS4 with the basic composition of EUROFER97 (9%Cr-WVTa) were doped with different contents of natural boron and separated 10B-isotope and irradiated in HFR Petten up to 16.3 dpa at multiple temperatures of 250-450 °C (irradiation programme HFR IIb - SPCICE). For comparative purpose and in order to exclude significant differences in the microstructure, ADS2 and ADS3 were doped with 82 wppm nat. B and 83 wppm separated 10B isotope, respectively. ADS4 was doped with 1120 wppm 10B isotope. The embrittlement behaviour and hardening are investigated by instrumented Charpy-V tests with subsize specimens. Boron-to-helium transformation lead to generation of 84, 432 and 5580 appm He in ADS2, ADS3 and ADS4 steels, respectively. At low irradiation temperatures T_{irr}≤350 °C the boron doped steels show progressive embrittlement and reduction of toughness with increasing helium amount. The analysis of the hardening vs. embrittlement behaviour at T_{irr}=250°C indicates that 84 appm helium produced in ADS2 leads to the extra embrittlement beyond that of reference EUROFER97 steel mainly due to extra, helium induced hardening. For ADS3, however, generated helium amount of 432 appm contributes to additional embrittlement mechanisms beyond that of hardening embrittlement. At T_{irr}=450°C, ADS2 does not exhibit extra embrittlement beyond that of reference EUROFER97 steel. ADS3 in contrast exhibits non-vanishing extra embrittlement also at this high irradiation temperature. Irradiation induced DBTT shift of EUROFER97 steel doped with 1120 wppm separated 10B isotope could not be quantified due to large embrittlement found in the investigated temperature range.

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