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FTP/P7-17: Research and Development Status of Reduced Activation Ferritic/Martensitic Steels Corresponding to DEMO Design Requirement

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Crucial issues on the path to fusion power are the development of plasma facing and breeding blanket materials which are capable of withstanding high neutron fluences and high heat fluxes. Reduced activation ferritic/martensitic (RAFM) steels are now considered to be the candidates for structural applications in the fusion demonstration reactor, DEMO, because they have a sound engineering basis. But it is also well recognized that the severe DEMO operating conditions, especially 14MeV fusion neutron irradiation, could cause extra degradation of mechanical properties, such as the loss of plastic deformability which is not covered by current design codes. Thus, estimation methods of materials behavior under 14MeV fusion neutron irradiation and a design methodology for highly irradiated structure have become indispensable elements in DEMO developments.
A critical issue is the materials loss of ductility under irradiation. This loss of plasticity could finally result in unstable crack propagation, when fracture or fatigue crack propagation is the failure mode. 14MeV fusion neutron irradiation effects, especially helium effects, are anticipated to enhance this irradiation induced loss of plasticity. Reports of helium effects such as extra hardening, increment of fatigue crack propagation rate, or increased ductile-brittle transient temperature shift indicate that a certain amount of helium could increase the possibility of unstable fracture. These results are based on simulation irradiation experiments, thus a mechanistic understanding of these property changes based on microstructural analyses is essential.
As of today, there are indications from many studies and helium effects can be modeled or estimated, however, it is mandatory to verify fusion neutron irradiation effects at an early date with 14MeV neutron irradiation. Above all else, the estimation and early experimental verification of the critical condition is found to be essential, up to the condition where no significant 14 MeV fusion neutron irradiation effects are expected and fission irradiation data can be used for design activity, regarding to the fact that an intense 14MeV neutron source –IFMIF - will not be available before 2020', and only the fission irradiation database and complementary modeling is available for design activity until that time.

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