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Fatigue Behavior of Ferritic/Martensitic Steels for Nuclear and Power Plant Applications

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Abstract – The stabilization of the martensitic structures is essential for the improvement of the fatigue behavior of the tempered martensite. These alloys, specially designed to fulfill operational requirements at high temperature in fusion reactor technology, exhibit attractive tensile strength properties and are microstructurally stable during subsequent ageing. However, under cyclic loading conditions, these materials show a noticeable cyclic softening up to failure. This work proposes a discussion about the evolution of the dislocation structure and fatigue response of different martensitic steels in connection with the Ms temperature of the steel and different temper treatments.

In the composition of reduced activation ferritic/martensitic steels, some traditional alloy elements like Mo, Nb and Ni are substituted by others that exhibit faster radioactive decay times [1]. In order to have a qualified material, it is necessary to perform a thorough investigation of these materials to gain knowledge about their mechanical properties. Some of these materials, like EUROFER 97 and F82H, are standards for reduced activation structural steels developed to obtain mechanical and metallurgical characteristics comparable to the properties of the commercial martensitic steels like AISI 410. In service, all these alloys will be subjected to complex thermo-mechanical cyclic loading. Such loading can be simulated by isothermal strain-controlled fatigue experiments. Therefore, investigation of the fatigue behaviour is of particular importance.

In general, the martensitic tempered alloys subject to fatigue exhibit a softening behaviour. Figures 1 and 2 show the fatigue response of EUROFER 97 and AISI 410. As it is observed in the figures, the linear stage in the curves follow an analytical expression of the type:

$$\sigma = A \times N^{-S}$$

where σ is the stress range; N is the number of cycles; A is the pre-exponential factor and **S** is the cyclic softening coefficient. Figure 3 shows that the S factor appears to be depending on both, the characteristic Ms temperature of each alloys and the test temperature.

Microstructural observations show that dislocation annihilation and rearrangement could occur during softening, thereby leading to break up of the martensite laths and to the gradual development of an equiaxed substructure. The initial high strength of hardened steels can be seriously compromised even after a low number of loading cycles, reducing their original strength and load carrying capabilities.

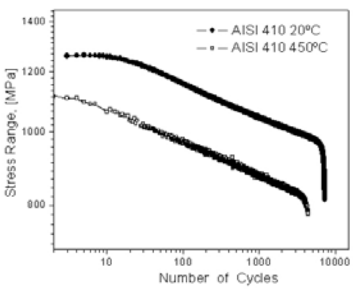

Figure 1: Cyclic softening curves of AISI 410

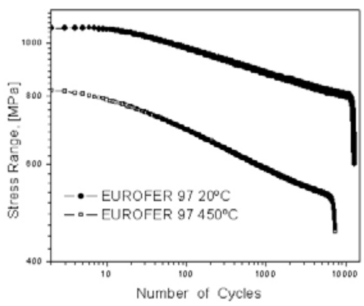

Figure 2: Cyclic softening curves of EUROFER 97

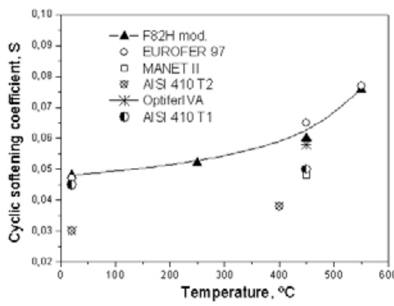

Figure 3: Cyclic softening coefficient S vs temperature

References

[1] R.L. Klueh, A.T. Nelson. J. of Nuclear Materials. 371, 1–3 (2007) 37–52.