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# HIGH TEMPERATURE LOW CYCLE FATIGUE AND CREEP-FATIGUE BEHAVIOUR OF A MODIFIED 9Cr-1Mo FERRITIC STEEL

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Modified 9Cr-1Mo ferritic steel (with alloying additions of Niobium and Vanadium and controlled amount of nitrogen) is extensively used as a structural material at elevated temperatures up to 873K in fossil-fired power plants, petrochemical industries and as a material for tubing in the reheater and super heater portions and as thick-section tube sheet material in the steam generators of Fast Reactor. In this paper the low cycle fatigue (LCF) and creep-fatigue properties of a hot-forged 9Cr-1Mo steel in normalized and tempered condition are presented. The steel was obtained in the form of forged rods of 70 mm diameter. The normalizing treatment was carried out at 1313 K for 1 h plus air cooling and tempering was done at 1033 K for 1 h plus air-cooling. LCF tests were carried out at a constant strain rate of $3 \times 10^{-3}$ $s^{-1}$ at different strain amplitudes (±0.25% to ±1.0%) in the temperature range 300-873 K and influence of strain rate was studied employing strain rates of $3 \times 10^{-4}$, $3 \times 10^{-3}$ and $3 \times 10^{-2}$ $s^{-1}$ in the temperature range, 773 to 873 K. In addition, a few tests were conducted on specimens thermally aged 10,000 h at different temperatures. Creep-fatigue interaction tests were performed by introducing tensile hold times in the range 1 min to 30 min at 823 K and 873 K.

The cyclic stress response behaviour, in general, showed an initial brief hardening for the first few cycles, followed by a gradual and continuous softening regime. Fatigue life was found to decrease with increase in the testing temperature and decrease in strain rate. Extensive crack branching and formation of secondary cracks marked the fatigue failure at high strain amplitudes and high strain rates of testing. Oxidation-assisted crack initiation and propagation contributed to life reduction at high temperatures and low strain rates. The lower strain rates at elevated temperature provide adequate time for the environmental interaction to take place, which accelerates both the crack initiation and propagation phases. In contrast, under conditions of low temperatures and high strain rates, oxidation effects were not significant.

It is seen that the fatigue life decreases with increase in hold time up to 30 min. This has been found to be associated with the influence of oxidation in fatigue. The fatigue life values observed in the present study under different testing conditions are plotted as a function of total strain amplitude and compared with the data available in the open literature and the best-fit curve deduced from the

French RCC-MR design code. Further, the capability of artificial neural network (ANN) approach to life prediction under LCF and creep-fatigue interaction conditions has been assessed by using the data from the literature and that generated in our laboratory. It is demonstrated that the predictions are well within a factor of two.

In this paper the current understanding developed on the effects of temperature, strain range, strain rate and hold time on the LCF behaviour of modified 9Cr-1Mo steel are discussed and the observed fatigue behaviour is explained with evidences from metallography and fractography.