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Analysis of cyclic plastic response of heat resistant Sanicro 25 steel at ambient and elevated temperatures

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Abstract

Austenitic heat resistant steel Sanicro 25 developed for high temperature applications in power generation industry has been subjected to selected low cycle fatigue tests at ambient and at elevated temperature. Saturated hysteresis loops at both temperatures were analyzed to deduce the probability density distribution of the internal critical stresses and to estimate the contribution of the effective stress for different strain amplitudes. The internal structure of the material at room and elevated temperature was studied using transmission electron microscopy and the results were discussed in relation to the cyclic stress-strain response

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Keywords: heat resistant steel, Sanicro 25, cyclic plasticity, dislocation structure, effect of temperature

1. Introduction

Austenitic stainless steel Sandvik Sanicro 25 has been developed for applications at elevated temperatures, namely for construction of supercritical boilers [1,2]. Mostly creep behavior and high temperature corrosion and to a certain extent also low cycle fatigue properties were studied [2].The present paper is devoted to the comparison of the cyclic stress-strain behavior at ambient and at elevated temperature and to the study of dislocation arrangement produced by cyclic straining at ambient and elevated temperatures.

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2. Experimental

Experimental material was supplied by Sandvik, Sweden in the form of the cylindrical rod of 150 mm in diameter. The chemical composition of the material can be found elsewhere [2]. Cylindrical specimens for cyclic straining at room and elevated temperatures were machined with the axis parallel to the rod. The gauge length and diameter of specimens were 14 mm and 8mm respectively for room temperature testing and 15mm and 6 mm for elevated temperature testing. Specimens were homogenized at 1200 °C for 10 minutes and cooled in air. Afterwards final grinding was done.

Cyclic straining was performed in computer-controlled electrohydraulic MTS system. Constant strain rate $5x10^{-3}$ s^{-1} was applied at room temperature and $2x10^{-3}$ s^{-1} at temperature 700 °C. High number of data points was recorded for each hysteresis loop. Hysteresis half-loops in relative coordinates were smoothed and digitally differentiated and the first and second derivatives of both tensile and compressive half-loops could be obtained in agreement with the statistical theory of the hysteresis loop [3]. The section of the plot of the second derivative vs. fictive stress corresponding to the probability density function of the internal critical stresses was fitted by the Weibull function.

Thin foils for the transmission electron microscopy were prepared using standard procedures from sections taken at 45 degrees to the specimen axis. They were studied in a transmission electron microscope STEM Philips CM-12 operating at 120 kV using a double tilt holder and a MegaView II digital camera.

3. Results

Fig. 1 shows the plot of the stress amplitude vs. number of cycles during several blocks of constant strain amplitude loading with suddenly increasing total strain amplitude at room temperature and at temperature 700° C. Number of cycles at each level N_i was inversely proportional to the applied total strain amplitude ε_{ai} so that $N_i\ \varepsilon_{ai}$ = 20. Room temperature cycling results in cyclic softening at all strain levels. When the strain amplitude suddenly increases, the stress amplitude increases too but later cycling leads to cyclic softening. Identical cyclic straining at temperature 700 ° results in cyclic hardening at all strain levels. In both cases the saturated levels of the stress amplitude were not achieved and thus the final data points cannot be used for the construction of the cyclic stress-strain curve.

Hysteresis loops recorded at the end of each block of strain amplitudes are plotted in relative coordinates (origin of coordinates of each loop was chosen the minimum strain and stress in each loop) in Fig. 2. The non-Masing behavior, as widely denoted [4], is apparent in cycling at both temperatures. It means that the shape of the smaller hysteresis loops cannot be derived from the shape of the largest hysteresis loop. At room temperature the small loops are higher than the corresponding part of the largest loop and at high temperature the small loop is well below the corresponding part of the largest loop.

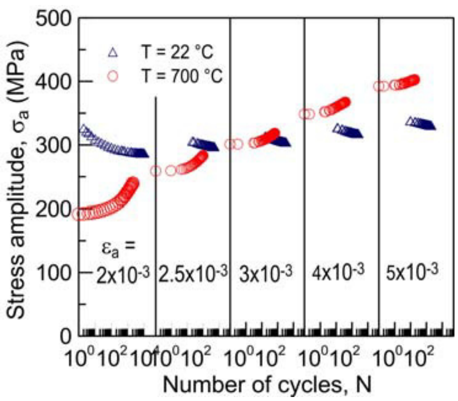

Fig. 1. Stress amplitude vs. number of cycles in loading with increasing strain amplitudes at two temperatures.