EXPERIMENTAL EVALUATION OF DAMAGE IN MATERIALS UNDER CREEP AND FATIGUE CONDITIONS

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Abstract: *Creep and fatigue damage was investigated in steels commonly applied in power plants (40HNMA, 13HMF and P91) using destructive and non-destructive methods. In order to assess both types of damage the tests for each kind of steel were interrupted for a range of the selected time periods (creep) and number of cycles (fatigue).*

1. Introduction

In order to assess damage during exploitation processes the tests for each kind of steel were interrupted for a range of the selected time periods (creep) and number of cycles (fatigue). As destructive methods the standard tension tests were carried out after every kind of prestraining. Subsequently, an evolution of the selected tension parameters was taken into account for damage identification. The ultrasonic and magnetic techniques were used as the non-destructive methods for damage evaluation. In the final step of the experimental programme microscopic observations were performed. In the case of ultrasonic method the acoustic birefringence coefficient was used to identify a damage degree in the steels tested. In the case of magnetic technique the classical Barkhausen effect (HBE) and magnetoacoustic emission (MAE) were measured.

Taking into account the results for the pre-fatigued 13HMF steel it is easy to note that this material in terms of typical stress parameters is almost insensitive to fatigue prestraining, i.e. the yield point and ultimate tensile stress variations are rather small. An opposite effect can be observed for the same material prestrained under creep conditions. In this case the prior deformation leads to the hardening effect. Details of investigations on the 40HNMA and P91 steels were described earlier by Kowalewski et al. [1] and Augustyniak et al. [2]. The results for creep prestrained 40HNMA steel exhibited significant effect of softening. For all steels in question the same effect was achieved in the case of prestraining induced by means of plastic deformation at room temperature, i.e. hardening.

The ultrasonic and magnetic techniques were used as the non-destructive methods for damage evaluation. The results indicate that the acoustic birefringence, Ub_{pp} - measure of the HBE and Ua_{pp} - measure of the MAE are sensitive to the amount of prior deformation. Having parameters of destructive and non-destructive methods of damage assessments their mutual relationships were considered in order to find their character. The results exhibited that magnetic techniques can be very sensitive to degradation development for the small strain levels (up to 2%), and almost insensitive above that value. The ultrasonic techniques gave a completely opposite assessment: very poor sensitivity for small deformations and good for deformations greater than 2%. Hence, it seems to be reasonable to use them together: in the first period of operation - magnetic methods, in the subsequent stages – ultrasonic ones.

In the case of material prestrained due to fatigue the destructive tests gave no clear assessment of material degradation, because the basic mechanical parameters (i.e. yield point and ultimate tensile stress) underwent increased. Therefore, in order to assess a degree of fatigue damage the alternative techniques were proposed. Investigations were performed in which variations of the hysteresis loop width were evaluated under constant stress amplitude. These studies have shown that this type of procedure gives an opportunity to assess a supply of the safe operation period of the material, and there is no need for so many experiments, as this is required for the Wöhler diagram determination. Moreover, an identification of damage measures was carried out. The behaviour of metals under fatigue, can be divided into two basic types of mechanisms in terms of the damage development. The first group is described by the ratcheting (a shift of the hysteresis loop as a result of the strain mean level increase), generated by local deformation around the voids, non-metallic inclusions and other defects in the microstructure, whereas the second one by cyclic plasticity (a gradual increase of the hysteresis loop width) generated at the local level grains by dislocation motion and slip bands. In both cases, the strain changes measured for the entire sample volume are the sum of local deformations developing around defects in the form of non-metallic inclusions and voids (first group) or developing slips within individual grains (second group). Both fatigue damage measures are well presented in Fig. 1.

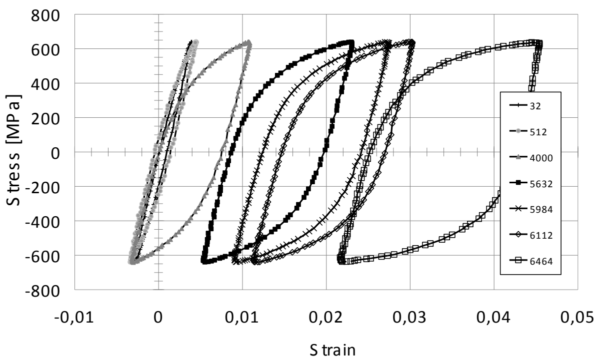

FIGURE 1. Strain evolution during fatigue of the P91 steel under stress amplitude of 640 MPa

2. References

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[2] Augustyniak B., et al.,: Comparison of properties of magnetoacoustic emission and mechanical Barkhausen effects for P91 steel after plastic flow and creep, *IEEE Tran. Mag.*, **4**, No 11, 2008, pp. 3273-3276.