INTERDISCIPLINARY METHODS FOR DAMAGE ASSESSMENT OF MATERIALS SUBJECTED TO CREEP AND FATIGUE

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1. Introduction

Many testing techniques commonly used for damage assessments have been developed up to now. Among them we can generally distinguish destructive and non-destructive methods [1, 2]. Having the parameters of destructive and non-destructive methods for damage development evaluation it is instructive to analyze their variation in order to find possible correlations. This is because of the fact that typical destructive investigations, like creep or fatigue tests, give the macroscopic parameters characterizing the lifetime, strain rate, yield point, ultimate tensile stress, ductility, etc. without any information concerning microstructural damage development and material microstructure variation. On the other hand, non-destructive methods provide information about damage at a particular time of the entire working period of an element, however, without sufficient information about the microstructure and how it varies with time. Therefore, it seems reasonable to plan damage development investigations in the form of interdisciplinary tests connecting results achieved using destructive and non-destructive methods with microscopic observations in order to find mutual correlations between their parameters. This is the main issue considered in this paper.

2. Experimental procedure and results

Damage development during creep and fatigue was investigated using destructive and non-destructive methods in steels commonly applied in power plants (40HNMA, 13HMF and P91). In order to assess damage during such type processes the tests for each kind of steel were interrupted for a range of the selected time periods (creep) and number of cycles (fatigue). The standard tension tests of specimens prestrained due to creep or fatigue were carried out as destructive method of damage assessment. Subsequently, an evolution of the selected tensile parameters was taken into account for damage identification. Taking into account the results for the pre-fatigued 13HMF steel, Fig.1, 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 [1, 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 MBE (magnetic Barkhausen emission) and Ua_{pp} - measure of the MAE (magnetoacoustic emission) 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%.

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 to increase. Therefore, in order to assess a degree of fatigue damage the alternative techniques were proposed. The Wöhler diagram was determined as the first step of fatigue tests on the 13HMF and P91 steels. It represents the number of cycles necessary to failure under given stress amplitude. In the case of 13HMF steel this diagram was determined for the material in the as-received state and after exploitation (80 000h). Both Wöhler diagrams differ significantly, identifying a fatigue strength reduction due to the loading history applied. In the second step of fatigue investigations the tests were performed in order to assess variations of the hysteresis loop width under constant stress amplitude.

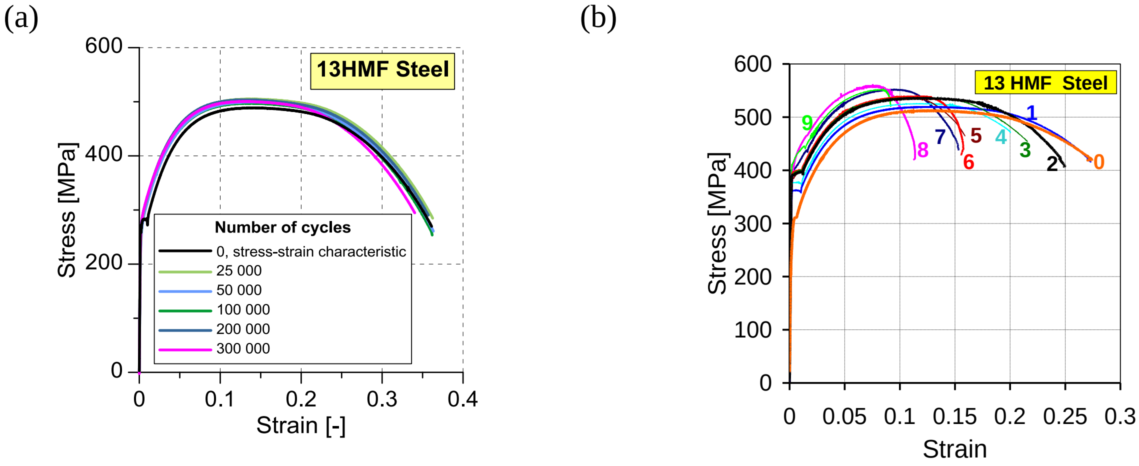

Fig. 1. Tensile characteristics after fatigue (a) and creep (b) prestraining for the 13HMF steel (numbers in the right diagram identify time to stop of creep test: 1 - 149h, 2 - 300h, 3 - 360h, 4 - 407h, 5 - 441h, 6 - 587h, 7 - 664h, 8 - 796h and 9 -1720h; 0 – as-received material).

The results of these tests enabled damage identification under fatigue conditions. Two basic types of mechanisms in terms of the damage development can be distinguished. The first group is described by the ratcheting, whereas the second one by cyclic plasticity. 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).

3. Conclusion

The results of parallel destructive and non-destructive tests on the prestrained power engineering steels enabled determination of damage sensitive parameters which were afterwards correlated, thus giving new tools for better predictions of damage development in materials subjected to creep or fatigue.

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4. References

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