ON THE EXPERIMENTAL ATTEMPTS FOR CREEP ANALYSIS OF MATERIALS

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Abstract: Development of creep damage was investigated using destructive and non-destructive methods in materials commonly applied in power plants or automotive industry. In order to reflect damage evolution of different materials, the tests were interrupted for selected time periods. A method for multiaxial creep data analysis is also presented.

1. Introduction

Many testing techniques commonly used for damage assessments have been developed up to nowadays. Among them one can generally distinguish destructive and non-destructive methods. Having the parameters of destructive and non-destructive methods for damage development evaluation it seems to be reasonable their further analysis that should provide possible mutual correlations [1]. This is because of the fact that typical destructive investigations, like standard tests, give the macroscopic parameters characterizing the lifetime, strain rate, yield point, ultimate tensile stress, ductility, etc. without sufficient knowledge 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 knowledge 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. Results

The results from uniaxial creep tests are not able to reflect complex material behaviour. Therefore, many efforts are focused on tests carrying out under multiaxial loading conditions. The well-known method of creep rupture data from such tests analysis is through isochronous stress-strain curves obtainable from the standard creep curves [2]. It gives comprehensive graphical representation of material lifetime. The curves of the same time to rupture determined on the basis of experimental programme are compared in Fig.1 with theoretical predictions of the three well known creep rupture hypotheses:

(a) the maximum principal stress rupture criterion,
(b) the Huber-Mises effective stress rupture criterion,
(c) the Sdobyrev creep rupture criterion.

As it is clearly seen, the best fit of the aluminium alloy data is obtained using the effective stress rupture criterion. It has to be noting however, that the lifetimes predicted by this criterion are still quite far from experimental data.

The second part of this paper is devoted to experimental assessments of damage development in steel commonly used in contemporary power plants.

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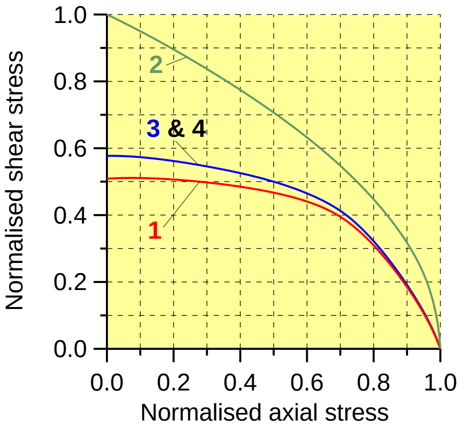

Figure 1. Comparison of the isochronous creep rupture surfaces (t_r = 500 [h]) determined for aluminium alloy (1 - experimental results; 2, 3, 4 – criterion of the maximum principal stress; effective stress; Sdobyrev, respectively)

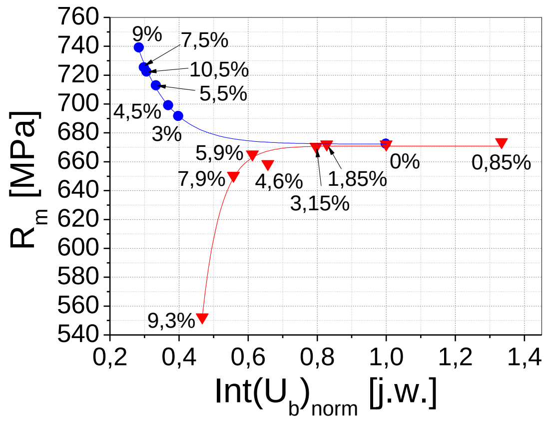

Figure 2. Variation of ultimate tensile stress of the X10CrMoVNb9-1 steel versus integral over half-period voltage signal of the magnetic Barkhausen emission (triangles – after creep; circles – after plastic flow)

Destructive and non-destructive testing techniques were applied. In order to assess damage using destructive method the specimens after different amounts of prestraining were stretched to failure. Afterwards, the selected tension parameters were determined (yield point, ultimate tensile stress) and their variations were used for identification of damage development. Ultrasonic and magnetic investigations were selected as the non-destructive methods for damage evaluation. For the ultrasonic method, the acoustic birefringence coefficient was used to identify damage development in the tested steel. In the case of magnetic method a several damage sensitive parameters were identified, e.g. amplitude of Ub or Ua envelopes reflecting the Barkhausen effect (HBE) or magneto-acoustic emission (MAE) variation, respectively, their integrals, and coercivity. Having selected parameters of destructive and non-destructive techniques, possible relationships between them were evaluated. The representative relationships are illustrated in Fig. 2. As it is seen, except specimen prestrained up to 10.5% due to plastic flow, all results are ordered, and as a consequence, they can be well described by adequate functions depending on the type of prior deformation and its level. Similar remark concerns the data for the steel after creep. The results clearly indicate that selected ultrasonic and magnetic parameters can be good indicators of material degradation and can help to locate the regions where material properties are changed due to prestraining.

3. Conclusions

It is shown that isochronous surface concept may serve as the effective technique for the multiaxial creep data presentation.

The paper is also devoted to damage analysis due to creep or plastic flow using interdisciplinary approach. The results exhibited that selected damage sensitive parameters of destructive and non-destructive methods can be correlated giving as a consequence more thorough knowledge of material degradation.

References

[1] K. Makowska, Z.L. Kowalewski, B. Augustyniak, L. Piotrowski. Determination of mechanical properties of P91 steel by means of magnetic Barkhausen emission. *Journal of Theoretical and Applied Mechanics*, 2014;52: 181-188.

[2] Z.L. Kowalewski. Isochronous creep rupture loci for metals under biaxial stress. *Journal of Strain Analysis Eng. Des.*, 2004;39:581-593.