CORRELATION OF PARAMETERS DETERMINED USING DESTRUCTIVE AND NON-DESTRUCTIVE TESTING METHODS AS A TOOL OF MATERIAL DEGRADATION ASSESSMENT

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ABSTRACT – Development of creep damage at elevated temperatures and structural degradation due to plastic deformation at room temperature were assessed in steels (40HNMA, 13HMF and P91) commonly applied in power plants using destructive and non-destructive methods.

INTRODUCTION: There are many testing techniques commonly used for damage assessments. Among them we can generally distinguish destructive, and non-destructive methods. Having the parameters of destructive and non-destructive methods for damage development evaluation it is worth to analyze their variation in order to find possible correlations. The ultrasonic and magnetic techniques were selected as the non-destructive methods for damage development evaluation. 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.

PROCEDURES, RESULTS AND DISCUSSION: As destructive methods the standard tension tests were carried out after prestraining of materials. Subsequently, an evolution of the selected tensile parameters was taken into account for damage identification. In order to assess a damage development during the creep and plastic deformation the tests on steels were interrupted for a range of selected strain magnitudes. The representative results of tensile tests for the P91 and 13HMF are presented in Fig.1. Taking into account the results presented for the P91 steel in Fig. 1a it is easy to note that this material in terms of typical stress parameters is almost insensitive on creep prestraining, i.e. the yield point and ultimate tensile stress variations are rather small. Only the extension is reduced significantly. An opposite effect can be observed for the 13HMF prestrained in the same way (creep conditions). In this case the prior deformation leads to the hardening effect. Details of investigations on the 40HNMA steel were described earlier by Kowalewski et al. [2008, 2009] 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. the hardening. In Fig.2a it was expressed for the 13HMF steel by variation of yield point with an increase of prior deformation.

(a) (b)

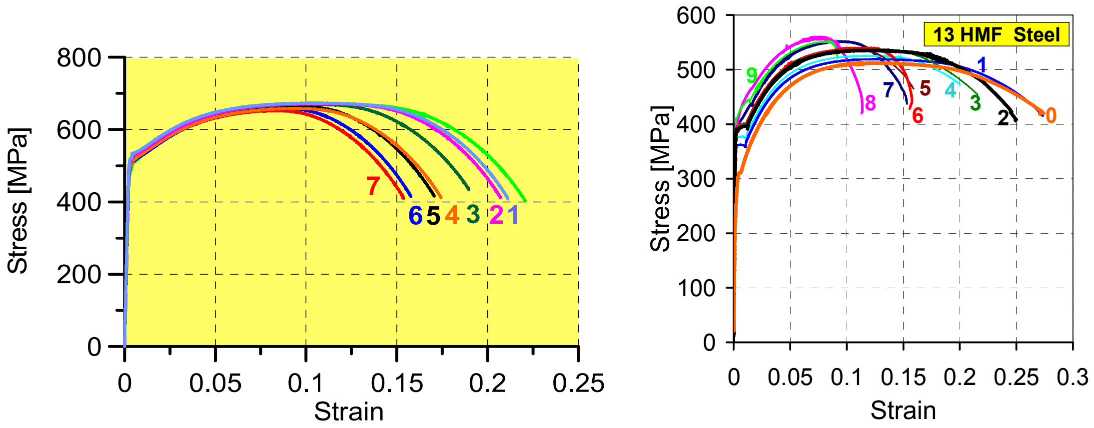
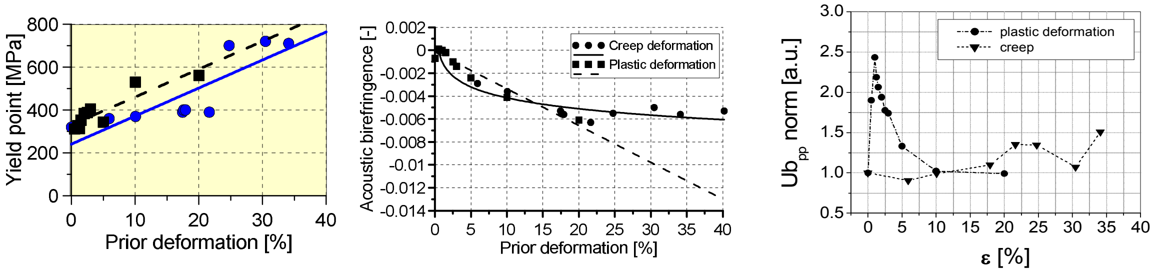


Fig. 1. Tensile characteristics after creep prestraining for: (a) P91 steel - 40h (1), 180h (2), 310h (3), 390h (4), 425h (5), 440h (6) and 445h (7); (b) 13HMF steel - 149h (1), 300h (2), 360h (3), 407h (4), 441h (5), 587h (6), 664h (7), 796h (8) and 1720h (9).

The ultrasonic and magnetic techniques were used as the non-destructive methods for damage evaluation. Some selected results of such investigations are shown in Figs 2b, 2c for the 13HMF steel. Figure 2b presents mean values of the acoustic birefringence measured in specimens after creep or plastic deformation. The plots presented in Fig. 2b indicate that the acoustic birefringence is sensitive to the amount of prior deformation. Another advantage of this parameter was achieved in the case of the 40HNMA investigations. Namely, it was very sensitive to the form of prior deformation. For specimens prestrained due to creep the increase of this parameter was observed with the increase of prior deformation. An opposite effect was achieved for specimens prestrained due to the plastic deformation at room temperature, i.e. with the increase of prior deformation a decrease of the birefringence was obtained. The effects appeared for the 40HNMA steel were not confirmed by the ultrasonic tests carried out on the 13HMF steel. In this case the same tendency may be observed independently on a type of prior deformation, i.e. a degrease of the acoustic birefringence with an increase of deformation level.



(a) (b) (c)

Fig. 2. Variation of: (a) yield point; (b) Barkhausen effect measure (Ub_{pp}); (c) acoustic birefringence as a function of prior deformation level for the 13HMF steel.

Having parameters of destructive and non-destructive methods of damage assessments their mutual relationships were considered in order to find their character. The representative results are presented in Fig.3 for the 13HMF steel. Similar variation trends of the parameters mentioned above are also observed for the P91 and 40HNMA steels.

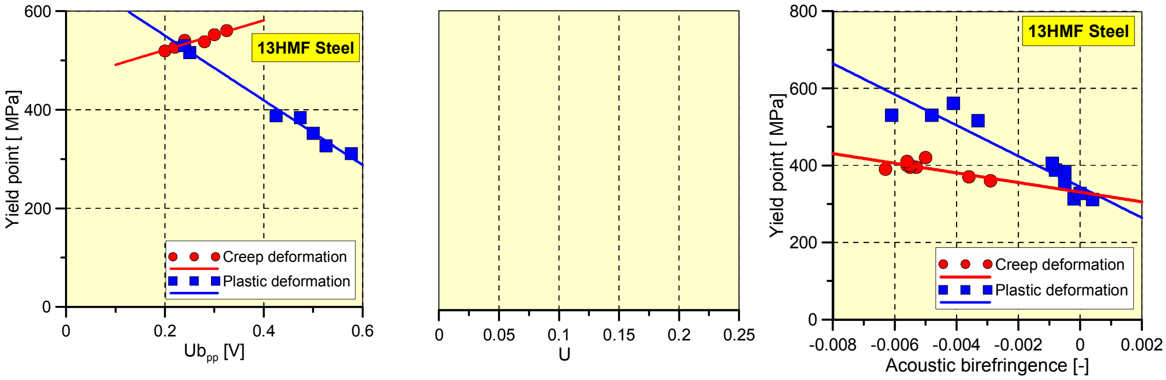

(a) (b) (c)

Fig. 3. Illustration of mutual relationships between the yield point and damage sensitive parameters of non-destructive investigations: (a) Ub_{pp} - measure of the HBE; (b) Ua_{pp} - measure of the MAE; (c) acoustic birefringence.

As it is seen (Fig. 3) the yield point variation exhibits with good agreement the linear relationships with respect to the damage sensitive parameters of selected non-destructive methods. The same result was also achieved for the ultimate tensile stress. Knowledge of such behaviour of the materials tested enables better predictions of the remaining lifetime of industrial elements on the basis of non-destructive monitoring of exploited constructions, and as a consequence, provides a basis for new promising experimental method of damage analysis.

CONCLUSIONS: In order to evaluate damage progress in specimens made of the steels tested the acoustic birefringence measurements was successfully applied. In the case of magnetic investigations the measurements of the Barkhausen effect (HBE) and the magneto-acoustic emission (MAE) were applied. It is shown that magnetic parameters used as a measure of these effects are sensitive not only to the magnitude of prior deformation, but also to the way of its introduction.

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REFERENCES:

Kowalewski, Z.L., Szelążek, J., Mackiewicz, S., Pietrzak, K., Augustyniak, B., 2008, ”International Journal of Modern Physics Letter B”, **22**, No 31/32, 5533.

Kowalewski, Z.L., Szelążek, J., Mackiewicz, S., Pietrzak, K., Augustyniak, B., 2009, “Journal of Multiscale Modeling”, **1**, No 3&4, 479.