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ASSESSMENT OF MATERIAL DEGRADATION BY MEANS OF ACOUSTIC BIREFRINGENCE AND ELASTOACOUSTIC COEFFICIENT

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1. Introduction

Ultrasonic method, that characterises a fast execusion of measurement and its relatively low cost, is the one of non-destructive techniques most often used for damage assessments. It has to be noticed, however, that the conventional ultrasonic parameters, e.g. ultrasonic wave velocity and attenuation coefficient have some limits in appliacation [1]. The difficulty in measuring of the both parameters appears in the case of material microstructure heterogeneity, surface roughness, and additionally, taking into account the wave velocity – in assessment of a thickness of the elements tested [2]. It hast to be also mentioned that the ultrasonic wave velocity and attenuation coefficient allow to detect material damage in the late stage of material exploitation, when voids are already created [2].

The paper presents an attempt for application of two other ultrasonic parameters such as acoustic birefringence and elastoacoustic coefficient in the early stage of degradation of medium carbon steel after plastic deformation and accelerated creep. The acoustic birefringence is based on a velocity difference between two shear waves polarized in the mutually perpendicular directions [3]. Its variation is attributed to the material texture (grain orientation, oriented voids resulted from creep for example) that changes itself during loading of a material [4]. The measurements are usually carried out using the same ultrasonic probes, rotated about 90º (ultrasonic beam goes through the same thickness of material and reflects from the same area of the opposite surface [2]). In this way the errors related to the construction design and heterogeneity of a material can be eliminated. The elastoacoustic coefficient represents a proportionality factor between stress and relative changes of the wave velocities [2]. In the measurements of elastic coefficient a phenomenon of the elastoacoustic effect is used. This effect is explained on the basis of nonlinear elasticity theory. According to it the wave velocity depends on stress introduced into a material [5].

The results of our investigations gave knowledge whether the changes in microstructure and mechanical properties may be detected in the early stage of material exploitation by ultrasonic technique.

2. Experimental procedure

The specimens of power plant steel were subjected to plastic deformation or accelerated creep. Each process was interrupted for a range of the selected time periods in order to achieve specimens with increasing level of prestrain. After each loading process the specimens were tested using ultrasonic technique.

The acoustic birefringence was calculated according to the following relationship:

$$B = 2\frac{t_{Tl} - t_{Tp}}{t_{Tl} + t_{Tp}} \qquad (1)$$

where:
t_{Tl} – time of flight of the shear wave for longitudinal polarization direction;
t_{Tp} – time of flight of the shear wave for perpendicular polarization direction.

The times of flight of the ultrasonic waves were measured by the echo method. The elastoacoustic coefficient was determined using the following equation:

$$\beta = \frac{t_0 - t_\sigma}{t_\sigma} \cdot \frac{1}{\sigma} \qquad (2)$$

where:

t_0 – time of flight of ultrasonic wave in the unloaded material,
t_σ – time of flight of ultrasonic wave in the uploaded material,
β – elastoacoustic coefficient,
σ – stress within the range of elasticity.

The times of flight of the ultrasonic waves were measured by through-transmission method. Subsequently, static tensile tests and microstructural investigations were carried out. Finally, the relationships between parameters determined by means of the non-destructive and destructive methods were found.

3. Selected results

The experiment was carried out on two series of the 40HNMA steel that consists of sorbite microstructure with remaining the needle martensite configuration. First series came from unexploited material subjected to quenching and tempering, while the second one was cut off from the exploited tube. In both cases the same conditions of creep testing were applied (σ = 250MPa, T = 500ºC).

In the case of 40HNMA steel without prior loading history a decrease of the acoustic birefringence was observed for specimens after plastic deformation and accelerated creep (Fig. 1). Variations of the acoustic birefringence were caused by the rotations of material grains. During this process they try to set themselves parallel to the stress direction enforcing a deformation [4]. The higher values of the coefficient for the steel after creep are explained by annihilation of material defects due to temperature of the process.

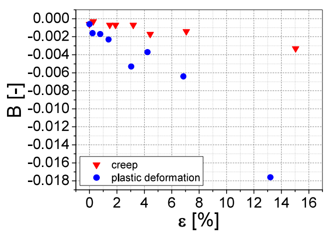

Fig. 1. Variation of the acoustic birefringence for the 40HNMA steel after quenching and tempering versus strain.

In the case of 40HNMA steel cut off from the tube an increase of the acoustic birefringence for specimens after creep was identified (Fig. 2). It is caused by an occurrence of microcracks in the material matrix.

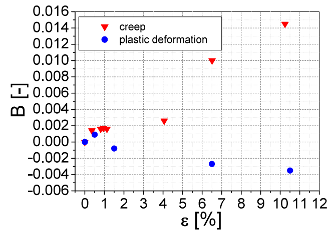

Fig. 2. Variation of the acoustic birefringence for the 40HNMA steel cut off from the exploited tube versus strain [3].

4. Conclusions

- The acoustic birefringence might be useful in assessment of a state of material degradation in the late stage of material exploitation.
- A variation of the elastoacoustic coefficient was observed in the early stage of exploitation for the 40HNMA steel cut off from the tube and subjected to accelerated creep. The parameter was not sensitive on damage development in the advanced stage of material exploitation.

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