39th Solid Mechanics Conference
Zakopane, Poland, September 1–5, 2014

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MICROSTRUCTURAL ASSESSMENT AND MAGNETIC STRUCTUROSCOPY OF MIDDLE-CARBON STEEL AFTER SIMULATED CREEP

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1. General

The paper describes an application of magnetic methods for evaluation of the exploitation period, microstructural degradation and mechanical property variations of the middle carbon steel after simulated loadings at high temperature. The research dealing with an assessment of mechanical properties using magnetic non-destructive techniques is called as a magnetic structuroscopy [1–3]. In this paper, magnetic techniques based on measurements of the magnetic Barkhausen noise and magnetoacoustic emission were applied. These methods are potentially useful for damage identification of ferromagnetic materials.

Magnetic Barkhausen noise (MBN) is the result of the irreversible movement of magnetic domain walls during a magnetisation cycle [4]. Domain walls are pinned by microstructural barriers and released abruptly in the changing magnetic field [5]. The barriers that break domain wall movement are the grain boundaries, dislocations, precipitates [4] and voids [5], for example. A movement of the 90° domain walls generates acoustic waves that are known as the magnetoacoustic emission (MAE) [6]. This is a consequence of local volume changes in the materials having non-zero magnetostriction. The acoustic waves can be detected by the piezoelectric transducers.

2. Material and experimental procedure

Two series of specimens manufactured using the 40HNMA steel commonly applied in the power industry were tested. The specimens of the first series were cut out from a flat delivered in the as-received state, and subsequently, they were quenched and tempered (cooling in oil) at temperature of $T = 850°\text{C}$ and $T = 500°\text{C}$, respectively. The specimens of the second series were cut out from a piece of pipe after its prior exploitation. We decided to produce specimens from the exploited pipeline since we expected creating voids in them during laboratory creep tests in relatively short time.

Both series of specimens were subjected to accelerated creep ($\sigma = 250$ MPa, $T = 500°\text{C}$). Additionally, the specimens cut out from the flat were subjected to plastic deformation at room temperature. Each prior deformation process was interrupted for a range of the selected time periods in order to achieve specimens with increasing level of strain. In the next step, non-destructive measurements were carried out. The yield point and ultimate tensile stress were determined on the basis of static tensile test. An evolution of material microstructure was extensively studied. Finally, the relationships between pre-strain level and parameters determined by means non-destructive methods were analysed.

3. Selected results

Figure 1 shows variations of the integral of half-period voltage signal of the magnetic Barkhausen emission $Int(U_b)$ and yield point $R_{0.2}$ of the 40HNMA steel cut out from the flat as a function of the creep pre-strain. As it is clearly seen, a trend of changes for both parameters is opposed. Moreover, both parameters are very sensitive into prior deformation either at the first or second stages of the accelerated creep. The relationships between $R_{0.2}$ and $Int(U_b)$ are presented in Fig. 2. In the case of plastic deformation linear relation between both parameters was found. It was also observed that the values of $Int(U_b)$ after plastic deformation are higher than those of $Int(U_b)$ after accelerated creep.

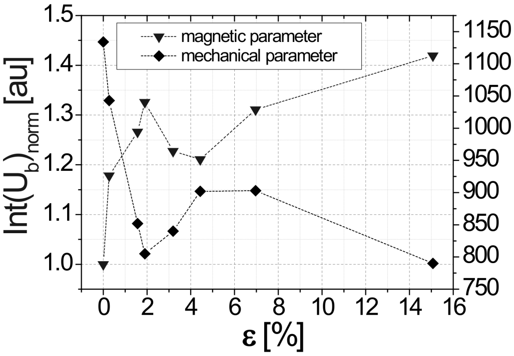

Fig. 1. Integral of half-period voltage signal of the magnetic Barkhausen emission $Int(U_b)$ and yield point $R_{0.2}$ versus pre-strain for the 40HNMA steel after laboratory creep.

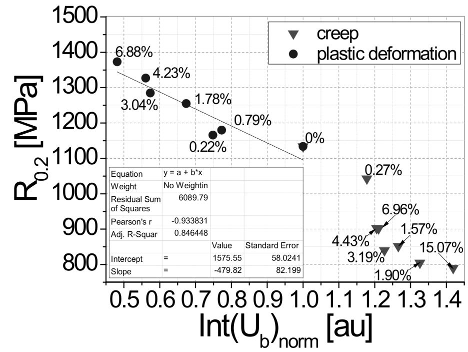

Fig. 2. Variation of yield point of the 40HNMA steel after accelerated creep/plastic deformation versus integral over half-period voltage signal of the magnetic Barkhausen emission: $Int(U_b)$.

4. Conclusions

The magnetic parameters, like the integral of voltage signal of the magnetic Barkhausen emission $Int(U_b)$ for example, are very sensitive into prior deformation at first and second stages of the accelerated creep. Parameters determined on the basis of non-destructive tests may be helpful in estimation of the basic mechanical properties of the prestress materials.

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