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BARKHAUSEN NOISE TECHNIQUE IN ASSESSMENT OF STRUCTURAL STEEL WITH PRE-DEFORMATION

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1. Introduction

Determination of mechanical properties is very important for construction safety, because this reflects data that may be directly used in engineering calculations as well as in assessments of a state either material or entire structure. It has to be mentioned, that destructive tests require removing a certain layer of material from the components for the preparation of specimens. Unforeseen deformations of materials may also occur and significantly affect the safety of the structures taken into account. Such cases can hold the operational processes or their inspection may be conducted too late to identify the critical state. Therefore, a fast non-destructive testing methods such as the Barkhausen noise (BN) technique, for example, may help significantly in material degradation diagnostics. The BN method enables to evaluate a degree of material deformation or damage and to determine the most important their parameters. In [1] was found that BN is sensitive to dislocation tangles introduced as a result of plastic deformation. It means that a stage of initial material deformation can be identified effectively.

2. Material and methods

The 41Cr4 (EN 10083-3, 40H) steel was selected due to its wide application in the automotive industry for manufacturing the following components: crankshaft bearings, front axles, steering parts, gears and grinding wheels.

The experimental procedure comprised two stages – monotonic tension up to selected values of total deformation and BN measurements. Mechanical tests were carried out at room temperature using a flat specimens, 8802 Instron servo-hydraulic testing machine, and 2630 Instron uni-axial extensometer. The width, gauge length and thickness of specimen measuring part were equal to 10 mm, 25 mm, and 3 mm, respectively. The specimens were loaded monotonically under strain control under velocity of 0.005 mm/mm. The test was interrupted for 9 strain levels up to 14%. The following levels of the deformation were applied: 1%, 2%, 3%, 4%, 6%, 8%, 10%, 12%, 14%. The specimen was unloaded after each pre-strain. Yield point (YP) and elastic limit (EL) were determined for each loading process.

The BN measurements were conducted using an MEB-4C defectoscope with a head consisting of a U-shaped core of electromagnets wrapped in the wound excitation coil. The pick-up coil was built-in to the sensor. In the pick-up coil, a voltage signal was induced. A triangular waveform was used. The fast-variable component was separated by means of a high-pass filter f = (0-500) Hz. Analysis of this component provided information on the degree of strain level of the steel tested [2]. The envelopes of magnetic BN were calculated as rms value U_b according to the equation [2]:

$$U_b = \sqrt{\frac{1}{\tau}\int_0^{\tau} U_{tb1}^2(t)dt}, \quad (1)$$

where:

U_b [V] - root mean square (rms) of the coil output voltage,

U_{tb1} [V] - fast-variable component defining voltage separated by means of the high-pass filter from the induced voltage in the pick-up coil,

τ [s] - integration time.

Then, the amplitude of BN (Ub_{pp}), defined as the voltage difference between the maximum peak value of the magnetic BN (U_b) and the background noise (U_{tb}), was determined. Moreover, the integral of the half-period voltage signal of MBN was calculated [2]:

$$Int(Ub) = \int_{-Ugmax}^{+Ugmax} U_{sb}\, dU_g, \qquad (2)$$

where:

U_{sb} [V] - rms of the Barkhausen emission voltage after correction due to background noise,

U_{tb} [V] - rms of background voltage,

U_g [V] - generator voltage.

3. Results

The 41Cr4 steel behaviour after various pre-strains exhibited some differences clearly illustrated in Fig. 1 by tensile curves representing material characteristics in the range from 0% to 1%.

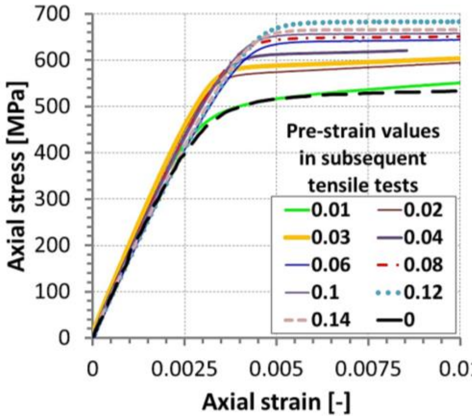

Fig. 1. Comparison of the tensile curve for 41Cr4 in the as-received state to characteristics determined after subsequent 9 steps of loading-unloading process

It was found, that the YP and EL were sensitive to the pre-strain , and moreover, they increased with its level. Envelopes of the BN before and after deformation are presented in Fig. 2, whereas the integral of the half-period voltage signal of MBN is shown in Fig. 3. Initially, the integral of BN decreases up to 6% deformation and then takes a constant value due to defects introduced to the material as a result of prior deformation.

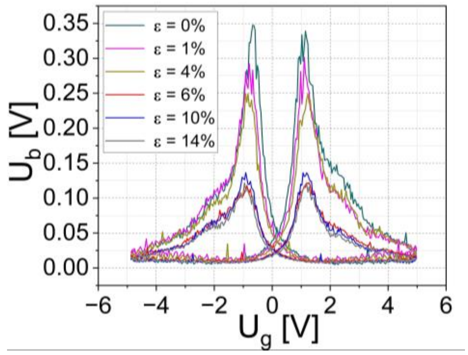

Fig. 2. Envelopes of rms Barkhausen noise before and after axial strain

Linear relationships between either the YP or EL and integral of the half-period voltage signal of MBN were obtained in the case of low pre-strain values, Fig. 4.

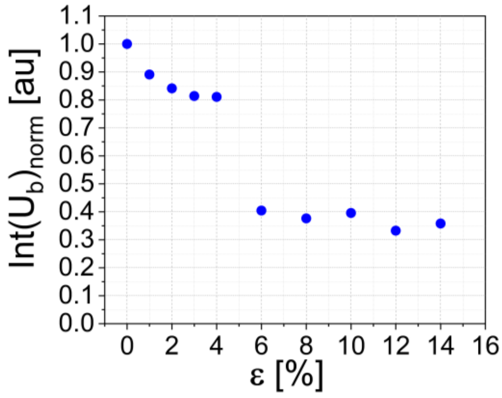

Fig. 3. Normalized Int(U_b) versus axial strain

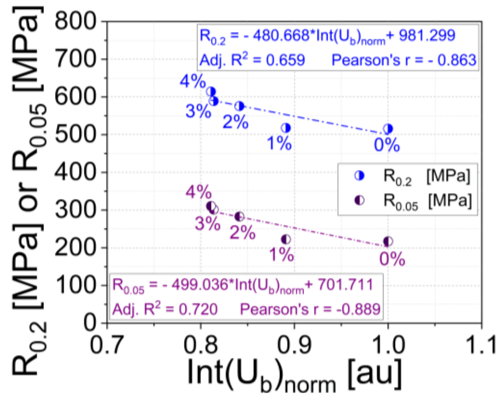

Fig. 4. YP ($R_{0.2}$) and EL ($R_{0.05}$) versus of integral of BN for lower values of strain

4. Conclusions

Plastic deformation has a significant impact on the exploitation properties of the steel tested. It can be well expressed by significant increase of the yield point and elastic limit of the material on one hand, and by selected parameters of non-destructive investigations using the BN method on the other.

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