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BARKHAUSEN NOISE AND MAGNETOACOUSTIC EMISSION AS A POTENTIAL TOOLS FOR MECHANICAL PROPERTIES ESTIMATION OF FERROMAGNETIC MATERIALS

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1. Introduction

It has been found that magnetic Barkhausen noise (MBE) and magnetoacoustic emission (MAE) are significantly sensitive to material damage, especially in the early stage of degradation [1-3]. The magnetic Barkhausen emission is defined as a voltage signal that is generated by the non-continuous domain walls movement in the magnetized material due to discontinues changes of the magnetic flux density [4]. In the case of steel the domain walls are of 180º and 90º types. Magnetic Barkhausen noise may be detected by both the contact probe and by the wound coil around the magnetized specimen. The movements of 90º magnetic domains generate the acoustic waves in materials having non-zero magnetostriction. The MAE may be detected by means of piezoelectric transducer. Due to the fact that elongation of antiparallel domains is the same, there are no acoustic waves coming from the 180º domain walls [4].

The aim of this work is an attempt for evaluation of mechanical properties variations by means of parameters calculated on the basis of measurements of Barkhausen noise, magnetoacoustic emission and magnetic hysteresis loop.

2. Investigation program

In the first step of experimental program, the first series of plain specimens made from power plant medium-carbon steel was subjected to creep process and the second series was subjected to plastic deformation in order to achieve material with increasing level of prestrain.

Subsequently, measurements of the magnetic Barkhausen signal, magnetoacoustic emission and determination of the hysteresis loop variations were carried out on the prestrained specimens.

After non-destructive tests the static tensile tests of pre-strained specimens were carried out in order to determine the basic mechanical parameters, e.g. yield point, ultimate tensile stress, etc. Relationships between the damage sensitive parameters coming from non-destructive and destructive tests are formulated.

3. Representative results

Analysis of the damage sensitive parameters reflects their different nature of changes (Fig. 1,2). Variations of the integral $\mathrm{Int}(U_b)$ determined from envelopes of the Barkhausen noise and those of the yield point $R_{0,2}$ presented as a function of prior creep deformation exhibit a mirror image, i.e. when $\mathrm{Int}(U_b)$ incresed, $R_{0,2}$ decreased, and vice versa, Fig. 1.

Similar behaviour can be observed in the figure representing variations of the integral $\mathrm{Int}(U_a)$, calculated from the magnetoacoustic emission envelopes, and yield point $R_{0,2}$ as a function of prior creep deformation, Fig.2.

4. Conclusions

Parameters coming from the rms envelopes of the Barkhausen noise and magnetoacoustic emission may provide complementary knowledge about mechanical properties variations caused by the history of deformation. It was observed that selected magnetic parameters are especially sensitive to damage development during the first two stages of creep.

$$\dot{\boldsymbol{\varepsilon}}^{v} = \frac{\boldsymbol{\sigma}'}{2\eta_s} + \frac{\mathrm{tr}(\boldsymbol{\sigma}) - 3\sigma_s}{9\eta_b}\mathbf{I} \tag{1}$$

where $\boldsymbol{\sigma}'$ is the deviatoric stress, $\mathrm{tr}(\boldsymbol{\sigma})$ – the trace of the stress tensor, σ_s – the sintering stress, η_s – the shear viscosity modulus η_s – the bulk viscosity modulus.

In the multiscale approach, macroscopic constitutive properties, including the elastic moduli, bulk and shear viscosity, as well as the sintering driving stress are determined from micromechanical simulations of sintering. The micromechanical model of sintering has been developed within a framework of the discrete element method [2]. The DEM considers large assemblies of particles which interact with one another through contact forces. The rheological scheme of the contact model for sintering is shown in Fig. 1b. It includes elasticity, thermal expansion, viscosity (creep) and the sintering driving force, which is consistent with the macroscopic model.

The constitutive parameters of the DEM model of sintering depend on the parameters which can be determined using atomistic models. The methods of molecular statics and dynamics will be used to determine the elastic constants, surface energy and diffusion coefficients used as input data in microscopic sintering models.

4. Case study

Sintering of NiAl powder has been analysed as a case study using the multscale approach. Figure 2 shows selected mechanisms of diffusion considered in the molecular statics analysis. Average shear viscous modulus determined from the DEM simulations is plotted in Fig. 3 as functions of sintering time and relative density.

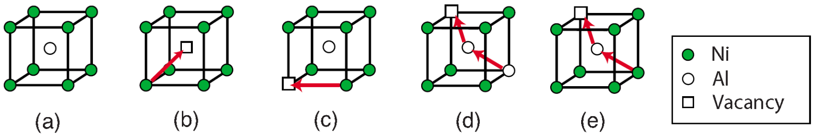

Figure 2. Schematic representation of NiAl crystal structure and selected hop mechanisms [3]

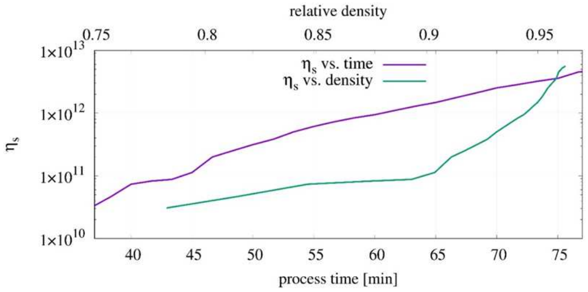

Figure 3. Average shear viscous modulus determined from the DEM simulations

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5. References

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