DA NUBIA ADRIA CSM CROATIAN SOCIETY OF MECHANICS

30th DANUBIA-ADRIA

Symposium on Advances in Experimental Mechanics

September 25-28, 2013 - Primošten, Croatia

3B24 085

CASE STUDY ON DAMAGE DETECTION POSSIBILITY IN P91 AND 40HNMA STEELS USING MAGNETIC NDT TECHNIQUES

B. Augustyniak[1], L. Piotrowski[1], M. Chmielewski[1], Z. Kowalewski[2], K. Makowska[3]

[1] Gdansk University of Technology, Faculty of Technical Physics and Applied Mathematics, Narutowicza 11/12, 80-233 Gdansk, POLAND. E-mails: bolek@mif.pg.gda.pl, lesio@mif.pg.gda.pl, bzyk@mif.pg.gda.pl

[2] Institute of Fundamental Technological Research, Swietokrzyska 21, 00-049 Warsaw, POLAND. E-mail: zkowalew@ippt.gov.pl

[3] Motor Transport Institute, Jagiellonska 80, 00-049 Warsaw, POLAND. E-mail: krystyna.makowska@its.waw.pl

1. Introduction

Elaboration of nondestructive technique (NDT) which is useful for damage detection of exploited steel elements of seems to be very actual and open task for scientific society. In the case of ferromagnetic materials one can assume that such a technique is possible because magnetic properties are strictly related to steel microstructure. We present results of research on tests of damage detection of two martensite like steels (grades P91 and 40HNMA) using two complementary magnetic NDT techniques based on classical Barkhausen effect (HBE) and magnetoacoustic emission (MAE), respectively. Microstructure modification of these steels was due to or plastic deformation made by tension (PD) or to creep damage (CD). This work enhances our previous tests with damage steel state detection where mainly results of MAE have been exploited [1,2,3,4].

2. Experimental

The microstructures of 40HNMA and P91 steels consist of the sorbite with remaining needle martensite configuration. They differ, however, in mechanical properties: the yelding point *Rm* and ultimate tensile stress *Re* are about two times higher for 40HNMA in comparison to P91 steel [2]. The plane specimens having rectangular cross section of 5 mm×7 mm dimensions and gauge length of 40 mm. Tensile tests had been performed at room temperature while creep tests were made at T = 773K with stress s = 250 MPa for 40HNMA and s = 290 MPa for P91 steels, respectively. Each process was interrupted for a range of the selected time periods in order to achieve specimens with an increasing level of plastic strain. After each loading process the specimens were tested using magnetic method. Magnetic properties were measured using standard laboratory method of magnetisation, where hysteresis loop $B(H)$ with the HBE and also the MAE can be achieved [5]. An intensity of the HBE is given by the rms (root mean square) voltage *Ub* induced in pick-up coil. We compared here the integrals of those envelopes for one period of magnetisation (*Int Ub*). The MAE voltage signal is detected with resonant acoustic transducer. The rms envelope (*Ua*) is integrated and provides an descriptor of MAE intensity - *Int Ua.*

3. Results

Full paper will present the nuances of the envelopes of HBE and MAE intensity signals. Here we report and compare the integrals *Int Ub* and *Int Ua* which are plotted as a functions of resulting plastic strain e in Fig. 1 for MAE and in Fig. 2 for HEB, respectively. These plots reveal that both types of damage lead to specific modifications of intensities of both effects. These features can be summarized as follows. Magnetoacoustic emission intensity, as shows Fig. 1, evidently decreases monotonously in function of plastic strain after tensile test. This decrease is of order -50 % against level for initial stage. Creep damage reduces MAE intensity for P91 steel and increases (in not monotonous way) for 40HNMA steel. One can state that decrease of MAE for P91 steel is more pronounced when tensile test is performed.

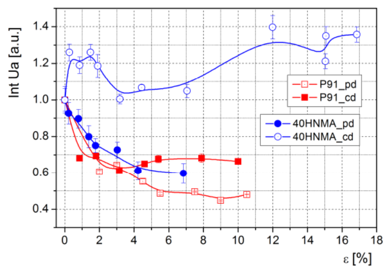

Fig. 1 Relative change of MAE intensity in function of deformation level for P91 steel (squares) and 40HNMA steel (circles) after plastic deformation (full) and creep damage (open)

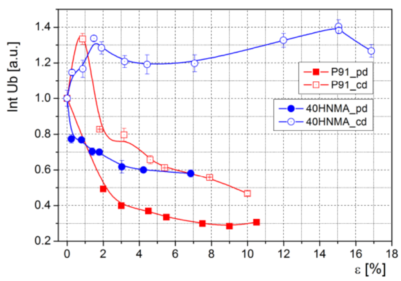

Fig. 3 Relative change of HBE intensity in function of deformation level for P91 steel (squares) and 40HNMA steel (circles) after plastic deformation (full) and creep damage (open)

Plots in Fig. 2 depict also monotonous like decrease of HBE intensity for both steels but only in the case of the tensile test. This decrease (of order of -70%) is higher for P91 steel. Creep test leads to non monotonous variation of HBE intensity. Its intensity (for both steels) peaks for relatively low level of strain (range of 1 – 2 %) and than decreases for P91 steel and again increases for 40HNMA steel. We will discuss qualitatively the as observed relationships linking them with modifications of dislocation densities and creation of voids. The as detected fundamental difference of magnetic properties of 40HNMA and P91 steels when creep test is applied can be attributed mainly to voids creation at 40HNMA steel. This effect was reported recently in [6].

4. Remarks

- All this depicts high capability of the as applied magnetic NDT techniques for detection and assessment of microstructure modification when mechanical damage is in question, mainly when both techniques are used simultaneously.

Acknowledgements

This work was supported partially by grant from NCBR Nr PBS1/A9/14/2012.

References

[1] Kowalewski, Z.L., Szelążek, J., Mackiewicz, S., Pietrzak, K., Augustyniak, B., Evaluation of damage in steels subjected to exploitation loading destructive and non-destructive methods, Int. Journal of Modern Physics B, vol. 22, 2008. pp. 5533-5538.

[2] Kowalewski, Z. L., Szymczak, T., Makowska, K., Augustyniak B., A role of destructive and non-destructive tests in creep damage identification, Key Engineering Materials, vols. 488-489, 2012, pp. 315-318.

[3] Augustyniak, B., Chmielewski, M., Piotrowski L., Kowalewski Z.L., Comparison of properties of magnetoacoustic emission and mechanical Barkhausen effects for P91 steel after plastic flow and creep. IEEE Transaction on Magnetics. Vol. 44, 2008, pp. 3273-3276

[4] Piotrowski L., Augustyniak B., Chmielewski M., Kowalewski Z.L., Possibility of application of magnetocoustic emission for the assessment of plastic deformation level in ferrous materials, IEEE Trans. on Magnetics, vol. 47, no. 8, 2011, pp. 2087-2092.

[5] Augustyniak, B., Chmielewski M., Sablik, M. J.; Multiparameter Magnetomechanical NDE; IEEE- Trans. on Magnetics, vol. 36, 2000, pp. 3624-3626.

[6] Makowska, K., Kowalewski, Z.L., Augustyniak, B., Structural degradation and mechanical properties variations of steels evaluated by means of Barkhausen noise parameter, 25th Symposium on Experimental Mechanics of Solids, Jachranka, Poland, October 17 - 20, 2012.