NON-DESTRUCTIVE ANALYSIS OF FERROMAGNETIC MATERIALS BY MEANS OF BARKHAUSEN EFFECT METHODS

G.S.VELEV*

Results from the analysis of structural steel and amorphous alloy specimens obtained by means of Barkhausen effect noise and magnetomechanical acoustic emission methods have been presented.Some conclusions have been drawn about practical application of obtained data on non-destructive control of internal stresses in structural steel and of structural state of amorphous alloys.

INTRODUCTION

The methods of Barkhausen noise (BN) and magnetomechanical acoustic emission (MAE),based on Barkhausen effect are now being used for non-destructive control of the structures and physical and mechanical properties of ferromagnetic materials [1,2]. The object of the present work is to study the applicability of magnetic noise and magnetomechanical acoustic emission characteristics - magnetic noise voltage, U_{BN}, and root mean square voltage, U_{MAE}, of the magnetomechanical acoustic emission for non-destructive control of the internal stresses in structural steel specimens having various levels of cubic plastic strain and for non-destructive control of the structure of amorphous alloy specimens having various compositions and structural defects.

MATERIALS AND METHODS

Specimens of 30Cr2MnA2F steel of rectangular section

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* Institute for Metal Science and Technology,
Bulgarian Academy of Sciences,Sofia,Bulgaria.

(10x4)mm and 100mm length have been used for the test. Specimens have been subjected to compression at 900 °C and their cubic plastic strain level, E - has been from 10% to 60%. All test specimens have been X-ray analyzed for quantitative estimation of the internal microstresses Fe-based amorphous alloys of $(Fe_xNi_{1-x})_{80}B_{20}$ system have been used for the preparation of test specimens which have been then super-quenched in the form of a strip of 50µm thickness [3]. Structure identification has been made by X-ray and metallographic analyses (Table 1).

TABLE 1 - Structure and composition of amorphous alloy specimens.

Group	Composition	Structure	Dimensions(mm)
1	1 st	Amorphous	13 x 100
2	1 st	Presence of crystal grains	13 x 100
3	2 nd	Amorphous	15 x 100
4	3 rd	Amorphous with pores	13 x 100

Fig.1 shows the blok-diagram of the apparatus for specimen investigation. The test speicmen 3 is placed between the magnetic core 4 and the piezo-electric transducer 1. Low frequency sine-wave voltage is supplied to the magnetising winding 5 and through the magnetic core 4 it leads to cyclic magnetization of the specimen zone located between the poles of the electromagnet. Thus BN and MAE are induced in the specimen. U_{BN} induced pulses in the receiving winding 2 are sent to BN block for processing and MAE signals are transformed by the piezo-electric transducer 1 into electric pulses which are then sent to the AE amplifier of the acoustic emission. From the BN and AE block the signals are sent for analyzing by the PC personal computer and for recording by the XY recorder. The measured characteristics are magnetic noise voltage U_{BN}, the root-mean square voltage U_{MAE} of magnetomechanical acoustic emission and the relationships $U_{BN}(I_N)$ and $U_{MAE}(I_N)$.

RESULTS AND DISCUSSION

Fig.2 shows the dependences of U_{BN} and U_{MAE} on the internal microstresses of the steel specimens. Data analysis has shown that the density of bn within the range of 8 kHz to 100 kHz is the highest at low internal stresses and it decreases when they increase up to

60.10^7 Pa, while MAE decreases almost linearly with microstress increase. Probably the increase of plastic strain extent results in the increase of material dislocation structure, where irreversible magnetostriction movements of 90° domain boundaries gradually decrease. By increasing the magnetizing field intensity, H, the movement processes of the 180° domain boundaries more and more distinctly shift to movement of 90° domain boundaries and rotation [1]. This phenomenom is in agreement with the results for $U_{BN}(I_N)$ and $U_{MAE}(I_N)$ in Fig. 3 where curve 1 relates to stress values of σ_i -(30-35).10^7 Pa, curve 2 relates to σ_i -(40-45).10^7 Pa and curve 3 relates to σ_i -(60-70).10^7 Pa. Fig.4 shows the $U_{BN}(I_N)$ and $U_{MAE}(I_N)$ relations for the groups of amorphous specimens of Table 1. The continuous lines refer to $U_{BN}(I_N)$ and the dash lines refer to $U_{MAE}(I_N)$. Fig.4 shows the $U_{BN}(I_N)$ relations within the frequency range of U_{BN}(8-100) kHz. Fig.5 shows in more details the $U_{BN}(I_N)$ relations for noise voltage discrete frequences (25, 35, 45) kHz for composition № 3, Table 1. Data analysis shows that for groups of one and the same composition (№ 1 and № 2 - Table 1) U_{MAE} values are almost identical while U_{BN} curves considerably differ. Fig. 5 shows distinct extremums of $U_{BN}(I_N)$ for U_{BN} discrete frequencies at low magnetization levels. Perhaps such extremums result from the uniaxial directed anisotropy which causes the occurrence of specific domain structure.

CONCLUSIONS

1. Test results confirm the fundamental differences between BN and MAE regardless of the fact that both phenomena are induced by one and the same source on the basis of the sharp irreversible movement of the domain boundaries.
2. U_{BN} and U_{MAE} characteristics can be used for non-destructive evaluation of internal stresses in steel subjected to plastic deformation and more precisely immediately after that.
3. These characteristics can find an application in non-destructive testing of structural state of Fe-based amorphous alloys where defects such as the presence of crystal grains, pores, dislocations, etc., are inadmissible.

SIMBOL USED

UN = magnetic noise.

MAE = magnetomechanical acoustic emission.

U_{BN} = magnetic noise voltage (μV)

U_{MAE} = root mean square voltage (μV)

I_N = magnetizing curent (mA)

σ_i = internal stress (Pa)

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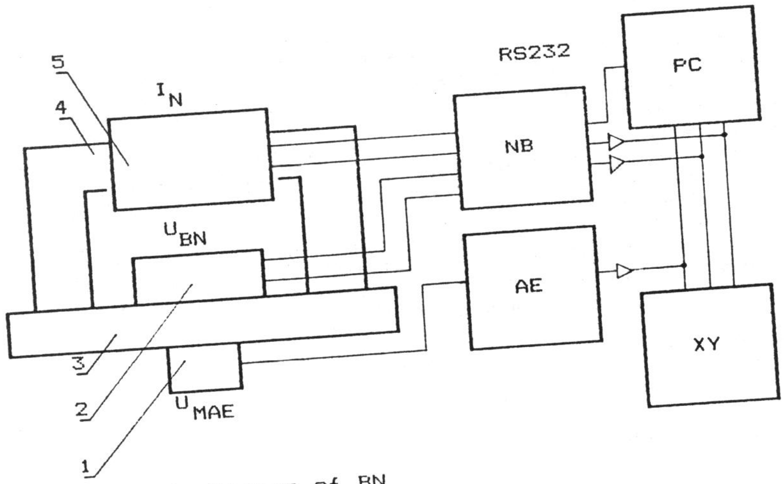

Figure 1.Blok-diagram of BN and MAE measuring apparatus

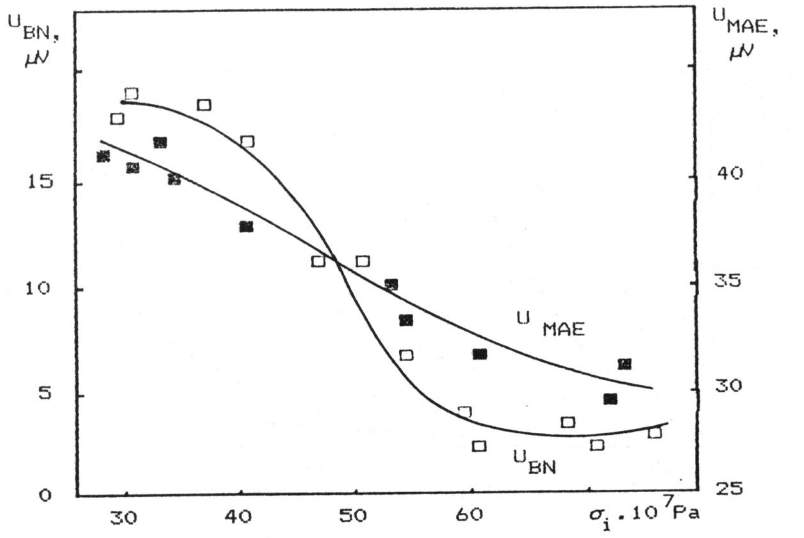

Figure 2. U_{BN} and U_{MAE} dependences on internal stresses

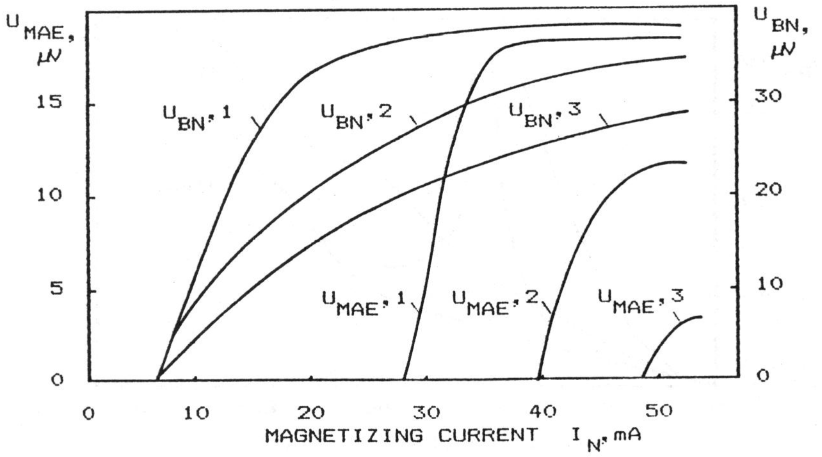

Figure 3. $U_{BN}(I_N)$ and $U_{MAE}(I_N)$ relationships for steel

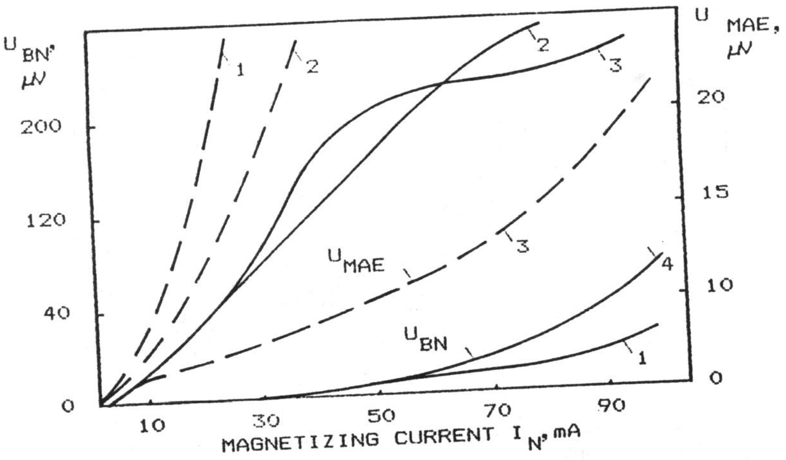

Figure 4. $U_{BN}(I_N)$ and $U_{MAE}(I_N)$ relation in amorphous alloys

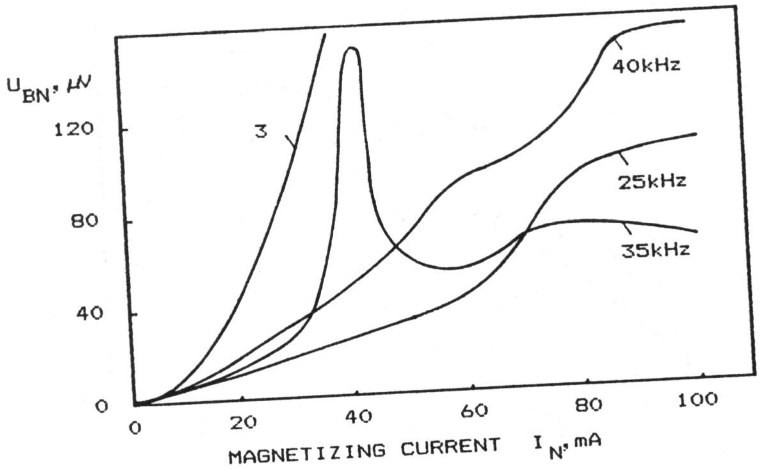

Figure 5. Relations in amorphous alloy for discrete frequencies