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NON DESTRUCTIVE EVALUATION OF STRESS STATE OF THE HIGHWAY BRIDGE VIA BARKHAUSEN NOISE TECHNIQUE

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ABSTRACT

The paper deals with non destructive monitoring of stress state of the new highway bridge by the use of magnetic Barkhausen noise. This is a pilot study in with the potential of Barkhausen noise is investigated as a promising technique employed for this specific purpose. Effective values of Barkhausen noise are studied as a function of exerted mass load. Barkhausen noise signals are measured on the one section of the highway bridge after assembly of steel body as well as after concreting of the bridge. Barkhausen noise signals are correlated with the real stresses obtained from the simulation. Except the conventional effective value of Barkhausen noise signals also Barkhausen noise envelopes and the corresponding parameters are analyzed.

Keywords: Barkhausen noise, stress state, bridge, loading.

INTRODUCTION

Magnetic Barkhausen noise (MBN) originates from irreversible and discontinuous Bloch Walls (BW) motion during cyclic magnetization. MBN is sensitive to stress state as well as microstructure alterations. Microstructure features affect the free path of BW motion whereas stresses affect mainly domain alignment and the corresponding BW direction (Moorthy, 2006). It is well known that BWs are preferentially oriented into the direction of external tensile stresses at the expense of BWs oriented in the perpendicular direction which contribute to the higher magnitude of MBN pulses. On the other hand, compressive stresses align BWs in the perpendicular direction against direction of exerted stresses. For this reason compressive stresses decreases magnitude of MBN signal (Karpuchewski, 2002).

MBN technique is widely adapted for many industrial and laboratory applications in which stress state and microstructure can be monitored in a non destructive manner. Moorthy et al. (Moorthy, 2006) analyzed stresses changes initiated by grinding on the MBN in case - carburized steel. Rosipal (Rosipal, 2012) and Mičúch (Mičúch, 2014) reported that progressively developed grinding wheel wear increases MBN as well as initiate tensile stresses in hardened bearing steel. Gatelier-Rothea et al. (Gatelier-Rothea, 1998) studied influence of stress and microstructure on MBN in pure iron and low alloyed steel. Čížek et al. (Čížek, 2014) linked decreasing MBN mainly with increasing dislocation density. Piotrowski et al. (Piotrowski, 2012) studied thermally induced microstructure changes in the P91 grade steel as a function of dislocation density via magnetic as well as acoustic Barkhausen noise.

However, this study reports about unique pilot research in which large body in the form of the highway bridge is investigated. MBN signals are analysed as a function of stress state

(bending) within the second and third pillars of the bridge at the different distances from the pillars. The total length between the pillars is 68 meters and contains 24 sections in which MBN signals were measured. The measurements were carried out on low loaded structure (loaded only by the weight of the bridge construction itself) as well as after concreting (referred as "loaded").

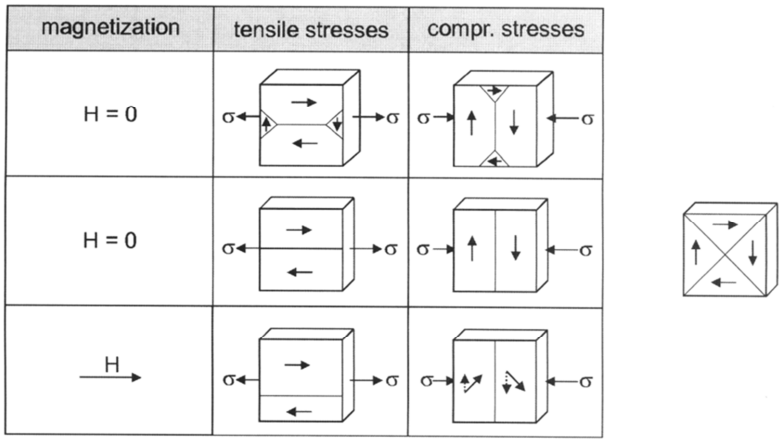

Fig. 1 -Magnetic domain configuration, effect of stresses and magnetic field, (Karpuchewski, 2002)

EXPERIMENTAL DETAILS

The measurements are carried out on the highway bridge made of low carbon hot rolled steel S460 MC (I profile of thickness varying from 30 to 60 mm). Chemical composition of this steel is in Table 1. Mechanical properties of this steel are as follow: R_m = 610 MPa, $R_{p0.2}$ = 540 MPa, A = 26.3%.

Table 1 Chemical composition of S460 MC - expressed in wt%.

Fe	C	Si	Mn	P	S	Al	V	Ti	Nb
balance	0.082	0.019	1.040	0.006	0.003	0.055	0.054	0.001	0.050

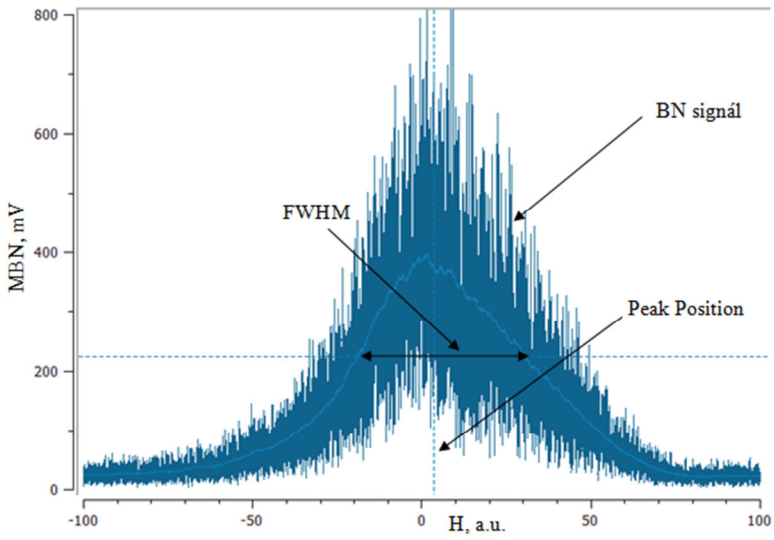

Fig. 2 - MBN envelope - parameters extraction

Surface of the steel was coated by spraying process. Total thickness of the surface coating is 240 μm composed of the 3 different layers: Hempadur (2 layers) + final layer of Hempadhone. Magnetic measurements were carried out by the use of RollScan 350 and software MicroScan (magnetizing frequency 125 Hz, magnetizing voltage 9 V, sine profile, sampling frequency 6.7 MHz, MBN signal in the frequency range from 10 to 1000 kHz). Effective (rms) value of the MBN signal was analysed as well as Peak Position and Full Width of Half Maximum (FWHM) of MBN envelopes and studied as a function of exerted stress state. The brief sketch in which these MBN parameters are illustrates is shown in Fig. 2. MBN refers to effective (rms) value of Barkhausen noise signal. All MBN parameters were calculated by averaging of 10 bursts (5 magnetization cycles). The real values of initiated stresses were obtained from simulation.

RESULTS

Fig. 4 shows that the higher compressive stresses initiate higher magnitude of MBN near by both pillars. As soon as the distance from the pillars is increasing MBN drops down and saturates early. Rms of MBN oscillates from 10 to 60 meters distance from the pillars and sensitivity against varying stresses is quite poor. Furthermore, influence of stresses on MBN is contradictory since compressive stresses usually initiates low magnitude of MBN a vice versa. The reason can be found in the fact that the real stress state is more complicated (not only poor bending) and I profile of the construction is strengthened by the cross stiffeners.

On the other hand, Peak Position of MBN exhibits better sensitivity against different stress states after loading as Fig. 5 illustrates. Compressive stresses tend to align BW in the direction perpendicular against direction of external magnetic field. For this reason, compressive stresses shifts MBN envelopes to higher magnetic fields and initiate the high Peak Positions whereas tensile stresses gives low Peak Positions, see also Fig. 3.

Very good sensitivity against stresses exhibit FWHM extracted from MBN envelopes (Fig. 6). Compressive stresses are easily linked with the low FWHM a vice versa. This aspect is associated with redistribution of BW alignment and widening of the magnetic field interval in which MBN occur. Table 2 shows correlation coefficients which refer to sensitivity of each MBN feature against stress state.

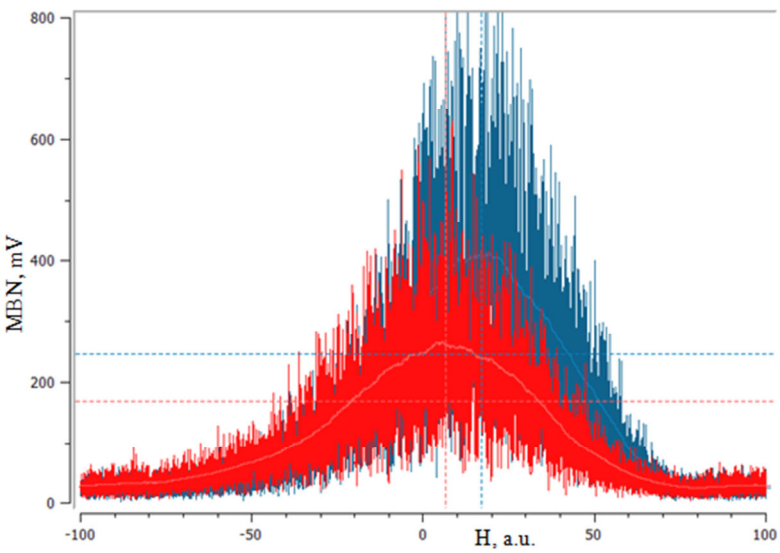

Fig. 3 - MBN envelopes, 1,45 m from the pillar 2 - blue, 30 m from the pillar 2 - red

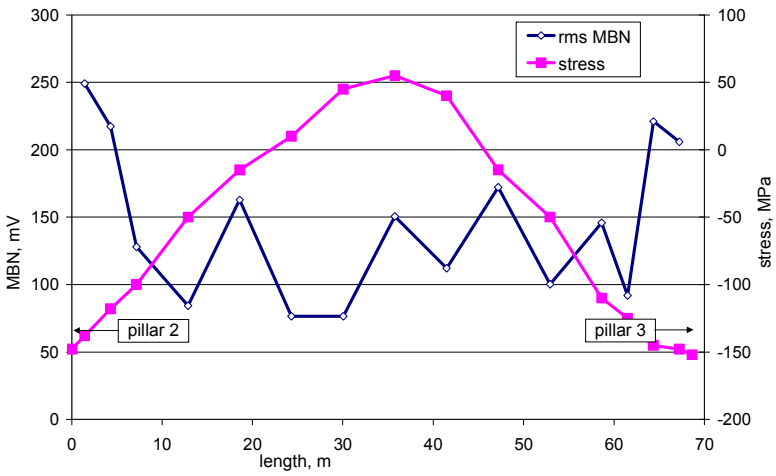

Fig. 4 - Distribution of MBN and stresses - loaded

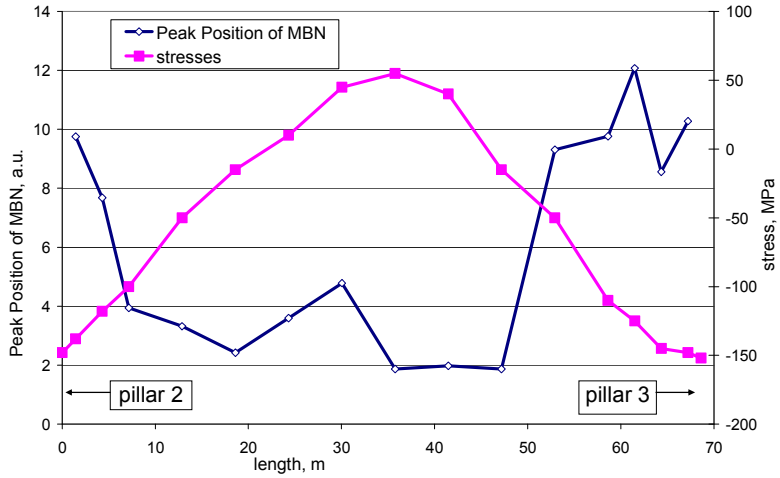

Fig. 5 - Distribution of Peak Position (of MBN envelope) and stresses - loaded

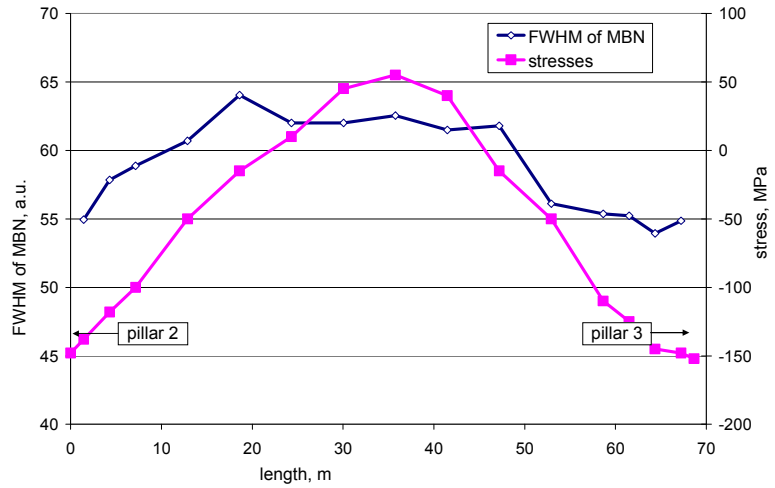

Fig. 6 - Distribution of FWHM (of MBN envelope) and stresses - loaded

Table 2 Correlation coefficients of the different MBN parameters against real stresses

MBN parameter	Rms (MBN)	Peak Position	FWHM
Correlation coefficient	-0.58	-0.8	0.89

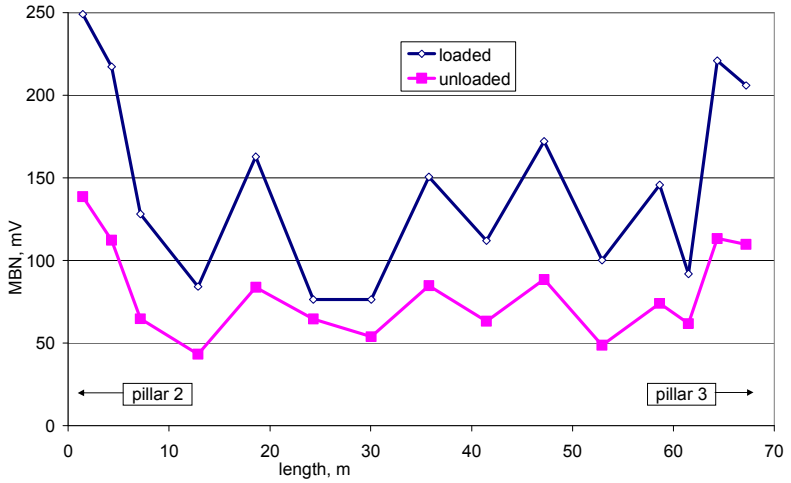

Fig. 7 - Distribution of MBN, loaded and unloaded state

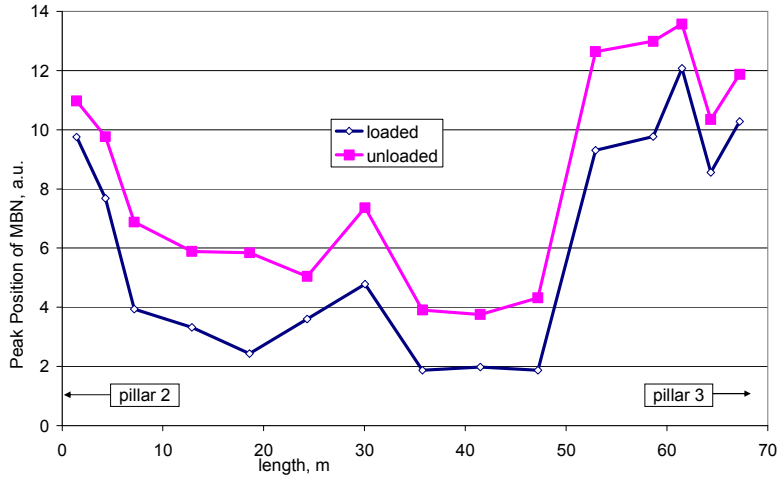

Fig. 8 - Distribution of Peak Positions of MBN envelopes, loaded and unloaded state

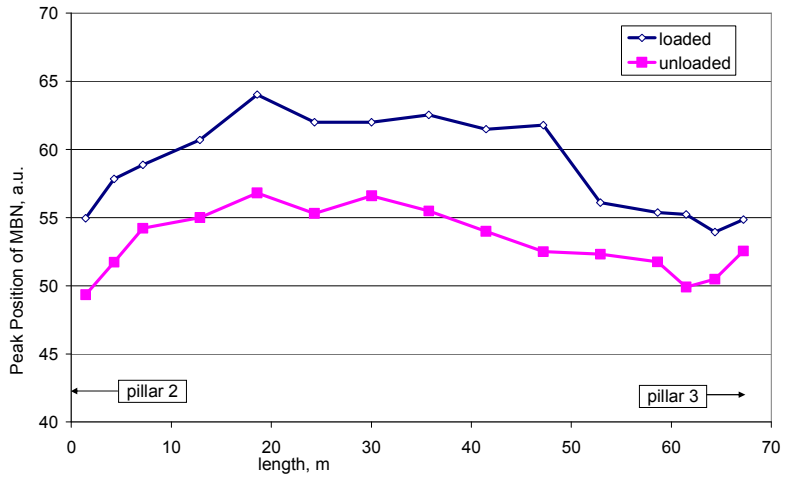

Fig. 9 - Distribution of FWHM of MBN envelopes, loaded and unloaded state

Figs. 7, 8 and 9 illustrate changes in MBN parameters before after loading. Fig. 7 illustrates that lower stresses (unloaded state) give lower MBN a vice versa. This figure also shows that rms values of MBN after loading are mainly a function of the unloaded state since the shape profile of rms stays nearly constant and loading of the construction results into higher MBN. The same character of changes can be found for FWHM, whereas Peak Positions after loading drops down.

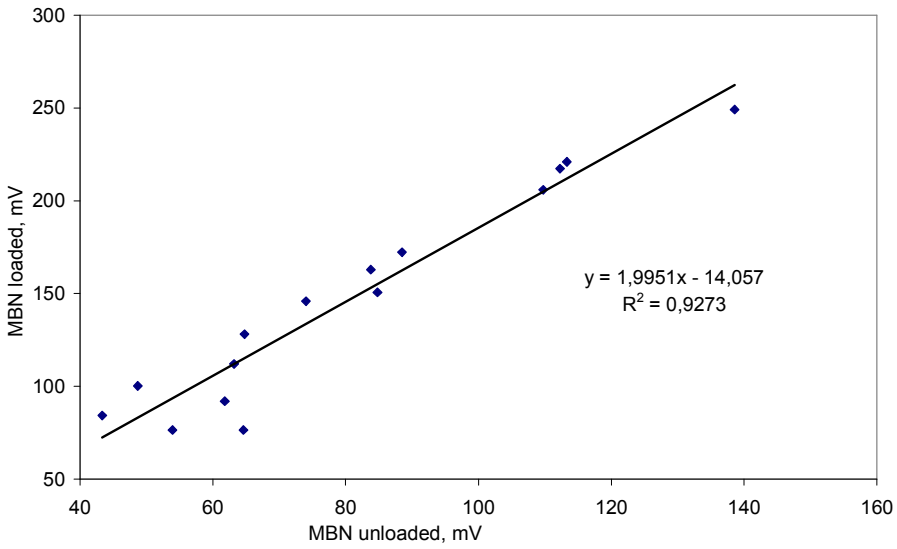

Fig. 10 - Rms values of MBN signals, loaded versus unloaded state

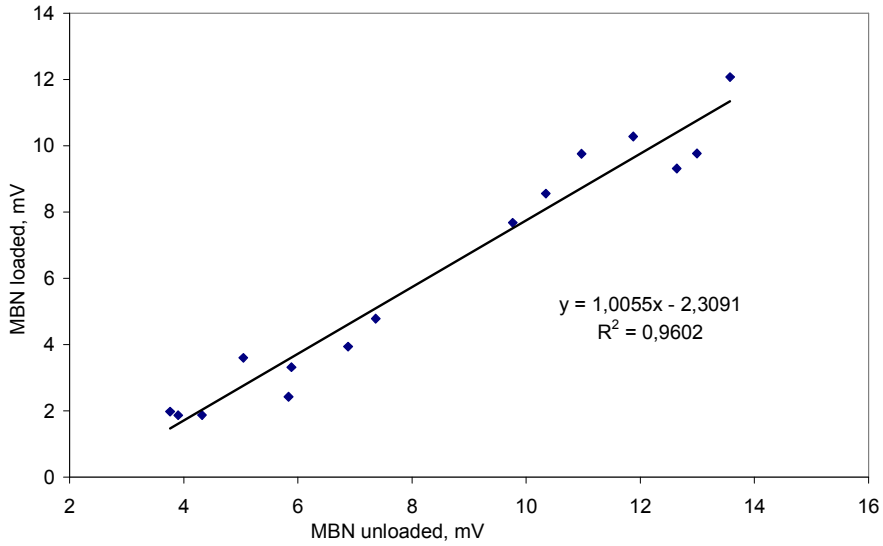

Fig. 11 - Peak Positions of MBN envelopes, loaded versus unloaded state

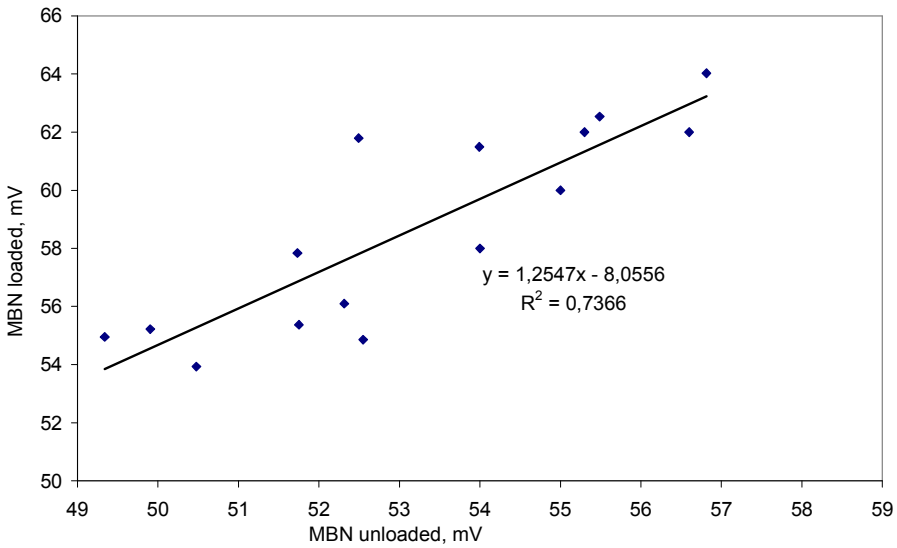

Fig. 12 - FWHM of MBN envelopes, loaded versus unloaded state

Figs. 10, 11 and 12 illustrates correlation between loaded and unloaded state for the different MBN parameters. Rms values, Peak Positions as well as FWHM after loading strongly depends on unloaded state, see also Table 3. Such behavior is due to quite thick surface coating in the scope of MBN sensitive depth. It is assumed that MBN sensing depth for this soft mechanical and magnetic steel is comparable with the thickness of the coating. Surface coating attenuates MBN pulses originated in the steel surface. Small variations in the coating thickness could affect measured MBN signal especially in low degree of stresses. Being so, this aspect should be carefully investigated in the near future.

Table 3 - Correlation coefficients of the different MBN parameters, loaded versus unloaded state

MBN parameter	Rms (MBN)	Peak Position	FWHM
Correlation coefficient	0.96	0.98	0.86

CONCLUSIONS

The main goal of this research is focused on monitoring of bridge degradation due to its long term exposition to the cyclic loading (initiation of cracking, corrosion, ect.). However, the progressive degradation process expressed in the term of MBN signals is superimposed with the initial stress state. The values of extracted MBN parameters as well as MBN envelopes could be established as the initial state and referred as poor stress state whereas all future signals alterations would correspond with degradation processes developed due to long term highway bridge in use.

ACKNOWLEDGMENTS

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