EMAT-EMAT SYSTEM PARAMETERS MEASUREMENT

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ABSTRACT

Article summarizes the measurement of selected parameters of laboratory proposed EMAT generator and EMAT sensor of acoustic emission signal. Measured results are the basis for designing of electronic instrumentation for transmitting and receiving EMAT equipment needed for the possibility of system functioning in real time without the use of averaging in the time domain.

1. INTRODUCTION

EMAT (Electro-Magneto-Acoustic Transducer) is a device for generating and sensing of acoustic emission signal. In principle it is based on interaction between static magnetic, dynamic electromagnetic and dynamic mechanical field [1]. Permanent magnet is the most common source of the static magnetic field, electromagnet can be used only with magneticaly conducting test sample material. The source of the dynamic electromagnetic field is linear coil. An important feature is reciprocity, therefore, usually the both parts of EMAT device are of the same design. Because our previous research is done on the aluminum sample, whether there is explained only EMAT based on the principle of Lorentz force [1].

Action of force is the result of eddy currents induced in the material as result of dynamic magnetic coil field and horizontal static permanent magnet field interaction. The resulting volume force [2] causes the generation of time-variable mechanical stress in the immediate distance of the material surface and associated surface deformation. Part of the energy resulting from the action of force consequence is spreading further in material in elastic waves form. The direction and type of elastic waves depends on the mutual setting of linaer coil and permanent magnet. When the elastic wave gets in the permanent magnet field, the inverse effect arises. In area under the receiving EMAT part the eddy currents with time and area distribution corresponding with dynamic mechanical field are generated. The same procedure as in the case of transmitting EMAT part is then time-variable electric current inducted in receiving EMAT coil and can be further processed.

Possibility of noncontact generating and sensing of acoustic emission signal is the main advantage of EMAT device. The other adventage is better shape of frequency characteristics compared to piezoelectric acoustic emission sensors. The main disadvantage is the very low sensitivity.

The aim of the practical experiment is to determine the properties of laboratory proposed EMAT, namely the size of surface displacement generated by transmitting EMAT part, and subsequently the corresponding size of electrical voltage induced in receiving part. Based on the measurement results the design of electronic instrumentation with required properties for the transmitting and receiving part will follow in further research as well as EMAT device improvement.

2. ANALYSIS

In this section a brief description of the proposed EMAT, description of practical experiment and the measurement results is shown.

2.1. EMAT TRANSMITTING AND RECEIVING PART DESIGN

The proposed EMAT is used to generate and sense Rayleigh‘s elastic wave, which is wave spreading in the small distance of the material surface with the amplitude decreasing exponentially with distance from the surface. Permanent magnet field is oriented verticaly to the surface of the test sample, linear coil is of meander type. In principle, the EMAT is shown in figure 1.

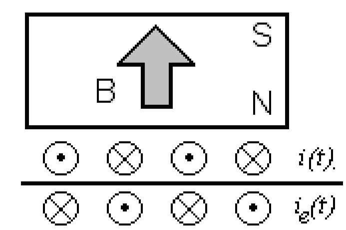

Figure 1: Principle of Rayleigh EMAT type.

Meander line coil span is chosen on the basis of predicted elastic wave wavelength [3]. The proposed coil has a 3 mm span and the corresponding frequency value of generated Rayleigh’s wave is 350kHz. Photo of proposed EMAT is shown in Figure 2.

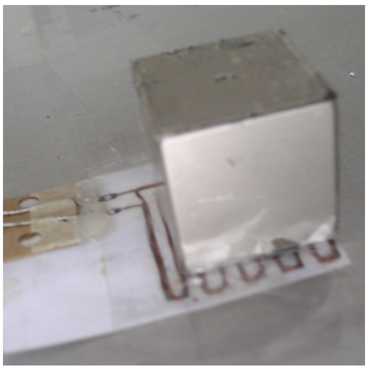

Figure 2: EMAT device photo.

The length value of each meander thread is 28 mm. Based on the findings published in [4] it is law of proportionality of voltage induced in time-variable coupled magnetic flux used [5] and linear meander coil is made from 8 copper wires with a diameter of 0.1 mm. The permanent magnet is Ne-Fe-B with table remanent induction 1,2-1,3 T and dimensions of 25x25x25mm.

2.2. PRACTICAL EXPERIMENT DESCRIPTION

The designed practical experiment is adapted to measure aluminium sample (size 6x26x43mm) surface displacement generated by transmitting EMAT part. For measuring the laser interferometer was used. Next aim was measuring of induced voltage corresponding surface displacement of an elastic wave. The exciting signal source generator is function generator Agilent 33220A. With regard to expected and experimentaly verified generation of standing wave, which has no sense for our experiment, it was necessary to excite transmitting EMAT part with finite sequence of harmonic pulses. Originally proposed 350kHz frequency value was changed to 410kHz, at which it was the greatest sensitivity of the sensor noted. Distance between both EMAT devices was 10 cm. In the results, therefore, any elastic wave reflections at the edges of the sample are not measured. Surface displacement was measured by laser interferometer Polytec OFV-505 with the evaluation unit OFV-5000. This device can measure the displacement and displacement velocity of surface. It has customized several decoders for this. There was chosen support decoder DD-300 in our experiment, which measures surface displacement in frequency range of 50kHz to 2MHz. Limiting of range at ± 75nm is negligible due to the expected surface displacement. The level of noise at choosen range is less than 0,05pm/$\sqrt{\text{Hz}}$, which is regards to frequency band corresponding with noise effective value of about 70pm. For the evaluation of measured surface displacement and the induced voltage signal, there was applied digital oscilloscope Agilent 54622D. The signal from the receiving EMAT part was amplified with 56dB amplifier in 500kHz frequency band.

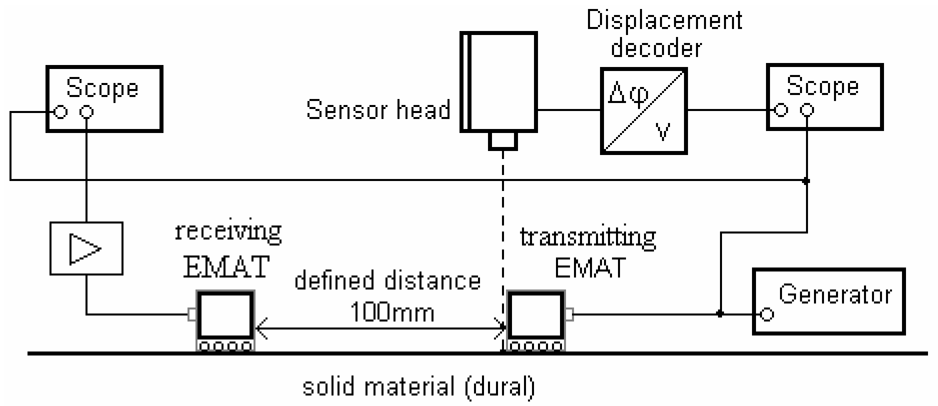

Figure 3: Praktical experiment description.

2.3. MEASUREMENT RESULTS

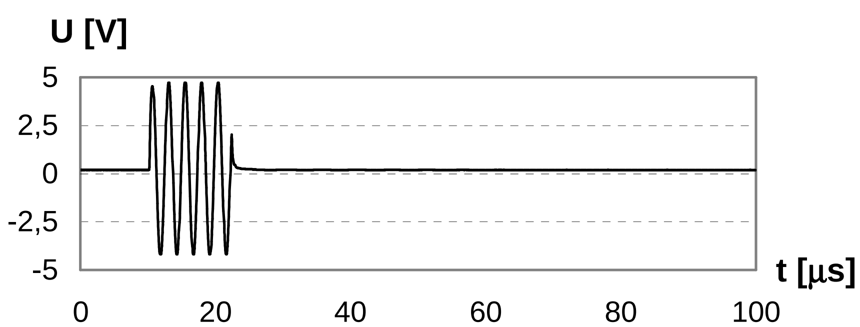

Figure 4: Exciting voltage signal waveform.

Measurement of surface displacement with piezoelectric acoustic emission sensors is in the small wavelengths (less than a cross-section of the sensor) guided with aperture effect. This is one of reasons for using of laser interferometer. This device is able to measure surface displacement at one point (the thickness of the beam is about 1 mm). Because the reflection of laser beam directly from the aluminium sample was accompanied by noise increasing, it was necessary to use the special reflecting area. Though, as is noticeable in figure 5, input noise is still very large and averaging in time domain is necessary. Averaged surface displacement is wieved in figure 6.

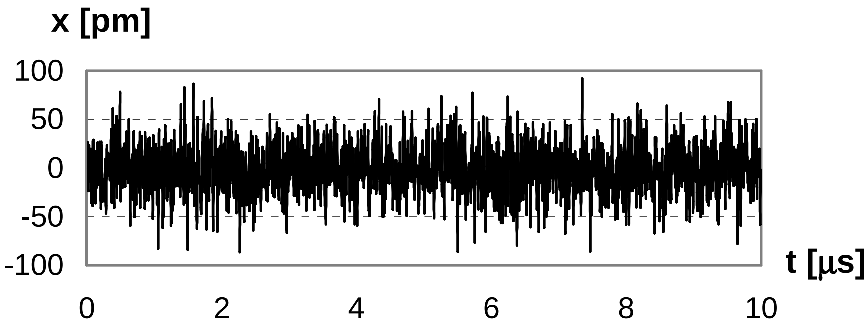

Figure 5: Input noise of laser interferometer.

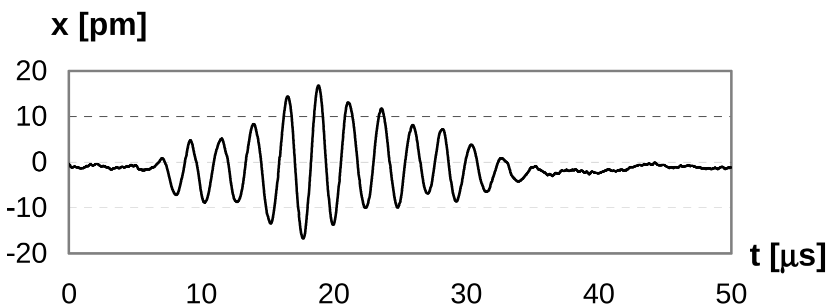

Figure 6: Averaged surface displacement response on exciting signal from figure 4.

The surface displacement value in pm is determined from the laser interferometer sensitivity 25nm.V^{-1} in the frequency band 50kHz to 2MHz. Figure 7 shows inducted voltage in receiving EMAT part sensing coil.

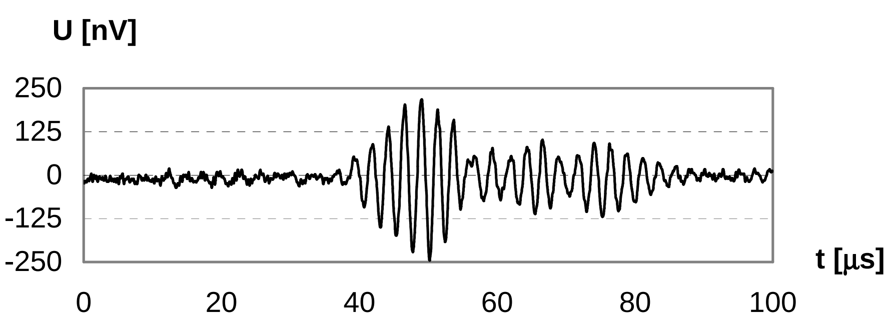

Figure 7: Averaged inducted voltage response on exciting signal from figure 4.

2.4. MEASUREMENT RESULTS EVALUATION AND IMPROVEMENT SUGGESTION

Based on the measurement results it was confirmed that the efficiency of the complete EMAT-EMAT system is very low. With proposed EMAT equipment with selected parameters and exciting signal of 5V amplitude a maximum surface displacement reached 18pm value and response of receiving EMAT part on the same excitation reached maximum value of 217nV. It is clear, that the value of electric voltage is on the low border of subsequent electronic workability and it is therefore necessary to improve the proposed EMAT device. The first step will be increasing of exciting signal. This can be achieved through a combination of several procedures. The first is increasing of supply current with reducing the internal resistance of signal source. It presumes design of broadband power amplifier. Another option is increasing of meander line coil number of conductors. This results in increasing of total current in each meander branch and, consequently, increasing of receiving part sensitivity. As a result, however, the rising inductance and the active component of coil resistance causes decreasing of excitation current. This can be compensated by increasing of conductor cross-section, which is limited by the size of the meander. Amplifier for receiving part is needed to be low-noise broadband with very high gain.

3. CONCLUSION

This article gives information about the behavior of the complete EMAT-EMAT system and forms the basis of electronic instrumentation design necessary for the possibility of signal evaluating in real time without using of averaging in time domain. With regard to very low efficiency, it is necessary to improve the proposed EMAT, which was designed for this experiment and creates an essential element for the subsequent optimizing EMAT parameters. With respect to low sensitivity of receiving part the numerable and repeatable source of acoustic emission signal is expectable primary using of EMAT. Receiving part using in practical measurement is assumed only in a substantial sensitivity increasing case.

ACKNOWLEDGMENT

This text was created with the support of the grant GAČR 102/09/H082.

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