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MEASURING SETUP FOR THE NON-LINEAR ULTRASONIC SPECTROSCOPY METHOD

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ABSTRACT

Non-linear ultrasonic spectroscopy methods appear to rank among highly promising methods to identify the structure defects in a wide range of materials (sandwich-type elements, composite materials as well as their coupling nodes) also on the micro-structure level. These methods are employing the fact that a crack-induced non-linearity makes an extremely sensitive material impairment indicator. Any intact material region generates almost zero non-linearity. The research and development of these methods and the respective data processing and evaluation devices is – in view of the topic complexity and the exigency of the instrumentation to be developed – in its initial stage currently. However, the knowledge attained until now shows these methods to be very promising for the material testing and defectoscopy in the near future. The present paper deals with the measuring setup design, providing for the best applicability of the various parts of the measuring and data processing chain and minimizing their mutual non-linear interaction.

Keywords: non-linearity, sensor, transfer function, acoustic coupling, elastic wave propagation

1 INTRODUCTION

One of the fields in which a wide application range of non-linear acoustic spectroscopy methods may be expected is the civil engineering. Poor material homogeneity and, in some cases, shape complexity of some units used in the building industry, are heavily restricting the applicability of "classical" ultrasonic methods, which are based on studying the linear parameters of elastic waves (propagation speed, attenuation etc.) Precisely these non-linear ultrasonic defectoscopy methods are less susceptible to the mentioned restrictions and one may expect them to contribute a great deal to the further improvement of the defectoscopy and material testing in civil engineering.

The research is focused mainly on following topics:

- theoretical modelling of non-linear phenomena in the materials under test
- development and systematic improvement of the measuring apparatus

- extensive experimental work designed to provide background for statistical analysis of measured data and verification of application limits for each of the various measurement methods.

2 EXPERIMENT

Non-resonance methods are used to study suppressed resonance specimens. These methods analyse the effect of non-linearities on acoustic signals propagating through them. These methods can again be split into two groups:

- measurements using a single harmonic ultrasonic signal (a single frequency f_1)
- measurements using multiple harmonic ultrasonic signals (usually, two frequencies f_1, f_1.)

2.1 Single Harmonic Ultrasonic Signal Measurement Method

In this case, where a single exciting frequency f_1 is used (Fig. 1), the non-linearity gives rise to other harmonic signals, whose frequencies f_v obey the Fourier series formulas:

$$f_v = n\, f_1 \qquad \big| \, n = 0, 1, 2, \ldots \infty \qquad (1)$$

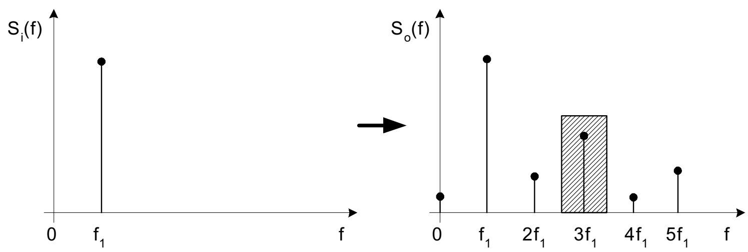

Fig. 1 Frequency spectrum of a non-linear medium response

In general, these frequency component amplitudes are falling when the harmonic order natural number, n, is increasing. If the non-linearity effect is not entirely symmetrical, there can arise low-amplitude second and higher even-numbered harmonic components, whose amplitudes may be much lower than those of the odd-numbered ones. Among these emerging components, the third harmonic is the most distinctive one. Therefore, its amplitude is being evaluated most frequently.

2.1.2 Measuring apparatus

A measuring apparatus featuring a single exciting harmonic ultrasonic signal has been designed, assembled and applied to this purpose. A block diagram of the measuring apparatus is shown in Fig, 2. The measuring apparatus consists of two principal parts, namely, a transmitting unit and a receiving unit.

The transmitting unit consists of four functional blocks: a controlled-output-level harmonic signal generator, a low-distortion 100 W power amplifier, an output low-pass filter to suppress higher harmonic components and ensure high purity of the exciting harmonic signal and a piezo-ceramic transmitter (actuator) to ensure the ultrasonic excitation.

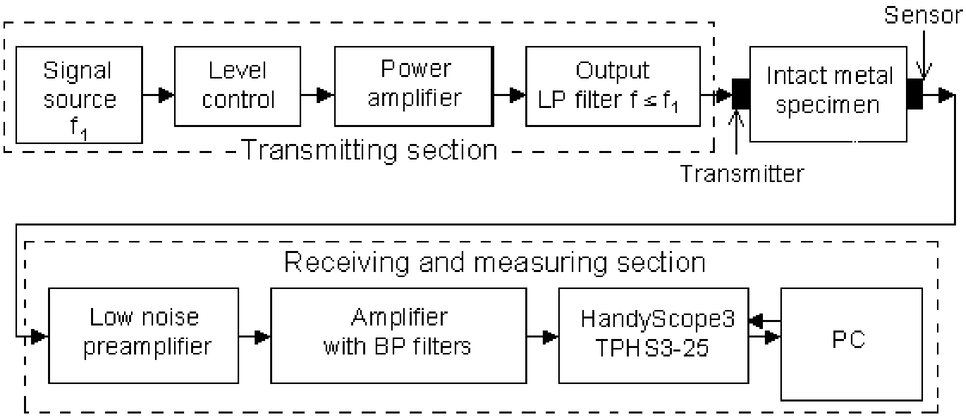

Fig. 2 Block diagram of the measuring apparatus

For the recorded data to be interpreted properly, each of the measuring instruments must meet following criteria:

- High linearity of all instruments (generators, amplifiers, sensor, transmitter,…).
- High resolution in the frequency domain.
- High dynamic range (90 to 130 dB).
- Highly efficient filtration of detected signals (fundamental frequency suppression).
- Frequency range 10 kHz to 10 MHz.
- Optimized sensor and transmitter location.

A program package to control the measuring process and the data processing and evaluation makes an indispensable tool.

2.2 Objective of the Experiment

The tests aimed at examining the linearity of each part of the measuring chain. A total of 6 pick-ups in conjunction with HTP03 ultrasonic exciter, Fig. 3, have been measured.

Fig. 3 Piezoceramic power transmitter with mechanical wave concentration

2.3 Measurement results

Fig. 4 shows the transfer function of S4 sensor, which represents a subgroup of satisfactory response sensors. Four harmonic components are apparent in the spectrum, their amplitudes decreasing with the harmonic component order. The frequency spectrum is not distorted by any non-linear effect, which means that no sensor transfer function induced parasitic components are taking place in this case.

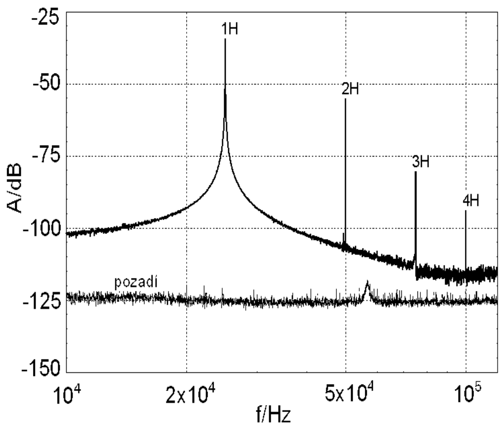

Fig. 4 Transfer function of S4 sensor

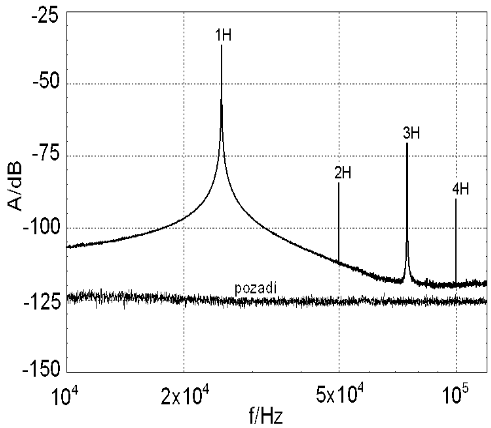

Fig. 5 Transfer function of SN1 sensor

The next Fig. 5 shows the response versus frequency plot for SN1 pick-up. The amplitude peaks in the diagram correspond to the first (1H) and the third (3H) harmonic frequency. The second harmonic amplitude peak (2H) is lower than that of the third harmonic amplitude. This is typical of a non-linear-effect-loaded signal transmission chain.

Fig. 6 compares the measurement results obtained from all of the six sensors available. Harmonic frequency amplitudes relative to that of the first harmonic frequency are shown in it. Based on the Figure, it is evident that neither SN1 nor SN2 meet the signal propagation non- linearity requirement.

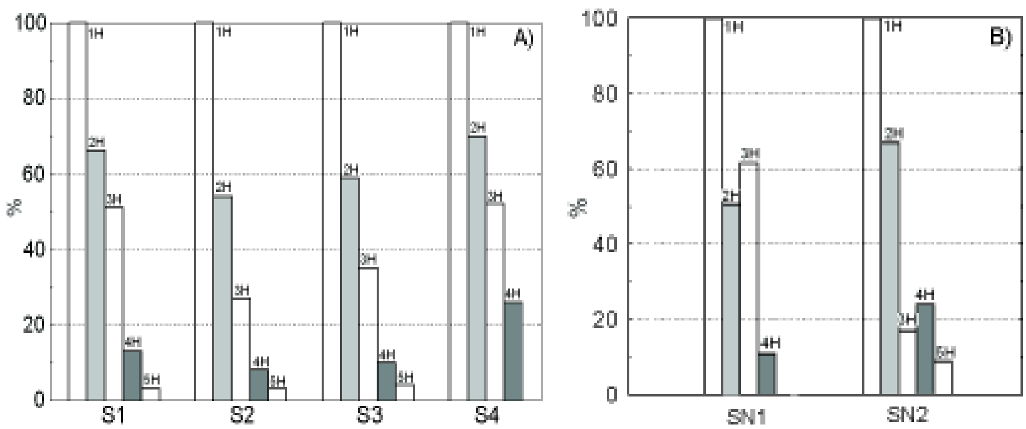

Fig. 6 Relative values of amplitudes: A) convenient sensors, B) inconvenient sensors

3 CONCLUSION

The measurement result analysis shows that detailed knowledge of the pickup transfer function and that of the acoustic coupling is essential for a correct result interpretation. For the results to be reasonably reproducible, perfect acoustic coupling must be established between the transmitter, the specimen and the sensor to ensure duality acoustic coupling for the signal transfer.

This is the only way to eliminate the pickup-induced distortion being attributed to structure defects in the specimens under test.

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