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DIAGNOSTICS OF CONCRETE COMPONENTS USING NONLINEAR ULTRASONIC SPECTROSCOPY

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ABSTRACT

Current methods of material non-destructive ultrasonic testing are based on the analysis of elastic wave reflection, absorption and interference. Their application is advantageous, above all, to the defectoscopy of homogeneous materials and bodies of elementary shapes. However these methods are difficult to apply to inhomogeneous building materials showing tiny cracks and defects distributed throughout the specimen bulk, or in the cases where the defect size is comparable with the wavelength. Analysis of these phenomena occurring in intricate shapes is difficult, too. To cope with such problems, application of wave propagation related non-linear effects and higher harmonic signal generation in the defect vicinity is advisable. Due to the presence of defects, the atom potential energy ceases to be exactly harmonic. Second and third harmonic frequencies arise. In this domain, methods employing the non-linear acoustic spectroscopy (NEWS – Nonlinear Elastic Wave Spectroscopy) achieved rush dissemination recently. These novel defectoscopic methods are based on the non-linear behaviour of current defects and inhomogeneities regarding the elastic wave propagation processes.

Keywords: non-destructive testing, building materials, crack, defect, concrete specimens

1 INTRODUCTION

One of the fields in which a wide application range of non-linear acoustic spectroscopy methods may be expected is 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. Precisely these non-linear acoustic defectoscopy methods are less susceptible to the mentioned restrictions and one may expect them to contribute to a great deal to further improvement of the defectoscopy and material testing in civil engineering.

The paper deals with studying the transfer characteristics of concrete specimens being tested by the non-linear ultrasonic spectroscopy methods using a single exciting harmonic ultrasonic signal. In the case where a single exciting frequency f_1 is used, the non-linearity gives rise to other harmonic signals, whose frequencies f_v obey the Fourier series formulas: 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, low-amplitude second and higher even-numbered harmonic components can arise, their amplitudes being 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.

In the first stage of the experiment, we have examined whether or not the inhomogeneous material gives rise to parasitic components being able to generate non-linear phenomena in the signal transmission. Concrete specimens which had been subject to repetitive freeze-thaw cycle based degradation were tested in the second experiment stage.

2 EXPERIMENT

The subject of the experiment consisted in concrete specimens of dimensions 100 mm x 100 mm x 100 mm of identical concrete batch composition. The specimens were tested prior to the degradation and, subsequently, after 25 and 50 freeze-thaw cycles. A total of 5 specimens have been tested.

A measuring apparatus featuring a single exciting harmonic ultrasonic signal has been applied to this purpose.

2.1 Measurement Results

Fig. 1 shows the pre-degradation transfer characteristics of the specimen denoted C2/0.

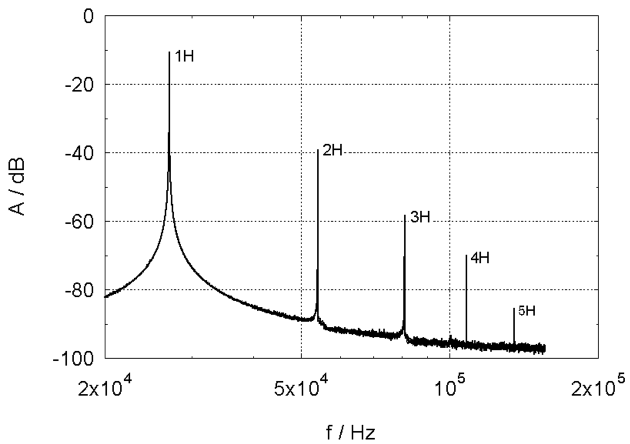

Fig. 1 Frequency spectrum of specimen no. C2/0 (before degradation)

The frequency spectrum shows a progressive fall in the first (1H) through the fifth (5H) harmonic amplitudes with the increasing harmonic serial number, no non-linearity asymmetry being apparent.

The curve of Fig. 2 corresponds to the frequency spectrum of the same specimen, C2/25, being tested after the application of 25 freeze-thaw cycles.

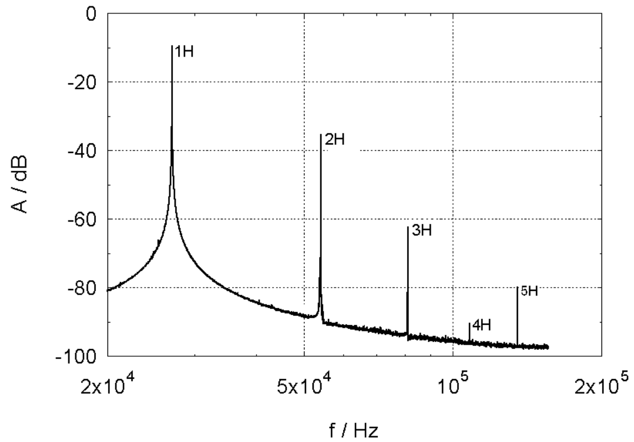

Fig. 2 Frequency spectrum of specimen no. C2/25 (after 25 cycles)

In this diagram, the fifth harmonic 5H is apparent, its amplitude exceeding that of the fourth harmonic 4H. The transfer characteristic of Fig. 3 bears similar non-linearity signs, too. The frequency spectrum contains again the 5th harmonic 5H, however, the amplitude begins to fall at the third harmonic frequency 3H.

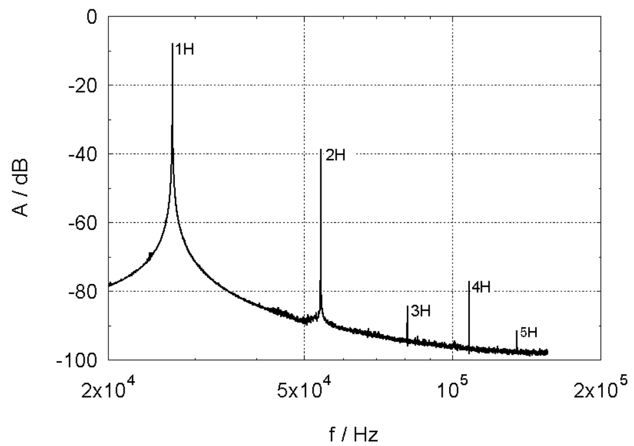

Fig. 3 Frequency spectrum of specimen no. C2/50 (after 50 cycles)

Fig 4 shows a harmonic component amplitude versus freeze-thaw cycle count (0, 25, 50) plot. The curve corresponding to the exciting frequency 1H show a slight increase in amplitude. It is to be emphasized here that a perfect mechanical coupling must be ensured between the exciter and the specimen and, further, between the specimen and the sensor during the experiment setup process. Substantial changes are observed from the third harmonic upwards.

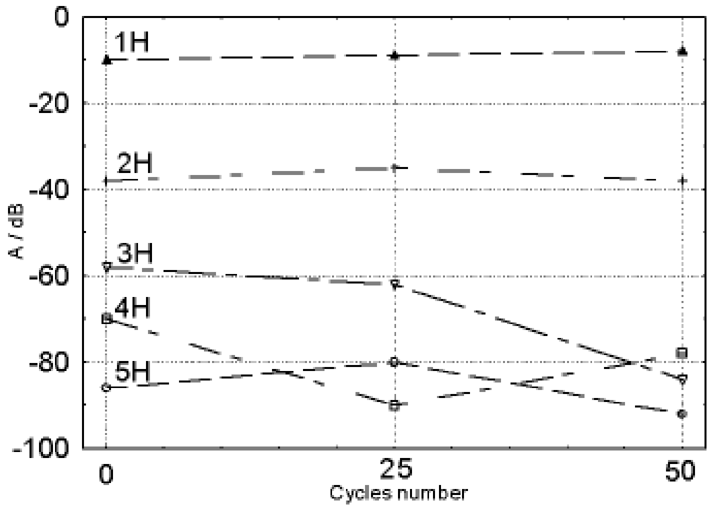

Fig. 4 Harmonic component amplitude versus freeze-thaw cycles number

The post-50-cycle third harmonic 3H show a drop in amplitude of some 25 dB against the preceding measurement results. The fourth 4H and fifth harmonic 5H amplitudes show the first changes to occur after the 25 cycle degradation. The 4H amplitude fell 20 dB against the pre-degradation value, whereas the 5H amplitude grew 5 dB against the previous measurement result. The post-50-cycle measurement results show the 4H amplitude to have grown up and the 5H amplitude to have fallen down.

3 CONCLUSION

Our measurements furnish evidence that the effect of a material inhomogeneity is very low in the case of non-linear ultrasonic spectroscopy, its non-linear effect being substantially lower than for common defects.

The freeze-thaw cycle induced material structure defects give rise to non-linear effects in the signal transmission which in turn took effect in the frequency spectra.

It is to be noted that a perfect mechanical coupling must be ensured between the exciter and the specimen and, further, between the specimen and the sensor during the experiment setup process.

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