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NONLINEAR ACOUSTIC METHODS WITH HELP OF TIME FREQUENCY ANALYSES DETERMINED STRUCTURE QUALITY

NELINEÁRNÍ AKUSTICKÉ METODY S POMOCÍ ČASOVĚ FREKVENČNÍ ANALÝZY URČUJÍ KVALITU STRUKTURY

Abstract

The article will describe relatively new Non-Destructive Testing tool - nonlinear acoustic (ultrasonic) method for determining structural properties. Continuous sine waves are used to excitation one or more ultrasonic transducers in contact with a test sample during a nonlinear acoustic spectroscopy inspection. The responses of the test sample structure are detected by receivers at second location on the surface. Time histories are recorded and frequency spectra are computed. Usual test frequencies covering 1 Hz to 500 kHz have been used in test of concrete structures. There are a lot of different methods with one or more generators and with fixed or sweep frequencies. In future, quality testing concrete or other structures can be followed by applications one of these nonlinear method. Time, frequency or jointed time and frequency analyses help evaluate followed structure. Applications this method is connected with technical progress. Because the method is in development there are a lot of questions with its utilization. It may be determine change of stress, defects or properties.

Abstrakt

Příspěvek popisuje relativně nový nástroj nedestruktivního testování – nelineární akustickou (ultrazvukovou) metodu pro určení vlastností struktury. Nelineární ultrazvuková spektroskopie používá k buzení vzorku spojité harmonické vlnění. Odezvy vzorku na buzený harmonický signál jsou zaznamenávána snímači umístěnými na povrchu vzorku. Časové průběhy jsou zaznamenány a z nich vypočtena frekvenční spektra. Obvykle, u betonových vzorků, jsou použity frekvence v rozsahu 1 Hz až 500 kHz. Je několik rozdílných metod, které používají jeden či více generátorů. Tyto generátory mohou generovat konstantní frekvence nebo rozmítané frekvence. Kvalitu sledovaného betonu nebo jiné struktury bude možné sledovat některou z nelineárních metod. Použití této metody je spojeno s technickým pokrokem. Jelikož uvedená metoda je ve stádiu vývoje, její použití obsahuje ještě spoustu nejasností při použití. Touto metodou lze sledovat změny v napětí, defekty či změnu vlastností. Časové, frekvenční a časově frekvenční analýzy mohou také pomoci při vyhodnocení.

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1 INTRODUCTION

Some imperfections in structures and materials, which could lead to ultimate failure, can be revealed by several non-destructive testing methods in common use. Typical examples are microscopic spectroscopy, X-ray inspection, strain measurements, flaw detection by dye penetrants, eddy currents, ultrasonic transmission or reflection, impact-echo, acoustic emission method etc. Non-linear acoustic (ultrasonic) spectroscopy is relatively new non-destructive testing technique.

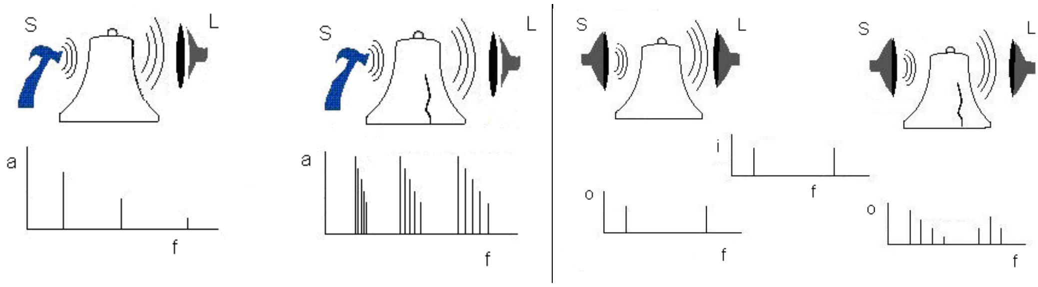

Fig. 1 Test by hammer an by generator (S – source, L – Loudness, a - spectrum, f – frequency, i – input spectrum, o – output spectrum), result with and without defect

There are two different types of sound test of samples quality in figure 1. The figure illustrates how the samples (bell) responds elastically linearly when undamaged, but elastically nonlinearly when damaged. The sample is loaded by strike (left parts of fig. 1) or by harmonic (right parts of fig. 1). If the sample has even a very small crack present, the frequencies depend on how hard the bell is loaded. A nonlinear effect is a change in wave frequency with wave amplitude. This method usually called nonlinear resonant ultrasound spectroscopy (NRUS), a subset of nonlinear elastic wave spectroscopy (NEWS). There are a lot of methods to generate impulse or harmonic loading. Analysis, evaluation and method choosing of the test are not easy too. [6]

Linear Resonant Ultrasound Spectroscopy is based on measurements of resonance frequency and sound attenuation variations due to damage. Resonant Inspection techniques are quite advanced. *Nonlinear Resonant Ultrasound Spectroscopy* is based on the measurements of resonance frequency shift and damping as a function of resonance peak acceleration amplitude for one or several individual resonance peaks. *Nonlinear Wave Modulation Spectroscopy* is yet another manner by which to evaluate the nonlinear acoustic parameters of a material. This is based on measurement of the modulation of ultrasonic waves by vibration. [4,5]

2 MEASUREMENT SET-UP

Basic idea of this method is excitation of tested specimen by one or two sinusoidal signals. Harmonic elements are studied in one exciter (see fig. 2)

$$f_n = n \cdot f_b \tag{1}$$

or in two exciters

$$f_k = \left| \pm n \cdot f_{b1} \pm m \cdot f_{b2} \right|, \tag{2}$$

where f_b, f_{b1} , f_{b2} are frequencies of excited sinusoid and n,m=1,2,3,..∞. The application domain of the ultrasound modulation spectroscopy, which is usually referred to as Nonlinear Wave Modulation Spectroscopy (NWMS), splits into two sub-domains, which differ from each another by the exciting frequency ratio. In the first case, the low-frequency and the high-frequency is generated (left graph in Fig. 3). Important parts of spectra are around f_{b2}- f_{b1} and f_{b2}+ f_{b1}. This option is well suited for high-sensitivity integral measurements. In the second case, the frequencies are close to each other (right graph in Fig. 3). Difference between the excited frequencies f_{b2}- f_{b1} is important for evaluation. This option is well suited for the defect localisation. [7]

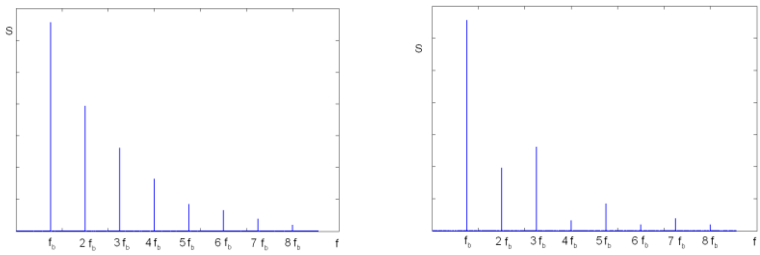

Fig. 2 Frequency spectra of samples without (left) and with (right) defect

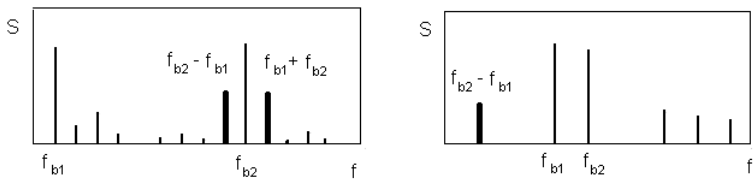

Fig. 3 Two exciters with frequency f_{b1} a f_{b2} .

Device contains excited and analysed parts (Fig. 4). Theoretical exciter can generate harmonic (sinusoidal) signal with different frequency. Real exciter, electrical to mechanical convertor, is made with resonant frequency. Band-pass filter is important for choosing followed part of frequency spectra. High resolution of analogue to digital convertor is advantageous, too.

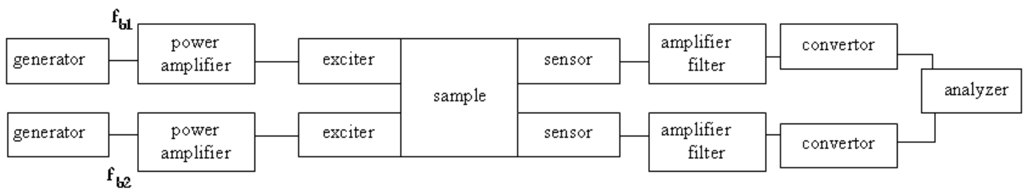

Fig. 4 Block diagram of measured set-up

2 EVALUATION OF REAL MEASUREMENT

Real experiment was carried on rail lines with and without defect (Fig. 5) by one excitor.

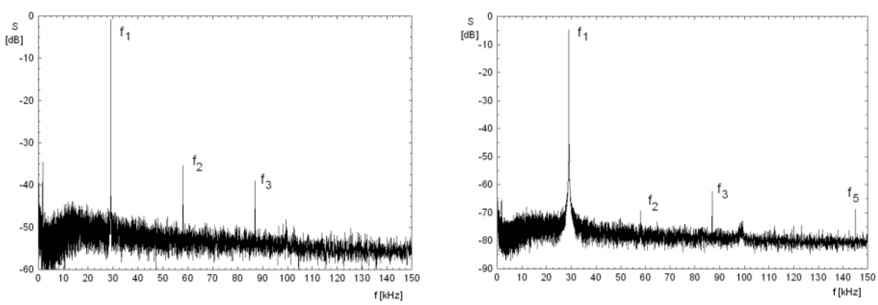

Fig. 5 Frequency spectra from real tested specimens – left without, right with defects

The specimen without defect contains spectral peaks - $S(f_1)> S(f_2)> S(f_3)$. That with defect has peak $S(f_2)$ smaller than peak $S(f_3)$.

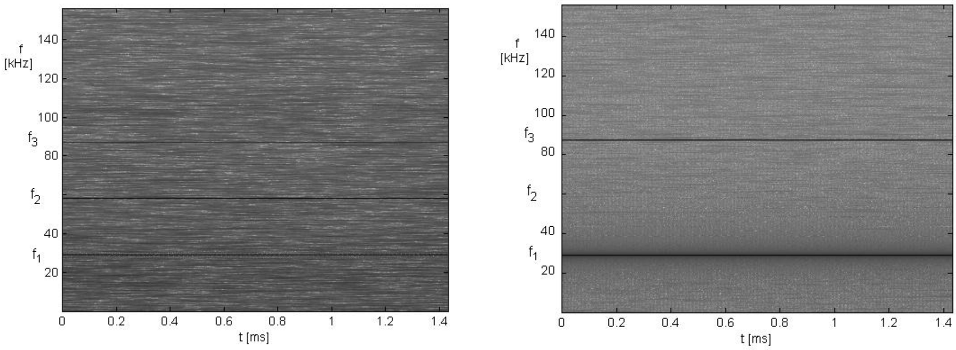

Fig. 6 Jointed time-frequency spectra from real tested specimens – left without, right with defects

Jointed time-frequency spectra are shown in Fig. 6. The spectrum of specimen without defect contained three significant frequencies (left). Defect into specimen hide 2nd frequency. [1]

3 CONCLUSIONS

Evaluation test of Nonlinear Acoustic Method by Jointed Time Frequency Analysis can help to easy determine some properties of specimen. Both methods are in development. Real experiment and evaluation was put on railway sleeper. [2,3]

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