V.V.Kazakov

ON PARTICULARITIES OF CRACK DETECTION IN PLATES BY NONLINEAR MODULATION METHOD

Institute of Applied Physics of RAS
46, Ul'ynov Str., GSP-120, Nizhny Novgorod, 603950, Russia
Tel.: (7-8312) 164986; Fax: (7-8312) 363792
E-mail: kazak@appl.sci-nnov.ru

Brought the results of developments nonlinear modulation method for crack detection in plates. Inflexion of acoustic features of cracks was realized by means of specially formed sequence of acoustic pulses. Considered particularities of using the Lamb waves in the mode "on passing". On examples of finding a single crack and cavity is shown that using difference temporary spreading the transverse ultrasonic waves and Lamb waves, reflected and passed through the defect of structure, realistically manages to distinguish an inflexion caused by presence the crack from inflexions, appearing in the place of contact of ultrasonic transducer. Explored carry out of creation separately-combined sensor for modulation defectoscope.

Usually at realization nonlinear modulation method of crack detection for inflexions of their acoustic features are used low frequencies vibrations or nock [1,2]. However for variety of objects such ways of excitement not always efficient. For instance, under bending the thick-walled objects or thin-walled ones it is necessary to create significant efforts for getting the necessary deformation that connected with significant technical difficulties, as well as side excitement nearby elements constructions that undesirable. Using a mechanical nock greatly simplifies a measuring process, however brings about need to take a side inflexion into account, appearing in the place of installing an ultrasonic transducer. In this connection it is interesting to consider a method of modulation, based on using a sequence powerful acoustic pulses [3].

Purpose of the given studies was concluded in the clarification of particularities of crack detection in plates or pipes and making a sensor in which combined ultrasonic transducer for location of defects and acoustic transmitter for modulation of their acoustic features. Particularity of under development method of measurements was concluded in that that inflexion was made by specially formed sequence of acoustic pulses, synchronous with a repetition frequency F of ultrasonic pulses changing phase of radiating, and using for the analysis only first half-waves these pulses. Under temporary and spatial coinciding of acoustic and ultrasonic pulses occurs an efficient modulation of solid and on the amplitude of modulation of accepted wave signal with the frequency $\Omega = F/4$ determination of presence of crack. Choice of area of analysis is realized by changing a delay of radiating the acoustic pulses with respect to ultrasonic.

As objects of study were used two metallic plates by sizes 305 x 50 x 6 mm with made by the single crack or cavity to perpendicular its axis on the distance 101 mm from their edge. Ultrasonic locator radiated pulses of frequency 2,67 MHz with the frequency F = 162,8 Hz. Corner of entering an ultrasonic wave is 70°. As acoustical transmitter was used component converter with the acoustic prism from fluorocarbon polymer, ensuring corner of falling 60° [4]. To surfaces of prism the ultrasonic transducer the Lanjeven's type of frequency 66 kHz was glued. Modulation of defects was conducted in the mode "on passing". Experimental installation scheme is brought on fig.1.

Location of crack (or cavity) in the plate 1 was realized by means of ultrasonic transducer 3, united with the ultrasonic locator 4. Signal from output of the radar come in on the dual-link block of installing the strobes. The first channel allowed to install strobes pulse manually for the signal from locator output. The second channel allowed to change delay of radiating an acoustic pulse, moreover initial position setup manually, but then delay was changed in the automatic mode with the step 0,75 μs.

The amplitude strobing signal was remembered by the device of sample-keeping 6 every period of ultrasonic repetition frequencies. Escalated in the block 7 signals of frequency to inflexions entered through the charge ADC in the computer, where was conducted its registration for a time of realignments of acoustic pulses. In the block 9 was conducted changing a phase of radiating under the law: 0°, 0°, 180°,180° , ensuring most efficiency to inflexions. Formed signals entered on the two-phase amplifier 10 and on component acoustic transmitter 11 hereinafter. With its help in the plate were become excited the asymmetric Lamb waves type a_0.

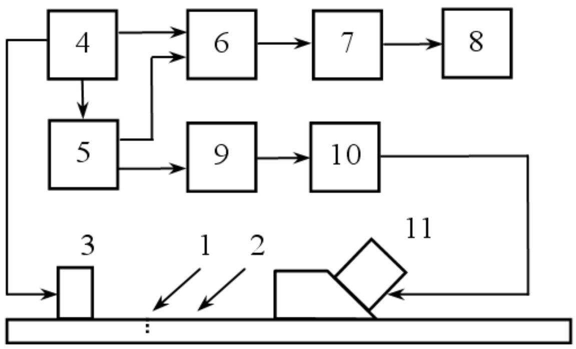

Fig.1. Scheme of the experiments:
1 — crack; 2 — plate; 3 — ultrasonic transducer; 4 — ultrasonic locator; 5 — block of installing the strobes; 6 — device of sample of keeping; 7 — resonance amplifier of frequency Ω_0; 8 — computer; 9 — law shaper of modulation; 10 — power amplifier; 11 — acoustic transmitter.

As a result experiments was registered changing an amplitude to inflexions for the chosen position of strobe pulse depending on delays of radiating by the acoustic pulse. Practically it reflects an modulation of ultrasonic wave at the passing of Lamb wave through the crack. Parameters of measurement scheme are choose so as transverse ultrasonic wave "have time to return earlier" to the ultrasonic transducer, than on he enters a Lamb wave. This allows to separate an modulation, caused by changing the features of crack, from inflexions, caused changing a contact ultrasonic transducer with the surface of plate.

On fig.2 brought signal of received wave for crack location (delay to crack is 70 μs, delay to edge of plate - 195 μs) and its modulation with the frequency 40,7 Hz for different delays of radiating an acoustic pulses.

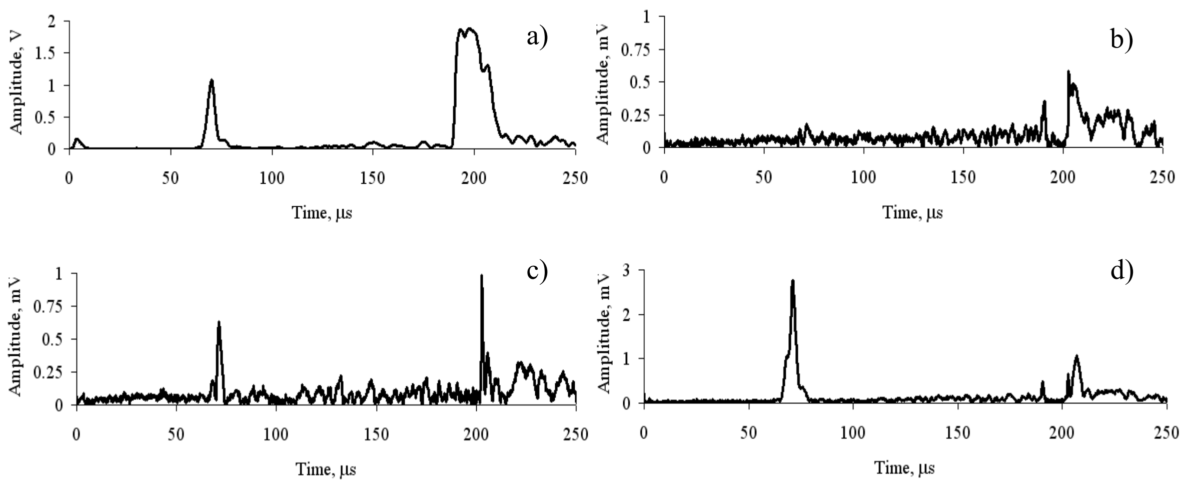

Fig.2. Signal of ultrasonic wave reflected from the crack (a) and its modulation for delays of radiating an acoustic pulses equal 0 μs (b), 18 μs (c) and 45 μs (d)

From fig.2 we can see that changing area of interaction of ultrasonic and acoustic pulses, on crossing a signal to inflexions of threshold (it is determined experimental and is 0,4-0,5 mV) defect is classified as a crack. If measure a peak value of signal, as a rule corresponding maximum value to inflexions amplitude-detection signal accepted ultrasonic wave, possible observe a periodic changes of amplitude to inflexions depending on delays of radiating the acoustic pulses with respect to ultrasonic (refer to fig.3). At location by longitudinal waves (fig.3c,d), ultrasonic sensor was pressed to the edge of plate.

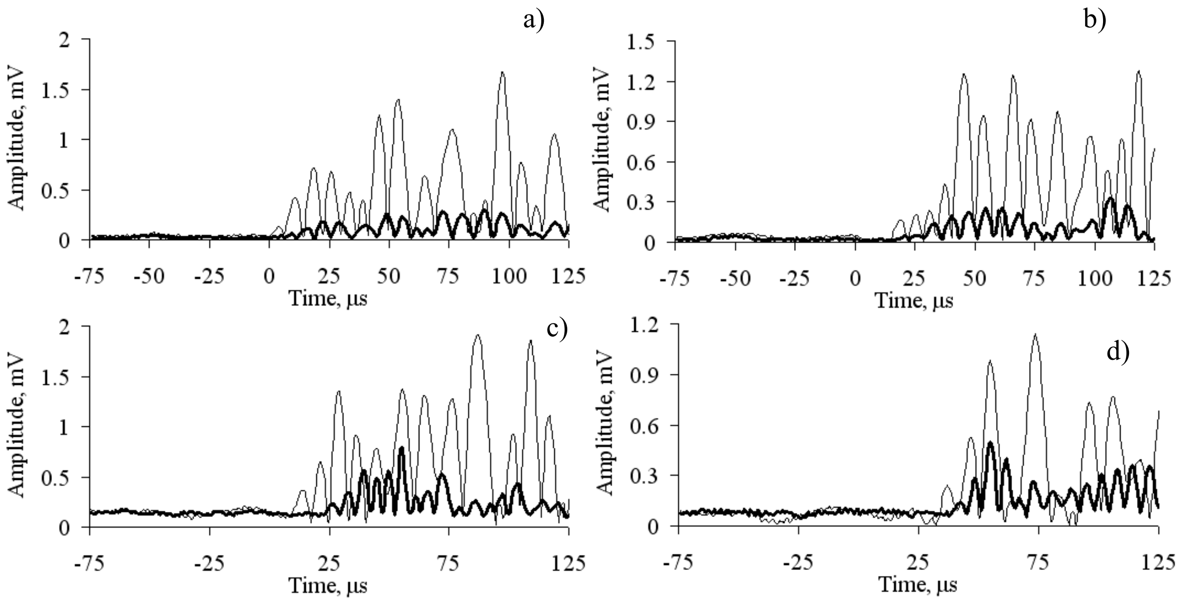

Fig.3. Changing an amplitude of modulation for crack location (fine lines) and cavity (fat lines) by transverse waves at the distance of edge acoustic transmitter before the defect equal 20 mm (a,b) and 60 mm (c,d) by location of transverse (a,b) and longitudinal (c,d) waves.

It is necessary to note that modulation of signal particularly at its small value measurement presence always. First, this is connected with mistiming between frequencies assigning ultrasonic locator generator and working of analog-to-digital converter, bringing to "jingling" fronts of accepted signals. Secondly, this is connected with presence geometric nonlinearity, caused changing a form of plates under bending, and, consequently, at periodic changing a route of location. Influence of second reason particularly significant for location transverse waves, as far as a rule a wave feels in the plate frequentative reflecting, previously than will be reflected from the defect. However, under correct organizations of measurements on modulation level realistically to distinguish a type of the defect: crack or cavity.

Findings have allowed to offer a design of sensor of modulation defectoscope in which ultrasonic and acoustic transmitter are united in general body. Choice of area of interaction is realized a priori. For this on certain range is installed strobe pulse, allowing measure a signal amplitude of accepted wave, but time of delays of radiating the acoustic pulses is installed experimental on the beginning of appearance to inflexions the signals of accepted wave (refer to fig.3), as well as with provision for velocities of spreading the acoustic pulses, hanging from the velocity of spreading the longitudinal waves in the prism, radiating frequencies and thicknesses of plate [4]. On fig.4 brought results of experiments on detection the crack and cavity in two plates. For this plates the crack and cavity was from below side. Overhand on the plate was installed combined sensor. Synchronous with its moving down to the plate within 0-110 mm at the speed of 1-2mm/sec was continuously registered two signals: amplitude strobbed signal and its modulation with the frequency Ω= 40,7 Hz. As far as area of analysis a priori known - possible consider that on the maximum of signal is defined position of defect, but on the level a modulation - its type. Time for fig.4

practically corresponds to a location area of interaction on the length of plate. From the drawing well seen that moving sensor on surfaces of object are possible to define not only presence of defect, as well as install its type. That is to say, method allows to detect cracks, inhering on internal surfaces of plates, and so not available visual checking.

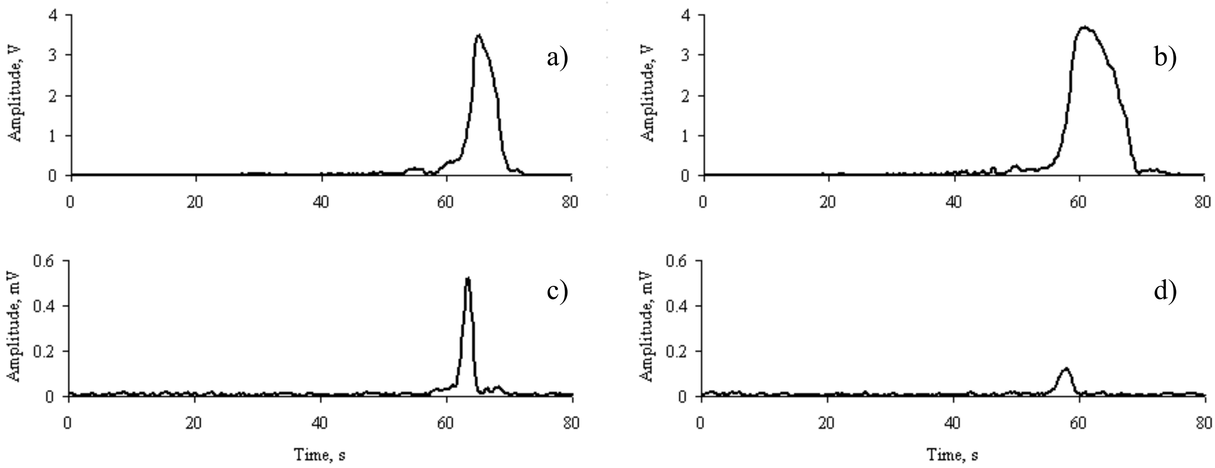

Fig.4. Changing an amplitude strobbed signal (a,b) and its modulation (c,d) when moving a sensor on plate with crack (a,c) and cavity (b,d)

Particularity of conducting measurements is also revealing a dependency between repetition frequency of ultrasonic pulses *F* and harmonicas of network frequency $n\Omega$. Obviously that both when radiating, and when receiving exists a noise pickup of harmonicas of network frequency on research signal. This brings about that that in the spectrum of signal to inflexions is present a whole kit combination frequencies $F \pm n\Omega$, which mask a signal of frequency Ω_0. Consequently, depending on required spectral resolution, defining sensitivity of measurements, depends and choice of difference between specified frequencies. Was it in particular observed deep influence of frequency $\Omega = 150$ Hz on the repetition frequency *F*, so optimum (with provision for available possibilities) is rendered necessary separate them on 13 Hz ($F = 162{,}7$ Hz). Increasing a difference brings about that that, appears an interaction on other combinational frequencies, which become close or are superimposed on the frequency of modulation Ω_0 that does an undertaking the measurements impossible.

Thereby, as a result performing a given work are conducted experiments, supporting possibility of finding the single cracks in plates with use a modulation their features by the sequence of powerful acoustic pulses. Determined the features choice of parameters of acoustic transmitter and ultrasonic repetition frequency. They allow to create a design of sensor of modulation defectoscope, in which ultrasonic and acoustic sensors are combined that will allow its use for flow checking the pipes and plates with high efficiency of measurements.

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