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V.V. Gerasimov

TO SELECT IDENTIFICATION PARAMETER BASED ON FOURIER TRANSFORM IN DEFECTOSCOPY OF COMPOSITE MATERIALS

Abstract. Investigated the dependence of the spectral parameter identification Kh of changes in the number of harmonics used to calculate the component. Proved Based on collected statistics prove optimality calculation methodology proposed previously specified parameter. Investigated the influence of the signal length of surface cracks in recognition of these signals on the background noise.
Keywords: Fourier spectrum, window Gaussian function, eddy current sensor, surface crack, identification parameter.

Statement of the problem. The process of defectoscopy of composite materials is complicated by the presence of interfering factors, including the need to mark uncontrolled left-off of eddy current sensor on the surface researched product and tilt effect of sensor relative to the normal to the surface. In such circumstances urgent problem is the problem of identification of modulation signal of surface cracks of composite materials against a background noise and separation them of the signals lft-off and tilt effect of plated eddy current sensor relative to the normal to the surface.

In [1] to identify surface cracks signals was proposed coefficient K_h as ratio of harmonics 6 – 14 to the sum of the amplitudes of harmonics 1 – 14. The question is how is optimal ratio selected?

The aim of this work is to study the methods of calculation proposed parameter identification K_h, namely its dependence on changes in the number of harmonics used to calculate its component.

Analysis of the last publications. As in [1-4] performed spectral analysis of these signals: difference exhibitor

$$s_1(t)=e^{-b^2t^2}-ke^{-2b^2t^2}, \qquad (1)$$

describing the signal from the surface cracks and paraboloid

$$s_2(t)=at^2+ct, \qquad (2)$$

corresponding lift-off/tilt effect signal of eddy current sensor relative to the surface of the composite. Since eddy current testing of composite materials is characterized by a small number of samples in the signal from the crack, and for a small number of errors of the first and second kind [2] requires the largest possible number of samples, then, subject to fulfillment of convenience Fourier transform, length signals studies were taken 32 samples. By length modulation signal from surface cracks in (1) the parameter b corresponds. In these studies this parameter was fixed at $b^2 = 1.5$, which provides a signal length of the surface crack (1) of 32 samples at 0.1 of the maximum amplitude [3]. The spectral components calculated using the discrete Fourier transform.

The main part. Input data and signal processing algorithms basically were the same as in [1, 4]. The amplitudes of the signal lift-off/tilt effect s^2 and signal of surface cracks (pulse modulation) s_1 were fixed at 1. The parameter k, which is responsible for the shape of the pulse modulation, changed in the range of 0,0.1, ..., 1. Investigated the spectral identification parameter K_h for signals with noise standard deviation $\sigma = 0$ and $\sigma = 0.5$. Each experiment was repeated 10000 times. Signal spectrum was calculated using Gaussian windows and without any window. Identification parameter K_h upgraded by changing the range of harmonics used to calculate its numerator and denominator respectively.

The dependence of a modernized identification parameter $K_{h(7/14)}$ (the numerator is amount of harmonics 7 – 14, the denominator is the sum from first to 14th harmonics) of the form of modulation signal s_1 of surface cracks (parameter k) for fixed values of noise are on Fig. 1.

Fig. 1a, 1c constant lines represent signal s_2, not constant are accordance the signal s_1. Fig. 1b, d to determine the effectiveness of the window function the value of identification parameter K_h of signal s_1 were normalized for appropriate values of this factor for the signal s_2 (lift-off/tilt effect of sensor).

As shown in Fig. 1 the change range of harmonics can lead to a significant deterioration recognazability signals s_1 and s_2. So without the use of window functions in a certain range of values of the parameter k is impossible to distinguish between these two signals without noise (Fig. 1a, b) using this modified identification factor $K_{h(7/14)}$. And with a slight noise ($\sigma = 0.5$) even use window function does not improve outcome (Fig. 1c, d). To determine the impact of changes in the calculation range of identification parameter K_h was chosen two key values of this parameter (normalized): for point defects ($k = 1$) and the minimum value of the data set ($k \sim 0.4$ □ 0.6). The results are summarized in Table. 1.

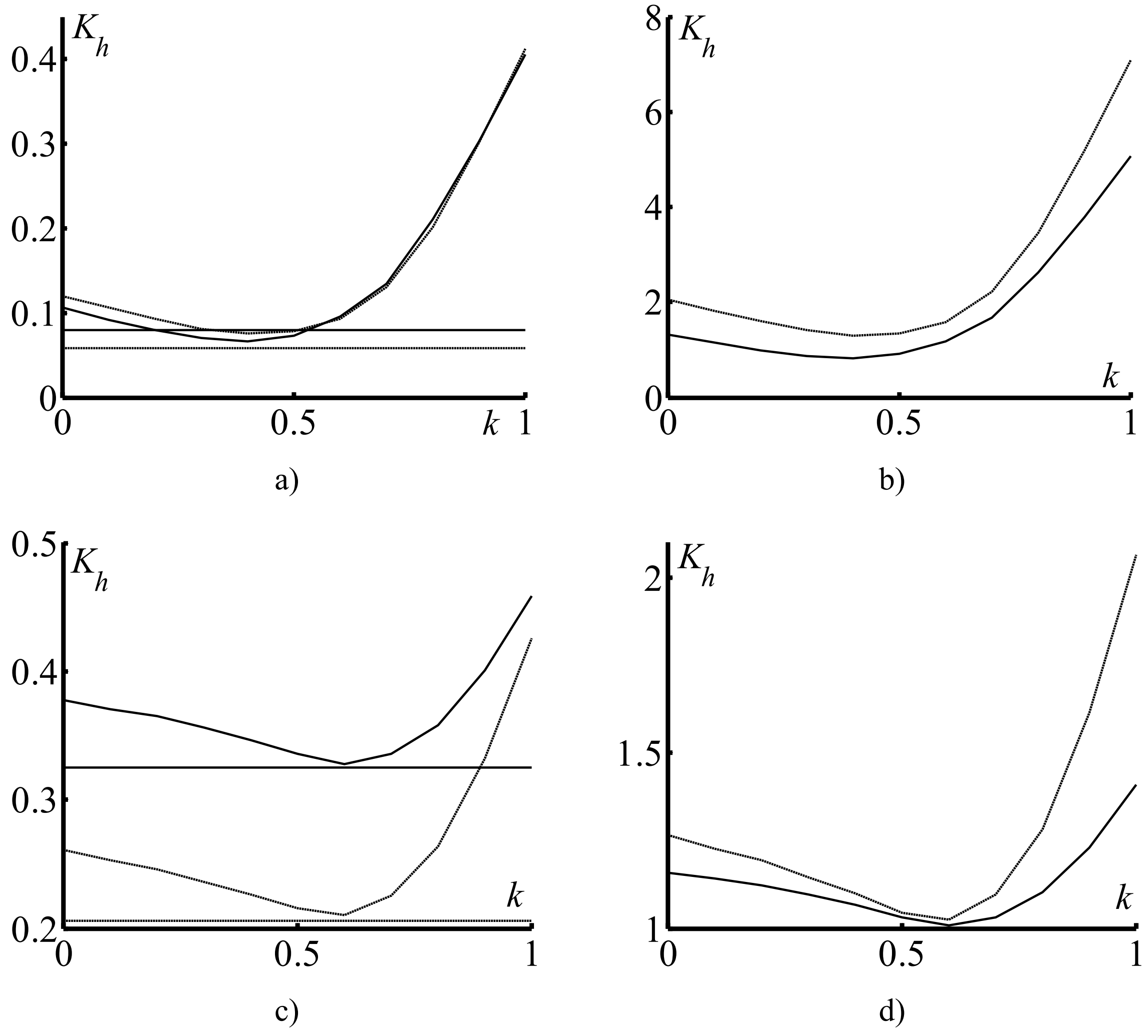


Figure 1 ÷ Dependence of the modified identification parameter K_h on the parameter k, characterizing shape of modulation pulse of cracks at σ = 0 (a, b), σ = 0.5 (c, d): — spectrum was calculated without window functions; - - with using Gaussian window

Increasing the number of components of the numerator to calculate the identification parameter K_{hn} leads to some improvement recognazability of signals s_1 and s_2 in the worst case, but worsens the discrimination signal point defect - case 5/14. Slightly improved the discrimination of the surface point defect while reducing the total number of used harmonics for background noise with standard deviation σ = 0.5, but worse for reducing noise to zero - case 6/13. Increasing the number of used harmonics leads to improved discrimination of point defect without noise, but with the advent of this latter figure worse - case 6/15.

Table 1.

Key value identification parameter K_{hn} for different ranges of harmonics

Harmonic range	K_{hn1}		K_{hnmin}	
	σ = 0	σ = 0.5	σ = 0	σ = 0.5
6/14 (14)	0.3495 (4)	0.2205 (2)	0.0439 (5)	0.0169 (3)
5/14 (15)	0.2791 (6)	0.1786 (7)	0.0573 (1)	0.024 (1)
7/14 (20)	0.3536 (3)	0.2196 (3)	0.0173 (7)	0.0049 (7)
6/13 (14)	0.3439 (5)	0.225 (1)	0.0441 (4)	0.0167 (4)
6/15 (15)	0.355 (2)	0.2164 (5)	0.046 (3)	0.0163 (5)
5/13 (17)	0.2733 (7)	0.1786 (6)	0.0563 (2)	0.0233 (2)
7/15 (17)	0.3594 (1)	0.2173 (4)	0.0188 (6)	0.0057 (6)

For the worst case when signals visually bad different, some steady improvement of the results observed only at increasing the number of components of the numerator of identification parameter, at which much worse discrimination of surface point defect - case 5/14. In other change in the number of used harmonics to calculate the identification parameter, improved performance is not observed.

The results were evaluated: the best indicator received a point, worse - two points and so on. Then the scores were summarized. So the best results were received for 6/14 and 6/13 cases. It should be noted that the decrease in the total number of harmonics to determine the spectral identification parameter degrades the detection of surface cracks signal on the background noise as its parameter K_h begins to approach the critical identification parameter K_{hsh}. So in the first case we have parameter value $K_h = 0.464$ for signal s_1 and $K_{hsh} = 0.649$ in the presence of noise with σ = 0.5. In the second case we have $K_h = 0.448$, and $K_{hsh} = 0.622$ respectively. The difference between them declined.

Taking into account the above, we can conclude that we have chosen in [1] for research harmonic range to calculate the spectral identification parameter for surface crack signal (harmonics 6 – 14 for the numerator, the first 14 harmonics for the denominator) is optimal.

The next step was the effect of the coefficient b in (1) for the identification process of signals from surface cracks investigated. From (1) can be pre say that reducing this ratio will lead to increased signal and increase according to a narrowing of the signal (Fig. 2a, b). So when $b^2 = 1$ length signal (1) at 0.1 of the maximum amplitude is 39 samples, when $b^2 = 2$ is 27 samples respectively. Signal spectrum (1) with $b^2 = 1$ is slightly narrower, at $b^2 = 2$ is wider respectively. With further increase of b the spectrum will continue to expand and converge to a constant value, which is determined by the pulse area - as known to short pulses of arbitrary shape have just such spectrum [5].

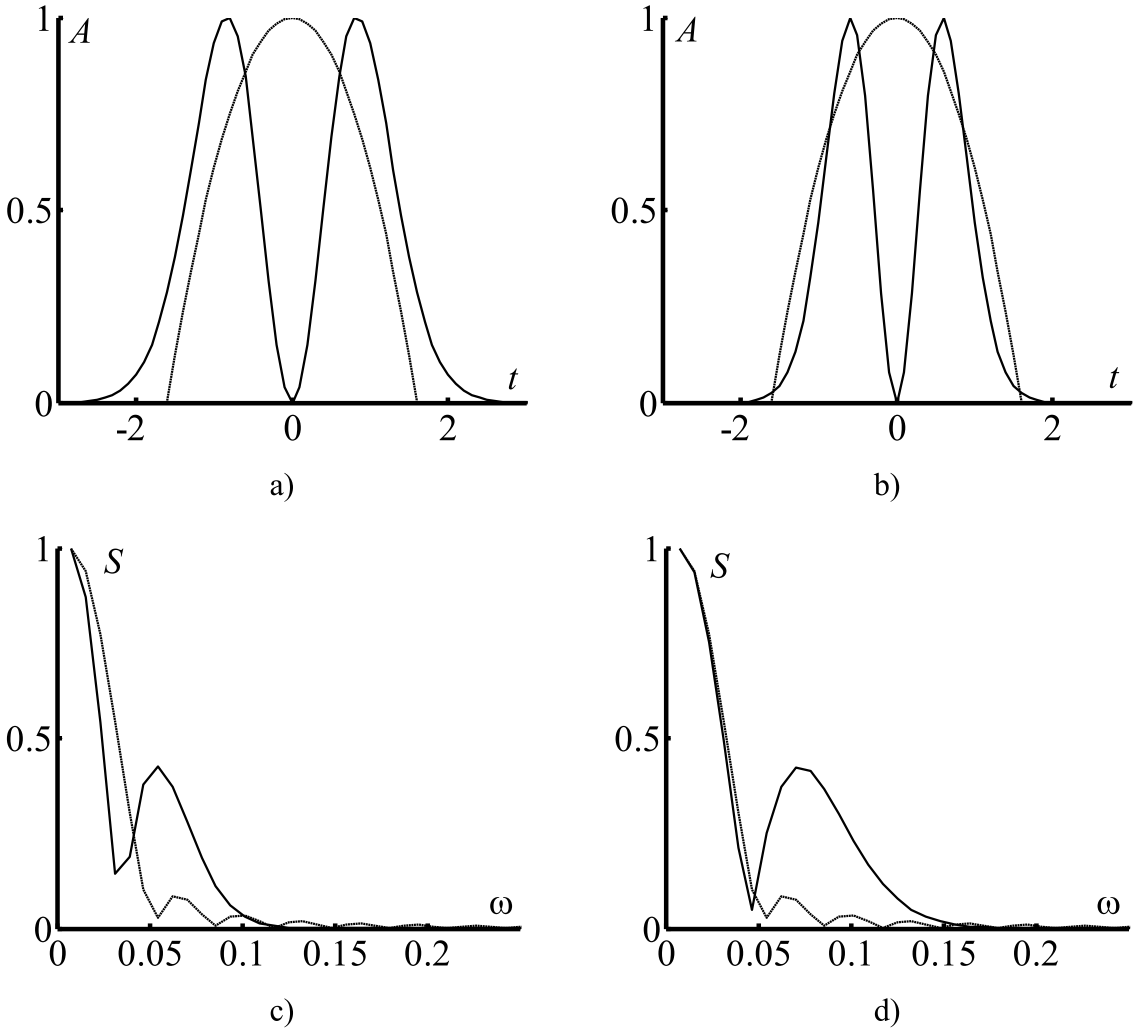
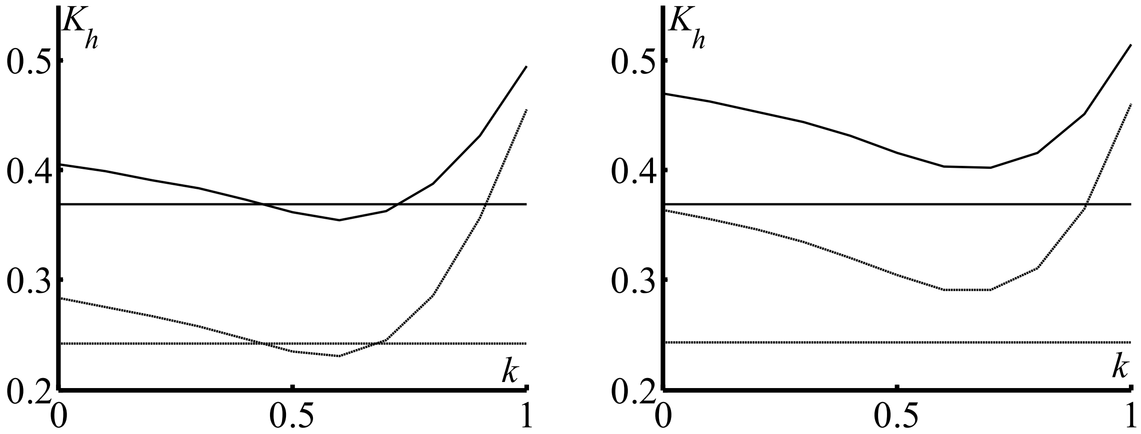


Fig. 2. Form and spectra of signals s_1 i s_2: a), b) $b^2 = 1$; c),) $b^2 = 2$;
— signal and spectrum of surface crack s_1; - - signal and spectrum of lift-off or tilt effect of sensor s_2

Fig. 2c, d shown the normalized (on the maximum) baseband of the first 14 harmonics of these signals compared to normalized baseband first 14 harmonics interfering signal (2).

Further studies were carried out depending the identification parameter K_h on length of surface cracks (coefficient k) for values of the coefficient $b^2 = 1$ and $b^2 = 2$. These dependencies for noise standard deviation σ = 0.5 are shown in Fig. 3.



a) b)

Fig. 3. Dependence of identification parameter on coefficient k, characterizing shape of modulation pulse of cracks at σ = 0.5: a) $b^2 = 1$; b) $b^2 = 2$;
— spectrum was calculated without window functions;
- - with using Gaussian window;

From these figures (Fig. 3) shows that the $b^2 = 1$ significantly deteriorates the signal separation of surface point cracks (k <1) from lift-off or tilt signal. When $b^2 = 2$ at first glance it seems that the situation is getting better and further increase of this ratio (narrowing of surface crack signal) will lead to even better results. But one needs to remember that the top value of identification parameter K_h limited value K_{hsh} = 0.643, which corresponds to pure noise without any signal [4]. With the increasing of the coefficient b identification parameter K_h with increasing noise begins intensive approach the limiting value K_{hsh}, ie detection of deteriorating (narrower) signals of surface cracks on the background noise (Fig. 3).

Conclusions. It was investigated the dependence of the spectral identification parameter K_h of changes in the number of harmonics used to calculate the component. We prove optimality proposed in [1] calculation methods specified parameter - harmonics 6 – 14 for the numerator, the first 14 harmonics for the denominator. Invetigated the influence of the length of the signal of surface cracks in characteristics recognition of these signals on the background noise.

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