5.3.8. ULTRASONIC "GAUGES" BASED ON MIRROR-SHADOW METHOD FOR TESTING ARTICLES WITH EQUIDISTANT SURFACES

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Mirror-shadow method (MSM) is used for detection of defects with given or larger extension in rolled profile and flat products and other metal products with equidistant surfaces. MSM is implemented, as a rule, by means of normal piezoelectric (PEP) or electromagnetic-acoustic (EMAP) probes exciting, respectively, longitudinal or transverse elastic waves [1, 2]. MSM is entered in GOST 18576 as one of the main methods for testing rails [3].

With MSM application, attenuation in certain, in advance known number of times of the bottom echo-signal by a defect is a sign of flaw detection. Any extraneous disturbance resulting in attenuation of the bottom echo-signal amplitude is a noise.

For evaluation of the defect detectability and noise level, *coefficient of defect detectability* K_d and *noise factor* K_n are introduced [1,2]:

$$K_d = U_d / U_0;\ K_n = U_n / U_0,$$

where U_0 – is amplitude of the first bottom echo-signal in the absence of defect and noise; U_d and U_n – are minimal amplitudes of the same bottom echo-signal in the presence of defect and under influence of a noise, respectively [1,3]. In this case ($0 \le K_d, K_n \le 1$); the larger is defect and the higher is noise level, the less is K_d and K_n. In order to detect a defect, it is necessary that $K_d < K_n$.

MSM noise immunity is pre-determined in many aspects by the number of local structural zones in test object causing attenuation of bottom echo-signals (hereinafter referred to as the "noise zones"). Thus, during testing of rails, noise zones are as follows: holes in bolt joints and joints of electric resistance welding with structure, where bottom signal is subjected to significant attenuation; mechanical damages of rolling surface under the rail web [4]. Extension l_p of the projection of these zones on the contact surface of rail amounts, respectively to ≈ 36; 200; 70 mm.

MSM immunity to noised of discussed types can be increased by application of finder with identical transceivers of D diameter located at the distance $L_0 = l_p + D$ between acoustic axes. Proposed finder forms as if ultrasonic "gauge" passing freely (with certain sensitivity) over noise zone, but recording defects with their projection on the contact surface going beyond the limits of the noise zone projection. Ultrasonic "gauge" was implemented for the first time in flaw detectors USD-NIIM-6M for detection of cracks in the bolt hole walls of rails [4, 5].

There are two possible principles of formation of resulting signal U_Σ during application of ultrasonic "gauge" with two normal probes receiving bottom echo-signals U_1 and U_2 (in this case, $U_1 = U_2 = U_0$ and their dispersions are $\delta_1 = \delta_2 = \delta_0$).

Principle 1 is based on the direct summing of two amplitudes U_1 and U_2 with Gaussian distribution law. In this case, amplitude of resulting signal $U_{\Sigma 1}$ in every insonification cycle will amount to $U_{\Sigma 1} = = U_1 + U_2 \approx 2U_0$, while noise factor – $K_n = 0.5$.

Principle 2 is based on selective summing of the same amplitudes U_1 and U_2, where amplitude of resulting signal $U_{\sum 2}$ takes on the value of amplitude U_1 or amplitude U_2 depending on whatever of them is larger within the current insonification cycle, i.e. $U_{\sum 2} = \max\{U_1;\ U_2\}$. In this case, noise factor is $K_n = 1$.

Functional characteristics (average value $U_{\sum}$ and dispersion $\delta_{\sum}$ of resulting signal amplitude, noise factor K_n) of ultrasonic "gauges" obtained in the result of theoretical and experimental researches are presented in Table below.

Table

Principle of $U_{\sum}$ formation	Principle algorithm	$\delta_{\sum}$	$U_{\sum}$	K_n
1	$U_{\sum 1} = U_1 + U_2$	$1.4\delta_0$	$2U_0$	0.5
2	$U_{\sum 2} = \max\{U_1;\ U_2\}$	$0.9\delta_0$	$U_0 + 0.46\delta_0$	1.0

Ultrasonic "gauge" with any principle of formation of resulting signal $U_{\sum}$ can be used for detection of the following:

– cracks in hole walls provided that total extension of projections l_d of a crack and hole of D diameter on the contact surface of article exceeds distance L_0 between acoustic axes of probes ($l_d + D > L_0$);

– defects of various types located in noise zone provided that total extension of projections of a defect l_d and noise zone l_n on the contact surface of article exceeds distance L_0, i.e. $l_d + l_n > L_0$;

– defects of various types located beyond the noise zone with their projection l_d on the contact surface of article exceeding the distance L_0, i.e. $l_d > L_0$.

At the same time, ultrasonic "gauge" must not respond to noise zones, if $l_n < L_0$.

Ultrasonic "gauge" under principle 1 can be implemented on the basis of typical flaw detector with conventional sensitivity of less than 0.5. Ultrasonic "gauge" under principle 2 can be implemented on the basis of two-channel flaw detector with a unit for selective summing of signals with unlimited conventional sensitivity.

References:

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