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INSTRUMENT-MAKING AND INFORMATION-MEASURING SYSTEMS

ПРИЛАДОБУДУВАННЯ ТА ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНІ СИСТЕМИ

UDC 621.39

RATIONING SIGNALS FROM EDDY CURRENT TRANSDUCER FOR FAITHFUL COMPARISON

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Summary*. The problem of detecting metal objects in different environments has always been important. Optimal for dichotomous distinction metals are impulsive VLF metal type. Transmitting antenna of the metal detector emits primary electromagnetic field which adopted the receiving antenna configured to the absence of metal objects between transmitting and receiving antennas at the receiver input signal was minimal. In modern metal detectors identify the type of metal is by providing informative signal to background interfering factor. Now use the amplitude, phase and frequency domain signal processing. Permittivity and magnetic permeability for nonferrous and ferrous metals are different, resulting in different amplitude of the signal at the input of the receiving antenna. Therefore, for correct comparison of signals other than the method of distinguishing threshold required for the normalization of their amplitude. Also investigated environment scanning antenna by hand, and it requires normalization of the received signal in duration. The solution to this problem and is devoted this article.*

Key words: *dichotomy, eddy current metal detector, metal distinction.*

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Introduction. The problem of detecting metal objects in different environments has always been important. To solve it using eddy current devices which is a location system of nearest zone of detecting and it's designed to detect and identify items on its electric or magnetic properties different from the environment in which they are located.

Optimal for dichotomous distinction of metals are impulsive metal detector of VLF type [1]. Transmitting antenna of the metal detector emits primary electromagnetic field which adopted the receiving antenna configured to the absence of metal objects between transmitting and receiving antennas at the receiver input signal was minimal.

If the metallic object gets in antenna's field, then by the law of Faraday alternating electromagnetic field on the surface of the object induces an electric current, which creates a secondary electromagnetic field. Under the influence of the secondary electromagnetic field changes and the initial output of the receiving antenna signal occurs. Electric and magnetic properties of an unknown metal object affecting the shape of a signal [2].

Modern metal detectors identify the type of metal by providing informative signal to interference background. Now use the amplitude, phase and frequency domain for signal processing.

Amplitude method is used when the obstructive factor affects the phase of a signal. For

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this purpose, the composition is administered amplitude detector metal detector, which monitors the amplitude of the input signal. Upon reaching a threshold level corresponding to the selected material of the object, triggered indicator device, which indicates the presence of the object. In this case, the change in phase or frequency will not affect the readings. Most modern metal detectors just used for metal identification signal threshold level [3].

Phase and frequency methods are used in case of a significant effect of preventing the factor on the amplitude of the signal. To implement these methods instead of the peak detector using phase or frequency. The last two methods are used in non-destructive testing instruments.

The most common method is of amplitude or threshold. For this purpose, the composition is administered amplitude detector in device, which monitors the amplitude of the input signal. Upon reaching a threshold level corresponding to the selected material of the object, triggered indicator device, which indicates the presence of an object [4].

Phase frequency and methods used in the case of a significant effect of preventing the factor on the amplitude of the signal. To implement these methods instead of using the amplitude or phase frequency detectors.

It is known that the permittivity and magnetic permeability for nonferrous and ferrous metals are different, resulting in different amplitude of the signal at the input of the receiving antenna. Therefore, for correct comparison of signals other than the method of distinguishing threshold required for the normalization of their amplitude.

Also investigated of environment are scanning by antenna in handheld mode, and it requires normalization of the received signal in duration. This article is devoted to the solution of this problem.

Theoretical and experimental results. It is known that the input signal $U_{ВД}$ of metal detector, which is excited by secondary electromagnetic field depends on the conductivity of the sample and its magnetic properties [4, 5].

$$U_{ВД} = \frac{\int\limits_{-\infty}^{\infty}\left[\left(\sum_{j=1}^{\infty} r_{j,j+1} e^{2ik\int\limits_{0}^{z_j} n(\tau,f)\,d\tau}\right)\int\limits_{-\infty}^{\infty} s(t)e^{-2\pi i f t}\,dt\right]e^{2\pi i f t}\,df}{R} * \quad (1)$$

$$j\omega\,\mu_0\pi N_Д N_З R_\partial \int\limits_0^{\infty}\varphi_1(x,\beta)\,J_1(xR_{З*})\,J_1(x)\,e^{-xh_*}\,dx,$$

$N_Д$, $N_З$ – number of turns of the receiving and transmitting antennas.

$$h_* = \frac{h_З + h_Д}{R_З}; \qquad R_{З*} = \frac{R_Д}{R_З}$$

$$\varphi_1(x,\beta) = \frac{\mu_r - \sqrt{x^2 + j\beta^2}}{\mu_r + \sqrt{x^2 + j\beta^2}} \quad (2)$$

μ_r, μ_a, σ – relative, absolute magnetic permeability of research materials and their conductivity, $x = \lambda R_З$, $\beta = R_З\sqrt{\omega\,\mu_a\sigma}$ – a generic parameter of eddy current testing (ГОСТ24289 – 80),

λ – setting integral transformation,

ω – angular frequency.

Transmitting and receiving antennas have a radius $R_З$ and $R_Д$ in accordance. J_1– Bessel function of the first kind of the first order.

$h_З$, $h_Д$ – distance from the transmitting and receiving antennas to the metal specimen.

Reflection coefficient $r_{j,j+1}$ from border z_j.

$k = \frac{2\pi}{c}$ – wave number in vacuum, c – speed of light.

Waveform samples obtained from various metals in size and shape with different scanning speed is shown in Fig. 1.

The process of normalization of the amplitude is not difficult and is carried out by known methods. The time response for the samples (see table 1) of steel, copper, aluminum shown in Fig. 2.

Table 1

Description of samples used in the experiment

№	Description of the sample
1	Round specimen with diameter 25 mm, thickness 3 mm, copper
2	Round specimen with diameter 25 mm, thickness 3 mm, iron
3	Round specimen with diameter 25 mm, thickness 3 mm, aluminum

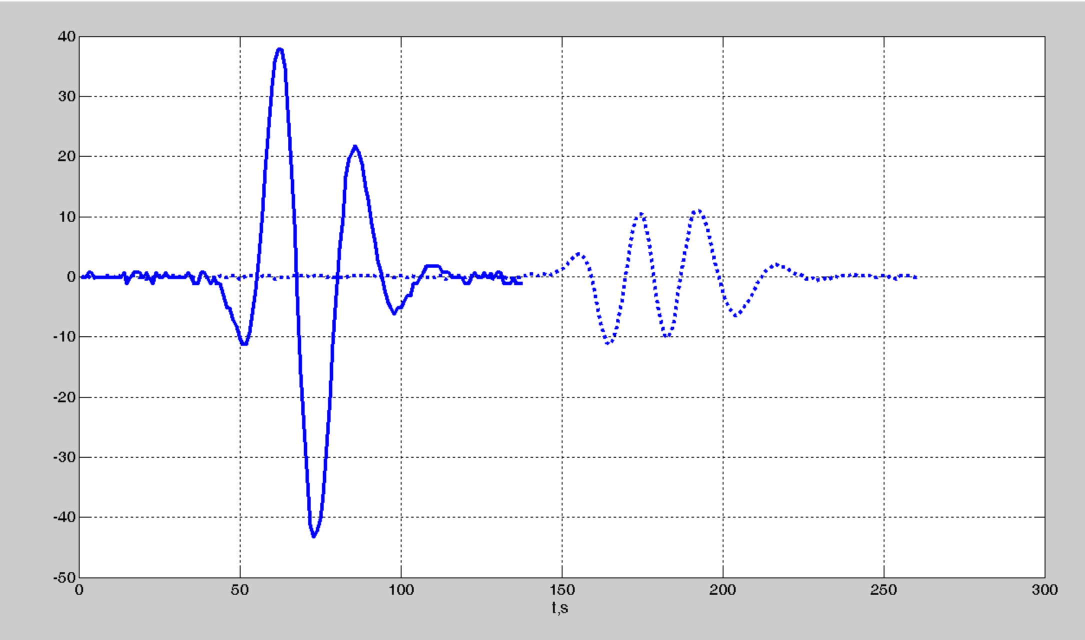

Figure 1. Waveform from receiving antenna depending on the type of metal, object size and speed of scanning (line – copper and dotted line – iron)

The received signals by reception antenna and amplifiered by electronic unit of metal detector, after overcoming the threshold amplitude and regulation have the form shown in Fig. 1, which shows the response time for the samples of steel, copper, aluminum.

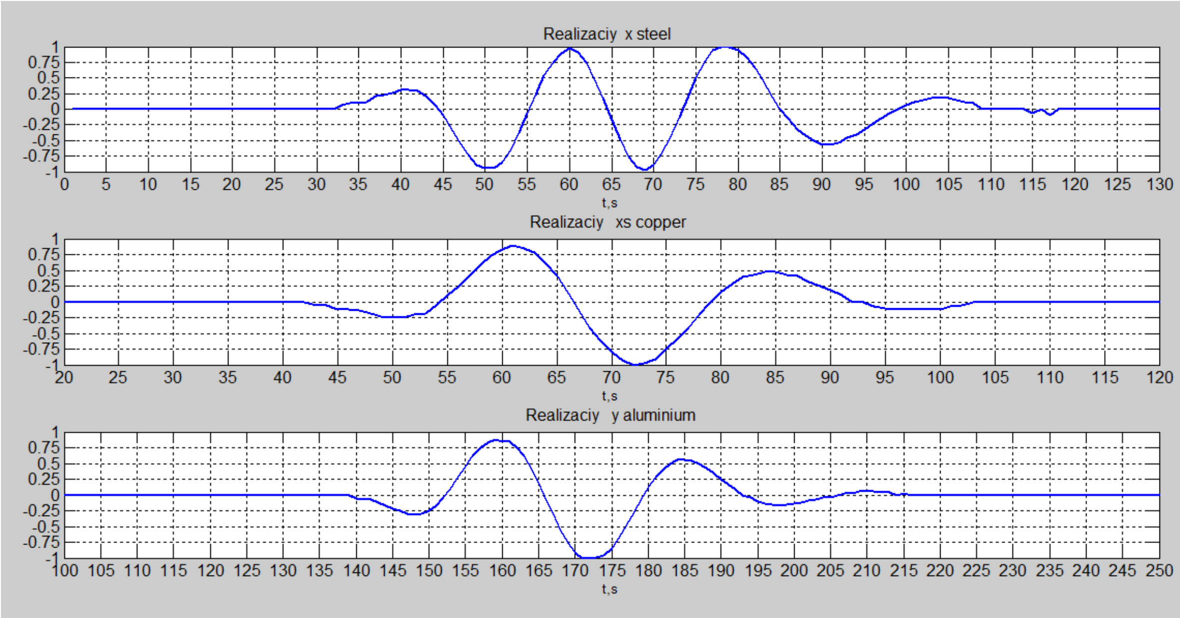

Figure 2. The time response for samples of steel, copper, aluminum (from top to down)

The duration of the signal depends on the speed of passage of the search antenna prototypes, which should be the same across the stage search metal samples, but in the real world of metal detector this does not happen.

The time difference is particularly pronounced if the search is in the field, through physiological features operator can scan the same speed search antenna research on surface [6].

For fair comparison signal parameters to further solve the problem of recognition, all received signals need to normalize (scale) for the duration. As an option valuation used the distance between two peaks of the signal (Fig. 3).

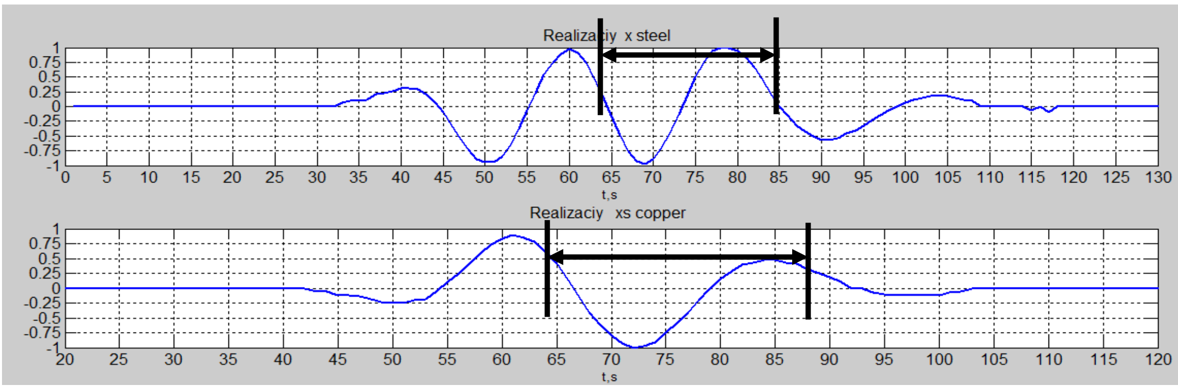

Figure 3. Option valuation for the duration of the signal (samples of steel and copper, from top to down)

The first scan is a reference. It is taken as a sample and all other normalized in accordance with it. At this stage of a digitizing the signal and reference signal is measured by the length between two peaks (Fig. 3) [7]. Signal processing was carried out by means of mathematical package MATLAB. To determine the peaks of a signal used specially developed algorithm averaging three points (Fig. 4), which is shown as placed point t1 – t3 with brute force value of the amplitude of the signal.

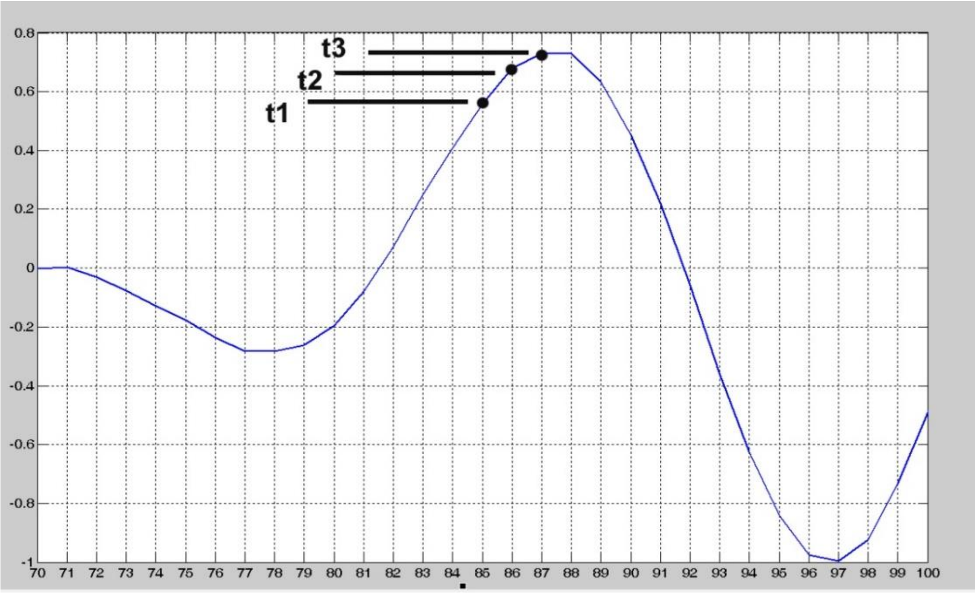

Figure 4. The process of sorting the points t1-t3 when determining the maximum amplitude of the signal

Search algorithm of maximum in signal is shown in Fig. 5.

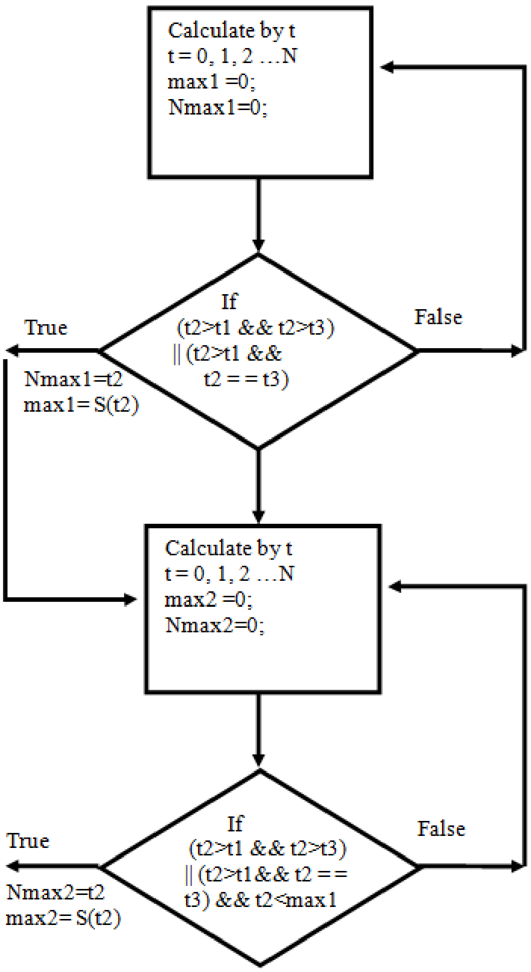

Figure 5. Search Algorithm of maximum in signal

The algorithm is based on the measurement of the amplitude maximum value from three points (t1, t2, t3) by brute force all signal values. As the score got out in the middle amplitude point t2.

Possible options for acute and hollow maximum.

Consider the case of a sharp peak. In this case, the point t2 amplitude greater than the amplitude of the next and previous points. The current number of iteration is taken as the desired maximum.

With a gentle peak amplitude at point t2 larger than the amplitude at point t1 and equal amplitude at point t3 for several iterations busting discrete signal. In this case, the latest iteration number at t2 and t3 equality adopted by the desired maximum.

Further, the duration of signals of new models was set to the length of the reference signal. Information on the critical points of the signal used for further piecewise polynomial approximation signal and comparing the signals together.

To set the statistical probability of obtaining reliable result 0.95 [8] for each metal sample was conducted on 100 measurements.

Conclusions. Thus, the technique and algorithm normalization signal taken from the antenna eddy current metal detector that allows correct identification of further types of detected metal.

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НОРМУВАННЯ СИГНАЛІВ ВИХРОСТРУМОВИХ ПЕРЕТВОРЮВАЧІВ ДЛЯ КОРЕКТНОГО ЇХ ПОРІВНЯННЯ

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Резюме. *Задача виявлення металевих предметів у різних середовищах завжди була актуальною. Оптимальними для дихотомічного розрізнення металів є імпульсні металошукачі типу VLF. Передавальна антена такого металошукача випромінює первинне електромагнітне поле, яке приймається приймальною антеною, налаштованою так, щоб за відсутності металевих предметів між приймальною та передавальною антенами на вході приймача був мінімальний сигнал. У сучасних металошукачах ідентифікація типу металу здійснюється шляхом виділення інформативного сигналу на фоні заважаючого фактора. На сьогодні використовують амплітудний, фазовий та частотний методи обробки сигналу. Діелектрична та магнітна проникності для кольорових і чорних металів різна, що призводить до різних за амплітудою сигналів на вході приймальної антени. Тому для коректного порівняння сигналів, крім порогового методу розрізнення, необхідне їх нормування за амплітудою. Крім того, сканування досліджуваного середовища антеною відбувається вручну, а це потребує нормування прийнятого сигналу за тривалістю.*

Автори розробили методику та алгоритм нормування сигналів, знятих з антени вихрострумового металошукача, який дозволяє подальшу ідентифікацію типів виявлених металів.

Ключові слова: *дихотомія, вихрострумовий металошукач, розрізнення металів.*

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