APPLICATION OF ALTERNATING ELECTROMAGNETIC FIELDS IN TECHNICAL DIAGNOSTICS OF ENGINEERING OBJECTS OF LONG-TERM USAGE

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Summary

Electromagnetic methods, which are based on determination of the characteristics of the electromagnetic fields radiated by inspected objects when alternating electrical currents flow in them, are widely used in engineering practice. Some results of investigations connected with application of alternating electromagnetic fields for searching defects of oil and gas pipes and rails in motion are presented in the report.

Keywords: Alternating electromagnetic field, Technical diagnostics, Long-term usage.

1. INTRODUCTION

Continuous development of new objects of railway transport, power engineering, various branches of industry and agriculture leads to increase of number and concentration of stretched engineering objects of long-term usage (such as oil and gas pipelines, main and town water pipes, urban and long-distance cables of various using, rails and the like). More accurate information about such communication and rails situation and technical state inspection (in particular, determination of insulation covering damages and investigation of corrosion processes in pipelines, detecting of rail cracks) are the conditions of their effective usage and trouble-free operation.

Effective usage and fail-safety of underground hidden engineering communications are guaranteed by possessing information about their location and inspection of their technical state, determination of places of insulation damages, abnormal groundings, and zones of appearance and progress of corrosion processes.

Electromagnetic methods, based on the measurement of some parameters of the electromagnetic field (EMF) caused by the alternating current that flows along the axis of an underground communication or a rail and is introduced there by special generators or by a station of cathodic protection, are now one of the most effective methods for solution of the mentioned problems [1-8].

Electromagnetic method as one of the most effective one for solving the mentioned complex of problems has been developed in the Karpenko Physico-Mechanical Institute of the National Academy of Sciences of Ukraine during 20 years. Remote inspection of underground communications is realized using the current which is introduced into a wire by a special generator or as harmonics of pipeline cathodic protection current.

In some cases the parameters of the underground communication magnetic field (MF) are measured in two points situated along the communication and values of current in these points are calculated. If difference between two current values is too big we can draw a conclusion that insulation covering is damaged. In other methods changes of electrical field (EF) can give information about such damages.

Also alternating current field measurement method (ACFM) can be used for detection of defects in rails.

2. DETERMINATION OF DEFECTS IN UNDERGROUND COMMUNICATIONS

There are many methods of searching underground communications and determining their coordinates. Contemporary searching-measuring devices measure mainly the magnetic field of the cathodic protection current (f=100 Hz) in pipelines, special generator of alternating current or proper signals of communication lines.

Our investigations have shown that measurement of parameters of alternating current field can give some information about pipe-ground impedance and dimensions of damages of the pipe insulation [4].

The mentioned methods are insufficiently effective in the cases when there are some other communications near the inspected pipeline or cable with similar signal that can be considered as an additive interference.

Such interference can be essentially decreased by usage of difference measurements [1-3]. This method is illustrated by Fig. 1, where linear communication 1 is situated in ground 2. For measuring MF of the current I in the communication two identical coils L1 and L2 with cores are used. For low-frequency MF.

$$H_1 = \frac{I}{2\pi h}, \quad (1)$$

$$H_2 = \frac{I}{2\pi(h+a)}. \quad (2)$$

The measuring device measures E_2 – the output signal of $L2$, which is proportional to H_2, and $\Delta E = E_1 - E_2$ – difference of the output signals of $L1$ and $L2$. Equality $\Delta E = 0$ means that the measuring device determines the communication axis.

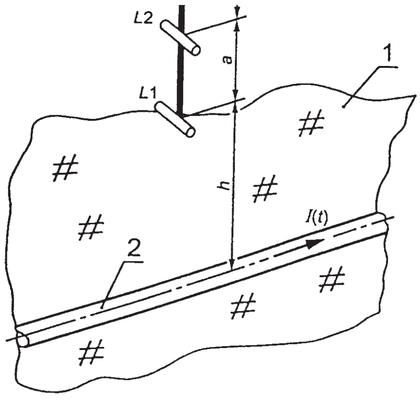

Fig. 1. Scheme of searching an underground communication and determining its coordinates

We can obtain taking into account Eqs. (1) and (2)

$$h = \frac{\Delta E}{E_2}. \quad (3)$$

$$I = 2\pi E_1. \quad (4)$$

This method is used in the IMK-5 equipment that is described in Section 5.

Existent electromagnetic searching-measuring systems, that use more effective non-contact methods, measure, as a rule, only the magnetic component of the EMF radiated by a communication. And the electrical component, which has some additional information about an investigated object, is measured now only in contact methods. Thus problems of determination, investigation and usage of new informative characteristics of electrical component of underground communications EMF are, without doubt, very actual (especially, elaboration of non-contact methods of electrical field measurement).

In the report the problem of determination of the electrical component of EMF of a metallic underground communication which model is represented as a stretched conductor (wire) with taking into account presence of boundary between two mediums (ground and air in our case) is considered according to methods described in [4].

3. RAIL DIAGNOSTICS BY APPLICATION OF ALTERNATING CURRENT

The method of alternating current field measurement (ACFM) is now developed in the Karpenko Physico-Mechanical Institute. It is based on the application of alternating current that is introduced into the rail by contact method or by using a special source of magnetic field that induced current in the rail [5, 8]. The induced current flows in the rail and creates magnetic field which spatial coordinates are measured by usage of induction sensors. The rail cracks and other damages cause disturbances in the magnetic field. Using those disturbances allows detecting defects and determining their character and dimensions. The method can be used during motion. The typical view of signal in the induction sensors for three components for the case of transversal crack in the rail is shown at Fig. 2.

a)

b)

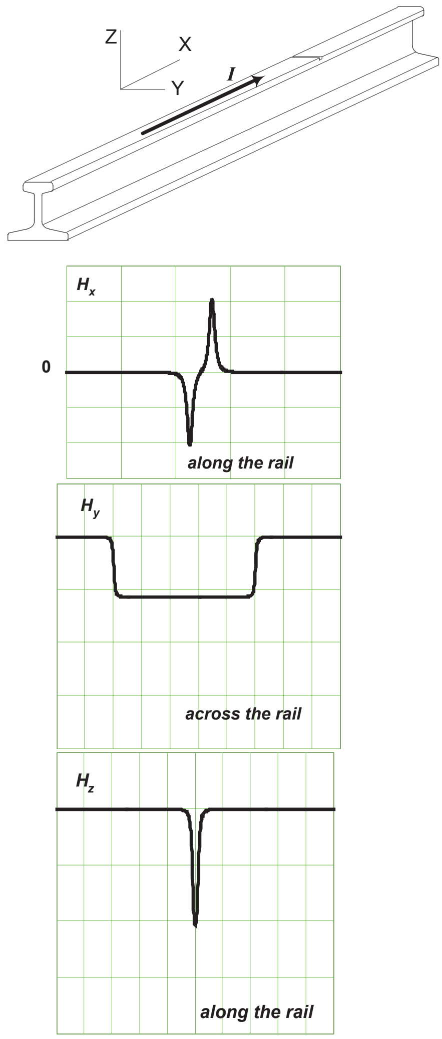

Fig. 2. Typical view of signal in the induction sensors for three components for the case of transversal crack in the rail:
a) axes orientation and the rail with the crack,
b) magnetic field components

4. ESTIMATION OF THE INFORMATIVE PARAMETERS OF ELECTOMAGNETIC FIELDS USED DURING TECHNICAL DIAGNOSTICS

During searching and electromagnetic inspection of the technical objects of long-term usage not only informative signals but also interference fields of continuous and impulse character influence on receiving sensors. That fact causes stochastic character of input signal. The signal structure and methods of such interference suppression are described, mainly, in [1-3].

The temporal and amplitude values (elements) of signal are stochastic values because of presence of additive noise $\eta(t)$. Their series can be presented for statistical processing by aggregate of discrete stochastic signals of the following type

$$\{\xi_i, i \in Z\}, \qquad (5)$$

where ξ_i – i amplitude, temporal or integral magnitude of a signal .

During impulse electromagnetic investigation there are the following informative elements: i-magnitude of the initial amplitude of the radiated dying oscillations, i-magnitude of the amplitudes sum and i integral characteristics.

The amplitude and the phase are informative parameters of a measuring signal when using harmonic electromagnetic.

Estimation of informative parameters of impulse and continuous stochastic signals are realized, as a rule, using only single realization. That demands fulfillment of local stationarity condition for discrete stochastic processes (5). If the problem of estimation of the s moment of the process (5) is discussed, the condition of local stationarity can be formulated as

$$\left|\hat{m}_i^s - \hat{m}_j^s\right| \langle \varepsilon, i, j \in (r, r+M) \subset Z, \qquad (6)$$

where $\hat{m}_i^s, \hat{m}_j^s$ – estimation of s moments of values ξ_{in}, ξ_{jn}, obtained as averaging of statistical ensemble of the realization, n – the realization number, ε – estimation tolerated error, $M = const$, (r, $r+M$) – the local stationarity interval.

During searching and electromagnetic inspection of hidden objects it is necessary not only to determine estimation of informative signals parameters but also carry out their functional transformation, for example, when determining depth of location h and current amplitude I_m of an underground communication it is needed to fulfill calculation based on the formulas:

$$h = a\frac{\hat{E}_2}{\hat{E}_1 - \hat{E}_2}, I_m = 2\pi\hat{E}_1, \qquad (7)$$

where $\hat{E}_1, \hat{E}_2$ – estimation of the electromotive forces induced in induction sensors by the communication field.

Recurrent algorithms, described by inhomogeneous difference equations of the first order, are used to guarantee synchronous realization of two tasks: determination of stochastic signal characteristics and specific functional transformation of their evaluation:

$$\Delta Q_i = aF(\xi_i, \zeta_i) - b\Phi(\xi_i, \zeta_i)Q(i-1), \qquad (8)$$

where $\Delta Q_i = Q(i) - Q(i-1)$ – change of the input parameter of computing transformer after registration of i-magnitude of the signal informative elements ξ_i, ζ_i, and $i \in A = 0, 1, 2, 3...$; a i b – constant coefficients; $F(\xi_i, \zeta_i)$ and $\Phi(\xi_i, \zeta_i)$ – functions of the discrete magnitudes transformations ξ_i, ζ_i. In our case additive sums of amplitude values E_1 i E_2 of induction sensors and instantaneous values η_{1i} and η_{2i} of interference $\eta_1(t)$ and $\eta_2(t)$, that are induced in them, can be considered as ξ_i, ζ_i, i.e. the registered signal can be described by the mathematical model in the shape of discrete stochastic signals of the following type:

$$\{E_{1i}\} \text{ and } \{E_{2i}\}, \text{ or } \{\Delta E_i\}, \qquad (9)$$

where $E_{1i} = E_1 + \eta_{1i}$, $E_{2i} = E_2 + \eta_{2i}$ and $\Delta E_i = E_{1i} - E_{2i}$.

Using Eq. (8) it is possible to formulate the following algorithms of synthesis of averaging depth measurers h:

$$\Delta Q_{1i} = a_1 E_{2i} - b_1 \Delta E_i Q_1(i-1), \qquad (10)$$

$$\Delta Q_{2i} = a_2 \frac{E_{2i}}{\Delta E_i} - b_2 Q_2(i-1). \qquad (11)$$

Recurrent expressions (10) i (11) can be realized using discrete analogue and digital elements or using microcomputer devices.

Technique of determination of statistical and dynamic characteristics developed on the basis of recurrent formulas of averaging computational devices is used in several technical realizations [1-3, 7].

5. THE IMK-5 SYSTEM FOR TECHNICAL DIAGNOSTICS OF UNDERGROUND ENGINEERING COMMUNICATIONS

The IMK-5 information-measuring device (Fig. 3) [7] is described in this section as an example of manufactured devices used described investigations. It is intended for searching, locating and detecting of insulation faults of main oil, gas and product pipelines and other underground communications (power lines, communication, telecommunication lines and others), and for rapid territory investigation before ground work conduction with the purpose of the indicated communication detection to prevent their damage.

The device operates on the basis of investigation of magnetic and electric components of alternate electromagnetic fields radiated by a communication.

The device allows determining an axis, a depth and insulation faults of a communication at the depth to 5 m.

An axis determination error in less than ±20 sm, and a depth error is less than ±10%.

Underground communication locating is conducted by difference signal of two magnetic sensors located on the same pole that gives it advantages over analogous devices by noise-immunity and axis and depth determination precision in the conditions of high noise level from power grid of industrial equipment and neighbour communications.

Insulation fault places are localized by remote determination of numerical characteristics of electric component of electromagnetic field on ground surface over communication axis.

At determination of axis and depth of a communication, there are three operating modes 50, 100 and 222 Hz. 222 Hz frequency is used at work under close conditions (a great deal of communications is concentrated) or at absence of 50 and 100 Hz currents in metal communications, and also for insulation fault locating. These signals are generated by the GS-2 generator.

In the device there are a sound indication for axis search, a digital one for depth registration and an analogue one for insulation fault location registration.

The IMK-5 dimensions are 860 x 230 x 60 mm; device weight - 2,7 kg.

The GS-2 generator dimensions are 300 x 190 x 130 mm; weight – 3,5 kg.

Fig. 3. General view of the IMK-5

6. CONCLUSIONS

In the report the following problems were considered: determination of location and insulation state of the underground communications and pipelines by investigating parameters of magnetic and electrical fields radiated by such objects, the most efficient methods of determination of corrosion state of pipelines by non-contact methods, new alternating current field measurement method of rail diagnostics. Technical parameters of the IMK-5 device for diagnostics of underground engineering communications that was elaborated in the Physico-mechanical Institute of the National Academy of Sciences of Ukraine are given.

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