Multifunctional Primary Transducers for Thickness Magnetic Measurement and Magnetic Induction Measurement

Vladimir SHARANDO, Andrey LUKYANOV, Alexander POLONEVICH, Institute of Applied Physics of National Academy of Sciences of Belarus, Minsk, Belarus

Abstract. The dynamic method of measurement of secondary magnetic fields with the help of primary transducers containing the magnetizing system and providing registration of change of a magnetic flow at transducer moving concerning a testing product is realized.
Using a uniform type of measuring devices as inductive coils and uniform design of recording devices based on electronic integrating elements a series of primary transducers allowing carrying out various function of the non-destructive testing is developed:

- transducers with magnetizing system on permanent magnets for measurement of thickness of not magnetic coverings on the magnetic bases, nickel coverings on the magnetic and not magnetic bases;
- transducers with magnetizing system on permanent magnets for simultaneous measurement of thickness of the magnetic basis and not magnetic covering on it;
- transducers with magnetizing system on electromagnets for simultaneous measurement of thickness of the magnetic basis and not magnetic covering on it;
- transducers without magnetizing system for measurement residual magnetization of products on size of a normal component of induction above their surface.

The functionalities of the transducers and prospects of expansion of their application for tasks of non-destructive testing are analyzed.

Contents

The primary transducers for thickness gauges based on a dynamic method of measuring the secondary magnetic fields contain magnetizing system and provide registration of the magnetic flux change when the transducer moves with respect to a testing product.

One solved the task to develop a series of primary transducers, which allow realizing various functions of nondestructive testing with use of uniform type of measuring devices in the form of inductive coils and a uniform design of registering devices (on the basis of electronic integrating elements).

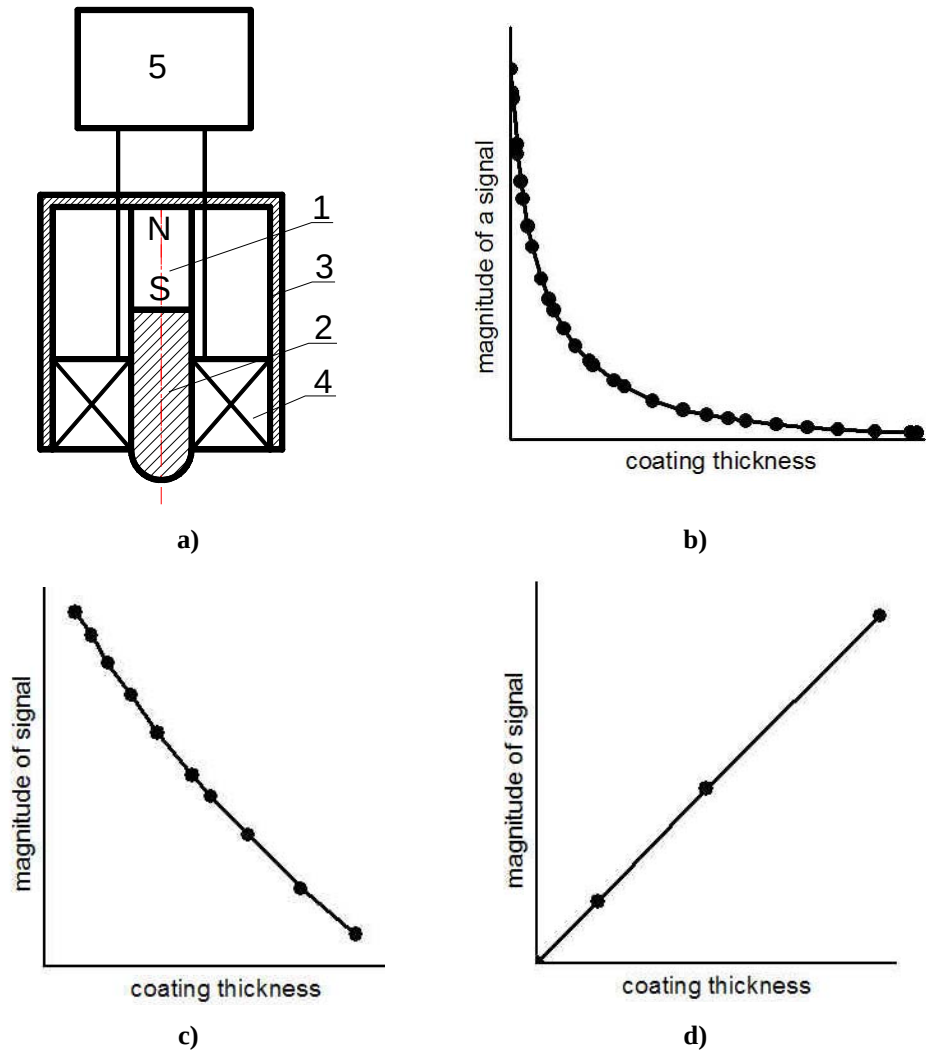
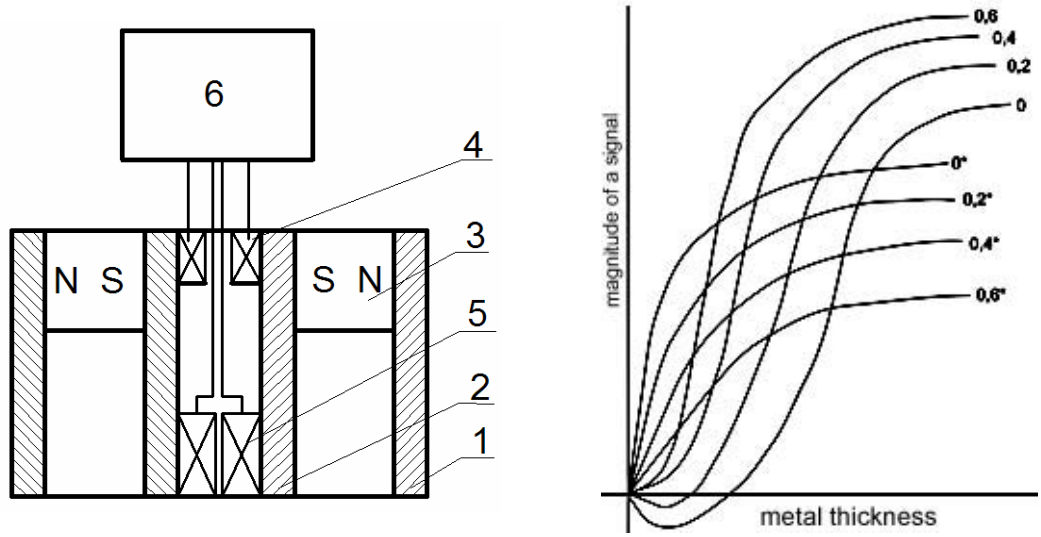


Fig. 1. The transducer (based on a permanent magnet) for coating measurements: **a)** the scheme of the transducer; **b)** the dependence of signal for the thickness of nonmagnetic coating on steel base; **c)** the same for the thickness of nickel coating on steel base; **d)** the same for the thickness of nickel coating on nonmagnetic base.

The **fig. 1a** presents a scheme of transducer with magnetizing system on a permanent magnet for measuring the thickness of nonmagnetic coatings on magnetic bases and the thickness of nickel coatings on magnetic and nonmagnetic bases. The transducer contains a rod-shaped cylindrical magnet 1 made from hard magnetic material, a soft magnetic tip 2, a soft magnetic screen 3, and a measuring inductive coil 4 that is attached to a recording device 5. For measurement of coating thickness, the bottom of the transducer is placed on a testing product and then braked off from it removed on distance at which magnetic interaction with the product disappears. The recording device automatically switched on in the braking off moment. It makes operations of integration and the further processing of a short-term electric impulse arising in the measuring coil. The dependence of signal for the thickness of nonmagnetic coating on steel base is shown on **fig. 1b**. The dependence of signal for the thickness of nickel coating on steel base is illustrated on **fig. 1c**. The dependence of signal for the thickness of nickel coating on nonmagnetic base is shown on **fig. 1d**. The certified range of measurement of nonmagnetic coatings is 0 ÷ 10 mm (it can be expanded up to several tens mm). The range of thickness measurement for nickel coatings on both kinds of bases is 0 ÷ 150 μm. Magnetic thickness gauges with such transducers (МТЦ-2М, МТЦ-3) are designed for testing of anticorrosive and decorative coatings in galvanic, paint and varnish shops of industrial enterprises and for testing of fireproof coatings on building structures, of a pipelines isolation, etc.

The transducer with magnetizing system based on permanent magnets for simultaneous measurement of thicknesses of magnetic base and nonmagnetic coating is developed. Scheme of the transducer is illustrated on **fig 2a**.



a) **b)**

Fig. 2. The transducer (based on permanent magnets) for simultaneous measuring the thickness of magnetic base and nonmagnetic coating on it:
a) the scheme of transducer; **b)** the dependence of signals receiving from two measuring coils on the thicknesses of base and coating.

The magnetizing system of transducer consists of two concentric soft-magnetic cylindrical cores 1, 2 and permanent magnets 3 that are placed between them on radius. The measuring inductive coils 4, 5 are established along the axis of internal cylinder of the transducer at various distances from the base. The mounting of transducer on a product causes the electromotive force impulses in the coils; they are separately integrated and then in common processed by the recording device 6. Features of spatial distribution of the secondary magnetic field and the choice of coils locations lead to that the bottom coil is more sensitive to the thickness of coating and the top coil – to the thickness of base. It allows us to carry out simultaneous measuring the thickness of coating in the range from zero to 1 mm and the thickness of base in the range from zero to 5 mm.

The example of experimental dependences of signals in the coils on the thickness of steel 45' sheet and the thickness of nonmagnetic coating on the sheet is demonstrated on **fig. 2b**. The curves 0, 0.2, 0.4, and 0.6 show the change of signal in the coil 4 when the steel sheet's thickness with coating changes as 0, 0.2, 0.4, and 0.6 mm accordingly. Curves 0*, 0.2*, 0.4*, 0.6* show the change of signal in the coil 3 simultaneously measured on the same products. It follows from the figure that the signal value in each coil can correspond to set of possible combinations of the thicknesses of base and coating. However, a coincidence of these combinations is only one for each pair of the signals. A quantity of combinations for the thicknesses of base and coating is limited only by resolution of the gauge and by the given accuracy of measurements. The resolution and the accuracy determine discreteness of measuring the thicknesses of coating and basis in the process of plotting curves.

How it is follows from the considered data there is the opportunity of unequivocal detection of the thicknesses of coating and basis by two measurements noted above. The processing of signals may include strengthening, a various sort of transformation (not leading to loss of information), the choice of necessary pair of the thicknesses of coating and base from the range of the preliminary set of discrete values or calculation of the thicknesses pair by means of mathematical programs.

The transducer allows simultaneous detecting the effective thickness of steel products under a layer of paint, corrosion, other nonmagnetic films and the superficial layer's thickness (or, at significant superficial roughness of the product, the effective thickness of nonmagnetic clearance in the range of this roughness). A device with such transducer (a universal magnetic thickness gauge УМТ-1) can be used for simultaneous detection the thickness of metal without corrosion and the thickness of a layer of corrosion or nonmagnetic coating that is the thickness of railway car's and automobile's walls, metal structures, pipelines. In the latter case, unlike the widespread ultrasonic method cleanup of a surface and removing of a liquid taking place inside are not required.

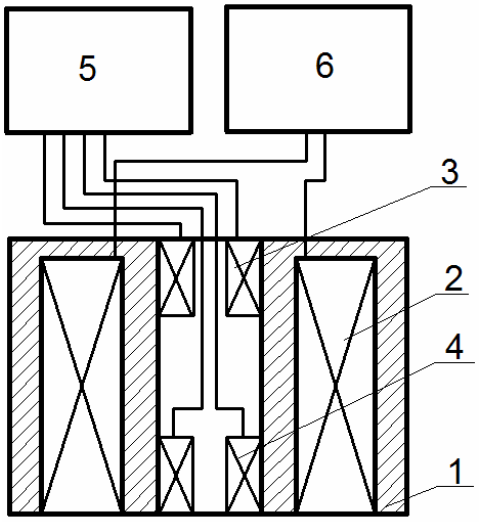


Fig. 3. The transducer with the magnetizing coil for simultaneous measuring the thicknesses of magnetic base and nonmagnetic coating.

The universal magnetic thickness gauge based on permanent magnets cannot be used for measurement of the steel wall's thickness, which is more than 5 mm. It is caused by the increase of sizes of the magnetic system and by appropriate growth of the ponderomotive interaction making impossible manual braking off the transducer from a product.

The **fig. 3** presents a scheme of transducer that allows eliminating the mentioned lack. The transducer based on an electromagnet has magnetizing system that includes a soft magnetic conductor 1. However, instead of the radial permanent magnets a magnetizing coil 2 supplying by impulses of a direct current is used. Setting of the measuring inductive coils 3, 4 is executed and integrating channels of the registering device 5 are connected to them like in the case considered above. Current supply for the magnetizing coil is carried out by means of a power block 6. The sizes of the transducer at growth of thickness of a product wall can be made as greater as it is required. The reasonable compromise has allowed developing a convenient portable design (with line supply or supply by accumulators) connected to an electronic block of the УМТ-1 and allowing capturing the range of the testing coatings' thicknesses from zero to 1 mm and the range of the metal thicknesses from zero to 10 mm.

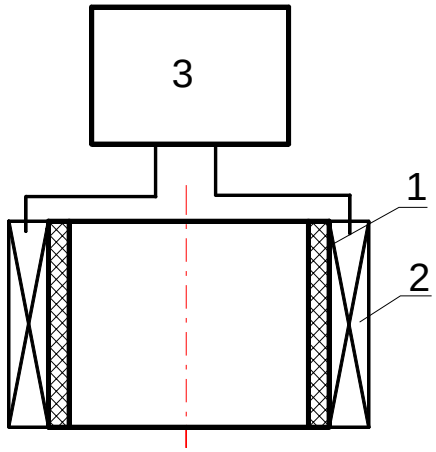


Fig. 4. The transducer for residual magnetization measuring

The chosen principle of measuring signal from the transducer is based on use of integrating electronic elements; it has allowed creating a transducer without the magnetizing system for measurement of product's residual magnetization with the help of an induction's normal component above the surface. A frame 1 made from nonmagnetic material is shown on **fig. 4**; a measuring inductive coil 2 is placed on it. The system is connected to a registering device 3.

The transducer establishes on the surface of a magnetized product, brakes off from it and removing on distance at which the magnetic fields are quite small. Before the brake off, the registering device that measures impulse of electromotive force switch on automatically. The impulse measurement allows detecting magnetic induction above the chosen area of the product in a direction normal to the

product surface. The thickness gauge includes such transducer has received the name of a measuring instrument of residual magnetization (ИОН-4). Its sensitivity and range depend on the consumer requirements. At in-line motion of the transducer, the characteristic feature of the gauge is full exception of the error connected with influence of the Earth field. Gauge application is connected with determination of magnetization of details and units of electric turbines, of planes' details at manufacturing and repair, of objects and testing equipment at crack detection of a railway transport, of condition of many other products under influence of magnetic fields.

The performed works have allowed us to create the series same on a design, but various on destination portable gauges for nondestructive testing. The development of universal electronic gauge with the set of replaceable transducers for solving all considered above problems in various industries is possible.