New Magnetic Thickness Gauge Based on a Dynamic Method of Measurement of Secondary Magnetic Fields

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Abstract. At thickness magnetic measurements, information parameter is function of the primary magnetizing field, of thickness, magnetic properties of the covering and the basis. In known types of magnetic thickness gauges of magnetostatic, induction, ponderomotive principles of action apply various ways of indemnification in an information signal of the component caused by the magnetizing field. However, to exclude the component completely it is not obviously possible. It results in decrease of the range of measuring thickness, of resolution, in necessity of creation narrowly band magnetic thickness gauges or their complectation by a set of transducers.

We investigate an opportunity and high efficiency of thickness magnetic measurements is shown based on primary transducers as permanent magnets with magnetically soft tips, motionless in relation to them the multicurve coil and the magnetic screen. The information signal is generated at installation or raising of the primary transducer in relation to the product.

Such method of measurements completely excludes the component in the signal from the magnetizing field. Based on this method of measurements the primary transducers and devices such as МТЦ are created.

Their advantages in comparison by analogues:

- measurement by one transducer of not magnetic coverings by thickness up to 10 mm on steel, nickel coverings on a not magnetic basis up to 1 mm, nickel coverings on steel up to 150 microns;
- high resolution (100-th shares of the micron in the beginning of the range of measuring thickness).

The paper gives the results of researches on creation of the primary transducer, expansion of its functionalities, data on influence of properties of the basis and coverings, geometry of the product on the error of measurements, and metrological characteristic for different combinations the covering-basis in a wide range of thickness.

The choice of the methods and means of the thickness control of a covering is defined by a combination of physical properties of materials of a covering - basis. The set of such combinations can be reduced to three groups:

1. dielectric and electroconductive non magnetic coverings on a magnetic basis;
2. magnetic coverings on a magnetic and non magnetic basis (nickel - steel, nickel - non-ferrous metals);
3. non magnetic coverings on non magnetic electroconductive basis.

It is most probable, that in practice about 99 % of details and units subject to the control, concern to the first and second group. It is all kinds of a electroplate, lacquering,

nickel, warm - and fire-proofing finish etc. coverings on steel. For their control it is most expedient to use magnetic methods, thus all physical properties of non magnetic coverings have not an effect for results of measurements, the indications of devices are function of thickness of a covering and magnetic properties of a basis. At use of a eddy current gauge, their indications depend on thickness of a covering, magnetic properties of a basis, electroconductivity of a covering and basis. The variations of electroconductivity of coverings and basis always take place, is especial for electroplate coverings, and it is the essential factor determining significant increases of an error of eddy current gauges.

Essentially other situation at magnetic thickness measuring: absence of influence of electroconductivity and other physical properties of a basis and covering (except of magnetic) on an error of measurements, opportunity to exclude or to minimize influence of variations of magnetic properties for the bill there is enough strong magnetizing fields of the primary transducer, when magnetizing of a magnetic covering and the bases come nearer to them magnetization of saturation.

All known types of thickness gauges at the expense of a choice of parameters of a source of primary magnetizing field allow as a first approximation to ensure this condition at some given ranges of measuring thickness and combinations of a properties of covering - basis. However basic difficulties connected to presence in informative signal of the component caused by primary magnetizing field, present methods of thickness measuring do not allow to remove. It causes decrease of a range of measuring thickness, resolution and functionalities of magnetic gauge. Tune-out from influence of primary magnetizing field is possible, at use as the primary transducer the constant magnet with motionless in relation to it by multiturn coil [1 - 3]. The information about property of a product is given a pulse of a current arising at installation or rise of the transducer. We are at first time investigated an opportunity and shown the high efficiency of a dynamic method of measurement of informative parameters (secondary magnetic fields) with reference to measuring of coverings [4 - 5].

Some results of theoretical calculation and experimental researches on creation of primary transducer and devices of measurement of thickness of coverings further are resulted.

In figure 1 the basic elements of the transducer and circuit to model of calculation are shown. The source of magnetizing field has cylindrical symmetry and consists of the constant magnet 1 (material NdFeB) and soft magnetic tip 2. The elements 1 and 2 and measuring coil 4 are ring in with the ferromagnetic screen 3 of low-carbon steel. Generally normal component of the flow of induction of secondary magnetic field (informative parameter) is determined by thickness of the covering 5, magnetic properties of the basis 6 (basis and covering), geometry and combination of properties of the magnet, tip and screen.

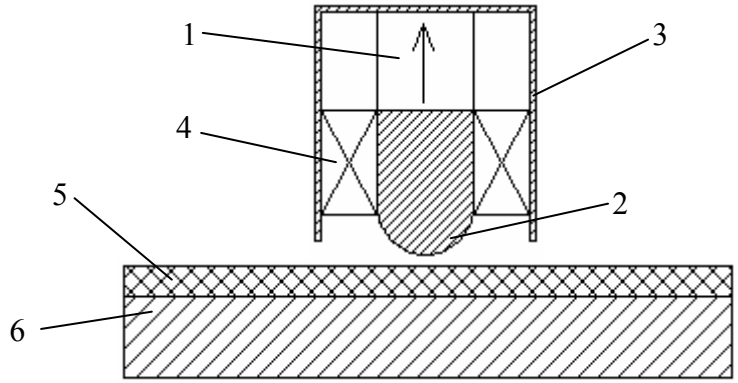

Fig 1. Elements of the transducer.

The task consists in the choice and optimization of parameters of the primary transducer with reference to concrete tasks of thickness measurement, namely given to the range of measurement thickness and combinations of coverings - basis.

Further we bring results of numerical calculation and experimental researches on creation of the device ensuring measurement by one transducer of non magnetic coverings on steel in the range 0 - 10 mm, nickel coverings on the non magnetic basis 0 - 1000 microns and nickel coverings on steel 0 - 150 microns. The calculations are executed by the method of final elements. Model of calculation: the magnetic basis from of low-carbon steel with homogeneous properties and different thickness of non magnetic (0 - 10 mm) and nickel (0 - 150 microns) coverings; nickel covering in the range 0 - 1000 microns on the non magnetic basis. The source of the primary magnetizing field: the cylindrical constant magnet with hemispherical polar tip, diameter 5 - 10 mm. Common long is 10 mm, diameter of the screen up to 16 mm. The material of the magnet is NdFeB, polar tip and screen is low-carbon steel.

Are received below-mentioned calculation and experimental data on functionalities of the device MTG-3 for measurement of three combinations of the covering - basis. In the table 1 the level of resolution of the device received experimentally on reference measures of thickness of coverings is shown.

Table 1.

Вид покрытия	Немагнитные по стали			Никель по стали				Никель по немагнитной основе			
Толщина, μm	10	100	300	5	50	100	150	10	50	100	150
Разрешение, μm	0,075	0,12	0,28	0,22	0,34	0,36	0,41	0,039	0,043	0,047	0,059

In figure 2 and 3 are represent calculation and experimental dependences on thickness of the non-magnetic covering on steel after equalization of their scales.

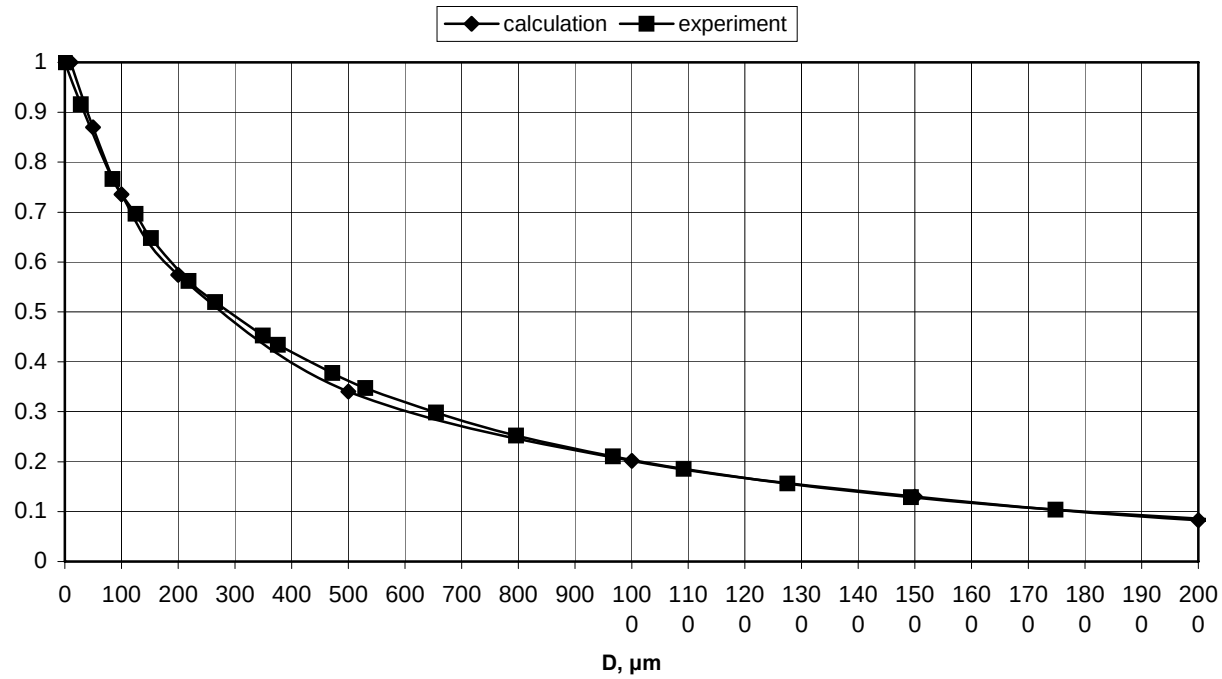

Fig. 2. Dependences of induction of the secondary magnetic flow and reading of the device on thickness of the non-magnetic covering on steel

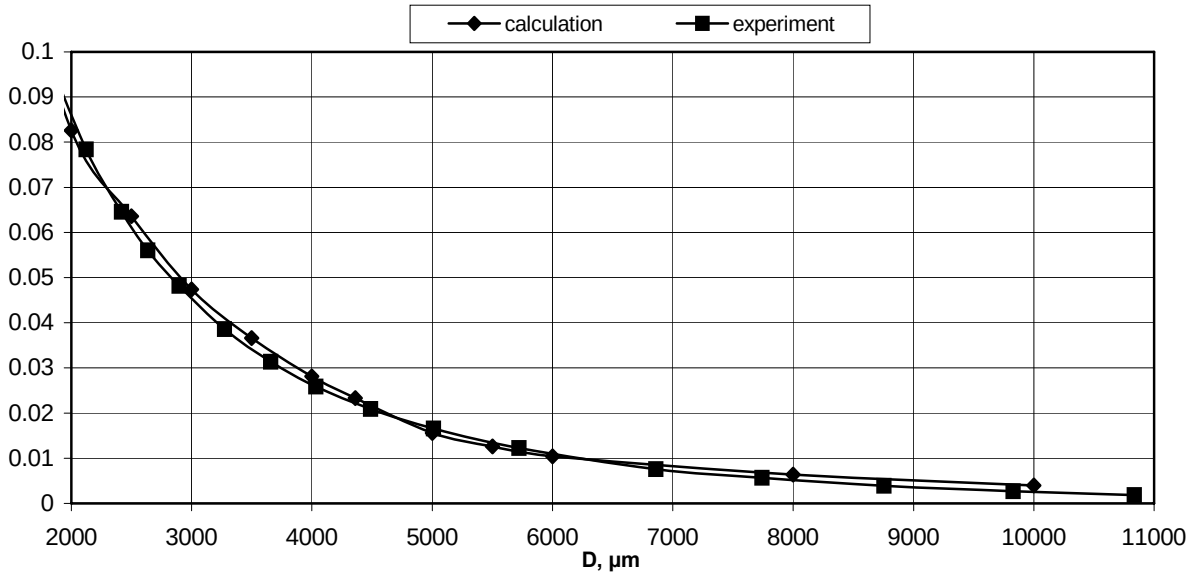

Fig. 3. Dependences of induction of the secondary magnetic flow and reading of the device on thickness of the non-magnetic covering on steel

The primary transducer with the diameter of the magnet of 5 mm is provided unequivocal dependence of the indications of the device on thickness of the covering, with average resolution 100 microns at thickness 10000 microns. The software and electronic circuit of the device provide automatic switching of range of measurement, the tuning of ranges is not required, the level of resolution of the converter is saved. There are no difficulties of expansion of the range of measurements, for example, at increase of the diameter of the magnet and tip twice practically on this size the range extends.

In practice of measurement thickness the most difficult task is the control of nickel coverings, is especial on the magnetic basis. The magnetic properties of coverings at the

expense of internal stress caused by parameters of technological process of their laying and thickness, can differ on dozens percents. Magnetization of saturation at insignificant change of chemical structure is staying constant. For minimization or exception of influence of internal stress of coverings on an error of measurements it is necessary to execute the condition their magnetization in volume of informative zone close to magnetization of saturation. This condition simply enough to execute for nickel coverings on the non magnetic basis at the expense of increase primary magnetizing field of the converter by change of geometry of the constant magnet with the tip, thus the range of thickness measurement is increased and the high resolution is saved. For nickel coverings on steel the situation is much more difficult. With increase of the field the depth of magnetization of the basis and non-informative component in measure signal is grows, that results to decrease of resolution. Besides, due to the demagnetizing influence of the basis, the volume of the covering with magnetization close to saturation considerably decreases in comparison with the covering on the non-magnetic basis at the same size of the primary field. Both named circumstances take place at any method of the magnetic control and limit the range of measurements by 150 microns.

According to calculation the average value of magnetization in volume of the informative zone of the converter with the diameter of the magnet and tip of 5 mm for nickel coverings with thickness up to 400 microns on the non magnetic basis is makes $8.8 \cdot 10^4$ A/m (magnetization of saturation pure nickel is $5 \cdot 10^5$ A/m), for the magnet by the diameter of 10 mm - $2.76 \cdot 10^5$ A/m. Calculated and the experimental data are shown in figure 4.

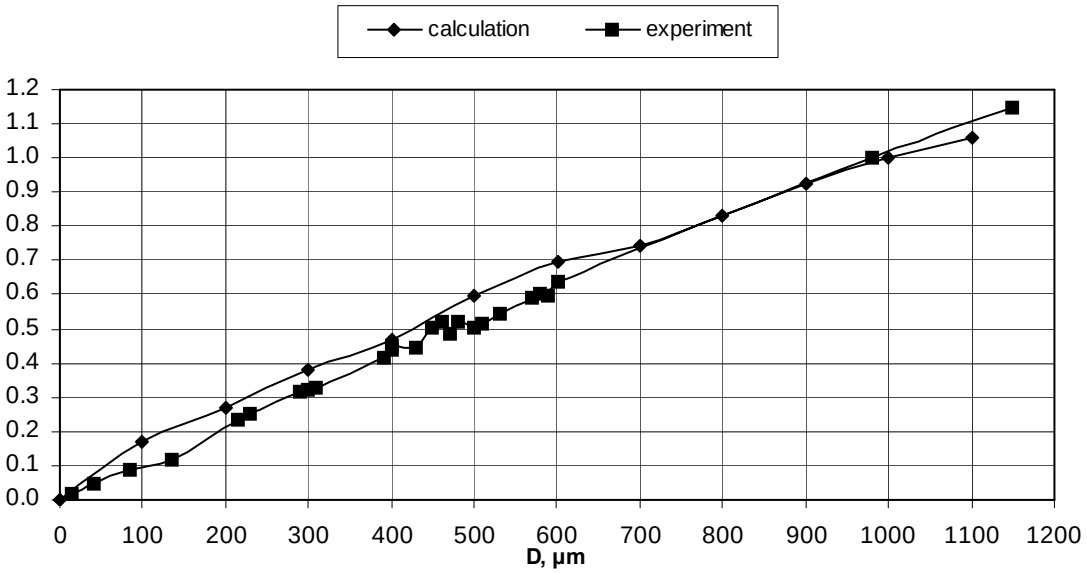

Fig 4. Dependences of induction of the secondary magnetic flow and reading of the device on thickness of nickel covering on non-magnetic bases.

For nickel coverings on the non-magnetic basis with the diameter of the magnet of the transducer of 5 mm the resolution is much higher (in figure 4 is not shown), than for the diameter of 10 mm (all data in figure 4 for this diameter). Samples of coverings up to thickness 160 microns are electroplate covering on bronze, from 200 up to 600 microns - nickel plates received by rolling from pure nickel with a degree of deformation from 5 up to 30 %, from 700 up to 1200 microns - plate received by milling with the subsequent polishing. It is possible to assume, that such set of samples provides close to the greatest possible dispersion of internal stress. Thus the linear dependence of the indications of the device on thickness is saved. For the transducer with the diameter of the magnet of 5 mm

these conditions are carried out at thickness up to 400 microns. In figure 5 the dependences of the indications of the device (relative units) on thickness of nickel coverings on steel, for the transducer with the diameter of the magnet 3 and 5 mm are given. With increase of the diameter of the magnet the resolution is reduced and the dispersion of the indications of the device decreases, that is connected to increase magnetization in volume of informative zone.

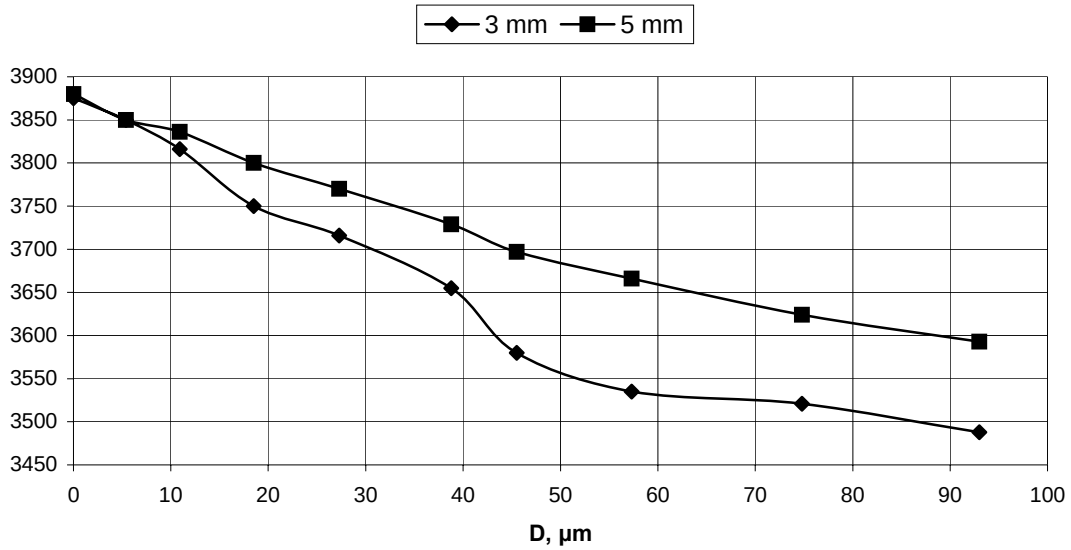

Fig. 5. Dependences of reading of the device on thickness of nickel covering on steel.

By results of calculations and experimental researches it is possible to formulate general laws. Changing epy ratio of length of epy constant magnet and tip it is possible in some times to increase resolution, use of bar magnets without the tip is inexpedient, the optimum ratio of the linear sizes is equal to one. The reduction of the diameter of the screen results in increase of resolution, decrease of the range of measurements and level of influence of the sizes of the product on an error of measurements. Irrespective of the ratio are long of the magnet and the soft magnetic tip the influence of thickness of the basis on an error of measurements is limited to size on the order smaller, than the diameter of the magnet, i.e. at the relation of thickness of the basis to the diameter of the magnet 0,1 does not arise of an additional error.

From the given results you con see advantages of the dynamic method in comparison with known methods. The expansion of the range of measurements, as well as increase of resolution for non-magnetic coverings on steel and magnetic on the non-magnetic basis practically is feasible at the expense of the choice of parameters of the primary transducer.

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