Dynamic Method of Measurement of Magnetic Properties of Products By Means of Turn of Magnetization Vector

A.A. LUKHVICH, A.L. LUKYANOV, V.R. CHURILO, Institute of Applied Physics of the National Academy of Sciences of Belarus, Minsk, Belarus

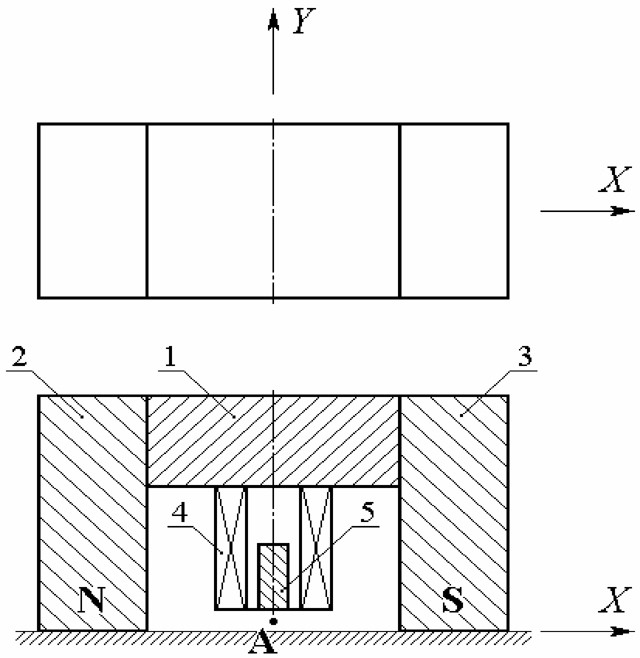
Abstract. The transducer as the coil with the core is offered and used. The core consists of two identical antiparallel magnetized permanent magnets. For measurement of magnetic properties of the product the transducer is been mounting on its surface and moving among line connected together along the line connecting middle of poles of the magnets. Between directions of magnetization and field of the magnet there will be the corner, that greater, than the coercivity is more. Parts of magnetic flux in the coil that directed from the product and to the product, become different on value, and in the coil appears uncompensated magnetic flux, on which it is possible to concept about coercivity of the product.
Measurements on steel samples with known values of coercivity shown, that the dependence of magnetic flux from coercivity in the coil of the transducer is unique, is monotonous and nonlinear. In the paper the questions of optimization and functionalities of the transducer are considered.

Any magnetic method of the control assumes magnetization (magnetic reversal) of a material of a product. From all variety of processes of magnetic reversal it is possible to allocate two limiting happen: forward and rotary. And though in the pure state these both happen practically are not used, any real process of magnetic reversal is possible to consider as a combination these two in some proportion.

At forward magnetic reversal the vectors of intensity of a field $\vec{H}$ and magnetization of substance $\vec{J}$ are parallel to each other and change by size and mark, not changing orientation. The magnetic characteristics of substance are in the best way shown at forward magnetic reversal. Therefore given way of magnetic reversal is most distributed both in scientific researches, and in practice of the nondestructive testing.

The rotary magnetic reversal consists in change of the direction of the vector $\vec{H}$ at its constant length. This way of magnetic reversal is used, for example, for research magnetic anisotropy of crystals. Thus between vectors $\vec{H}$ and $\vec{J}$ is appear the corner of displacement, dependent from orientation of these vectors in relation to the direction of easy magnetization. The majority of products of magnetic materials are polycrystals and on macro level do not show anisotropy. In polycrystalline and in material without coercive properties at rotation of a field $\vec{H}$, magnetization $\vec{J}$ is strictly following this vector by direction. Therefore rotary magnetic reversal of such materials does not keep any information about their magnetic properties. However majority of magnetic materials have the coercive properties, i.e. in materials take place the factors preventing magnetization follow behind change of the magnetic field. At rotary magnetic reversal the action of these factors is shown that magnetization lags behind on a direction the field on some corner, constant for the given material and given size of the field. This phenomenon was discover already in the end of XIX century and named by a rotary hysteresis [1]. Further it was investigated mainly in connection with definition of losses at rotary magnetic reversal [2]. Researches [1, 2] have shown, that the corner between vectors $\vec{H}$ and $\vec{J}$ with increase of the field at first grows, achieving a maximum in fields close to coercive force, and then decreases, transformation in zero at the approach to saturation. In an identical field the greater corner off-orientation shows the material having greater coercive force.

From said above follows, that the rotary magnetic reversal can be applied in the magnetic control for obtain the information about coercive properties of the material of products. We shall consider, how such magnetic reversal with the help of the constant magnet is possible to realize. In a fig. 1 are shown two projections of the U-type transducer (bottom projection represents the section by the plane Y = 0). Let's consider, that the surface of the controllable product place in a plane XY. To subject the product to rotary magnetic reversal it is possible by movement of the converter or product along an axis X.



1 - constant magnet, 2 and 3 - pole tips, 4 - measuring coil, 5 - core
Fig. 1. The circuit of the converter on the constant magnet

In the product near to its surface under South Pole S of the transducer there is a point, in which the vector $\vec{H}$ is directed vertically upwards. If to move the transducer in a direction X, inevitably there will come the moment, when above this point there will be the North Pole N of the transducer, and the vector $\vec{H}$ will be directed vertically downwards. It means, that the vector $\vec{H}$ has turned during movement of the transducer on the corner 180°; thus the module $|\vec{H}|$ changed not so strongly (at least, its did not pass through zero, as it would be in case of forward magnetic reversal at change of the direction of the field on opposite). Hence, the considered process of magnetic reversal carries mainly rotary character. We have to solve the problem, how thus to receive the information about coercive properties of the product.

Represented on the fig. 1 converter has mirror symmetry to planes X = 0 and Y = 0. The consequence of symmetry is that the field of the transducer in a plane X = 0 has to a unique component H_x that is parallel the surface of the product. If in any point of the plane X = 0 (for example, in the point A) establish indicator of the component of the field normal to the surface of the product, at absence of the product it will show zero. If the product is don't have the coercive properties or was approached to the transducer in previously demagnetize condition, the vectors $\vec{H}$ and $\vec{J}$ in product will be parallel to each other, and consequently will be observed the symmetry, i.e. in the plane X = 0 will be satisfied condition $J_z = H_z = 0$. In result the indicator of the field in the point A, zero will show still. If the transducer to move in a direction X above the product with coercive force which is non-zero, will arise displacement of the vectors $\vec{H}$ and $\vec{J}$ on some corner and the symmetry in distribution of magnetization will be disturbed. In points of the product belonging of the plane X = 0, will appear the non-zero component of the magnetization J_z, which will call in the point A appearance of the secondary field $H_z \neq 0$, as will record the indicator of the field.

For check stated above is developed the transducer including constant magnet 1 of NdFeB and pole tips 2 and 3 of permendure (see the fig. 1). For measurement of the field the coil 4 was used, fixed between poles of the transducer so that is the axis coincided with planes of symmetry X = 0 and Y = 0. The coil was connected to microfluxmeter, with which the magnetic flow arising in the coil during the movement of the transducer on the surface of the product was measured. For amplification the signal inside the coil the thin core 5 of soft magnetic material was placed.

The converter was put on the controllable product far from its edges. After the microfluxmeter switch on in mode of measurement the converter was moved in the chosen direction so long as the indications of microfluxmeter stop grow up to some maximal value F_1, which then was fixed.

In the fig. 2 the results of measurements of the magnetic flow F on samples with known coercive force H_c are shown.

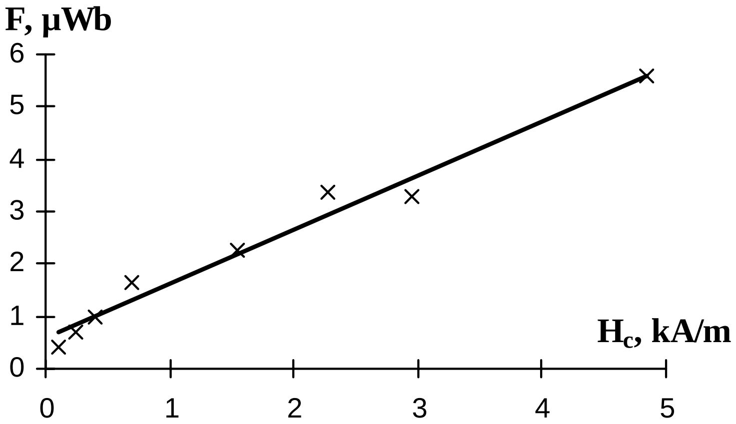


Fig. 2. Dependence of the magnetic flow F from coercive force H_c.

It is seen, that represented on the fig. 2 dependences is unequivocal, is monotonous and even, despite of some dispersion of value of the flow, is close to linear.

As coercive force is connected with mechanical properties ferromagnetic materials and most often is used for measurement of hardness, on the fig. 3a the results of measurements on standard measures of hardness are shown. On the fig. 3b the results of measurements received on steel samples with coercive force, ambiguously connected with hardness are shown. The degree of correlation is much lower, than in the two first cases, however tendency is saved.

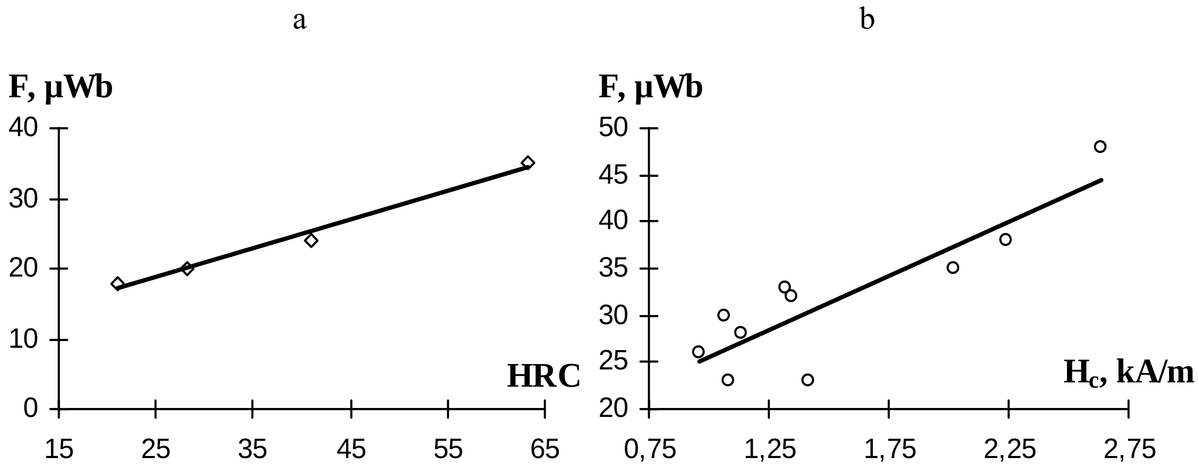


Fig. 3. Dependence of the magnetic flow F from hardness HRC (fig. 3a) and coercive force (fig. 3b)

The given results indicate to an opportunity of creation the techniques and means of the nondestructive testing on measuring of parameters the process of rotary magnetic reversal (for example, coercive force meter without the source of the magnetization current). The inconvenience connected to moving of the converter on the surface of the product, can appear advantage at the control of moving products.

References

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