WAYS OF CONSIDERING THICKNESS METAL ON INDICATORS COERCIVE FORCE

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The article is devoted to the existing methods of solving the problem of under-performance coercive force obtained by Structuroscopes type КРМ-ЦК-2М, with increasing thickness of the metal elements controlled. Conclusions on the basis of research and planned future research directions

Problem setting. Industry of Ukraine is going through hard times. In a difficult economic situation, when industrial companies have to fight for survival, renewal of hoisting machines is slow, and does or does not occur. Therefore, the situation of crane park is difficult. Every year it gets worse (Figure 1). According to recent data [1] 84 % of cranes exceeded their regulatory period.

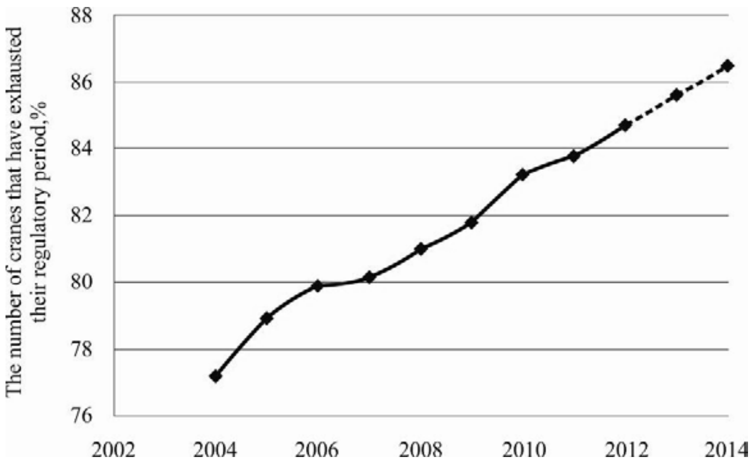

Fig. 1
Schedule of changes in the number of cranes that have exhausted their standard time and forecast (extrapolation) to 2014

In these circumstances the current task is to determine the real state of the metal cranes for further prediction of the term safe operation. One of the instruments defining the properties of the metal are the methods of nondestructive control (NC). A large spread was magnetic coercive method of NC.

Recent research analysis. In Ukraine regulatory framework for the use of magnetic coercivity of the method of NC is limited and imperfect. In 2005, were approved "Guidance for the magnetic control of the stress-strain state of metal climbing structures and determination of their residual life" MB 0.00-7.01-05 [2]. They are based on Russian methods "РД ИКЦ "КРАН"-007-97/02" [3]. On approval of the Methodological guidelines for expert examination of overhead cranes listed in ОМД 00120253.001-2005 [4].

The study of magnetic control based on the coercive force of metal construction of the lifting structures are dealt with in the papers by Kotelnikov V.S., Grigorov O.V., Popov V.A., Popov B.E., Lipatov A.S., Levin E.A. [3, 4, 7, 8, 9].

Unsolved aspects of the general problem. If the auxiliary magnetic circuit to increase the amount of current that magnetizes (I_{nc}, A) such as metal thickness δ (mm), then gradually reached saturation induction (B_s, H) for certain values of the thickness of the controlled element $\delta = \delta_m$ (mm). Further increase I_{nc} will not increase induction. That will be achieved minimum thickness of magnetization uniform in structure massive body. And a further increase in the thickness of a homogeneous structure for the controlled object ($\delta > \delta_m$) does not affect the readings Coercimeters. To change the depth of penetration of magnetic flux in a controlled metal to change the geometrical dimensions of the auxiliary electromagnet [10]. $\delta = \delta_m$ – The value of the minimum thickness of magnetization uniform in structure to a massive body is calculated by the formula

$$\delta_m = 2\sqrt{S_å} \ , \qquad (1)$$

where S_e (mm) – the area of cross sections poles ladders electromagnet.

Thus, the control elements of metal construction from one metal, but with different thicknesses will receive gradual lowering indices coercive force with increasing thickness of the metal [6] to a certain value δ_m. That, in turn, lead to significant errors in the analysis of the results of magnetic coercive method of NC metal construction with different thicknesses of elements.

Moreover, all the nomogram, which are given in [2, 3], derived for the metal thickness of 8–12 mm. Therefore, further use of the nomogram for a thickness of more than 10–12 mm will lead to significant errors in the final results.

Objective of the article. Compare existing methods of solving the problem of underestimation of evidence, coercive force, measured Structuroscopes type КРМ-ЦК-2М, with increasing thickness of the metal elements controlled.

Basic material. In MB 0.00-7.01-05 [2] offer a coercive force value in the state of supply (H_C^0, A/cm) and coercive force values that correspond to the critical mode of operation (H_C^{crit}, A/cm). They are calculated by the formula (2):

$$H_{C(new)} = H_{C(table)} + k*h, \qquad (2)$$

where $H_{C(table)}$, A/cm – coercivity obtained the object of control; h, mm – wall thickness controlled object; k – coefficient, which depends on the coercive force obtained on-site supervision. Selected from Table 1:

Table 1
Dependence of coefficient k, the value of coercivity obtained at the facility control

H_C, A/cm	k
1–2	0,05
3–6	0,1
7–10	0,15
11–14	0,2

Using the recalculation proposed in MB 0.00-7.01-05 [2] in practice, raises several questions to be considered in this paper.

Use the formula 2 offers for all crane steel from Ст3 (with relatively small values H_C^0 = 1,7 A/cm) with steel 10ХСНД (with relatively large values H_C^0 = 4,0 A/cm). Thus, the coefficient k does not change. But, magnetic parameters (coercivity) of different steels differ. Therefore, the algorithm conversion can lead to significant errors in the evaluation of metal structures controlled by the parameter coercivity.

The use of calculated using the formula 2 shows that it was correct to give the dependence of H_C(k) is in tabular form, in the form of interpolation in a graph of coefficient k on the value of coercivity obtained at the site control (Figure 2). As a result, the accuracy of conversion will increase significantly. For example, the sample of steel 09Г2С thickness of 16 mm measured coercivity was $H_{C(table)}$ = 6,0 A/cm. After converting the formula (2):

– coefficient k = 0,1 was taken from Table 1, $H_{C(new)}$ = 7,7 A/cm

– coefficient k = 0,14 was taken from Figure 2, $H_{C(new)}$ = 8,56 A/cm.

The difference in recalculation of more than 10 %, which is quite significant.

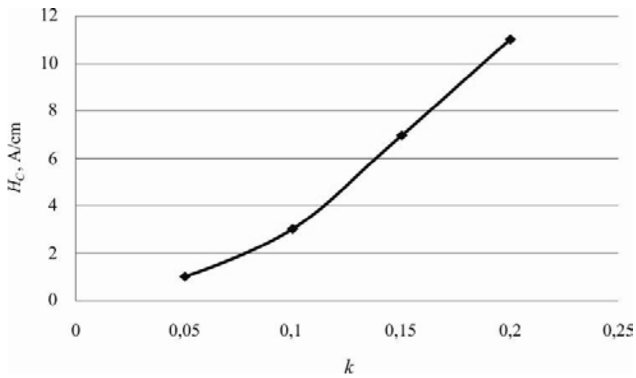

Fig. 2
Dependence of coefficient k on the value of coercivity obtained at the facility control

An important feature is the metal ball of grain. Increase the size accompanied by a decrease liquid limit ($\sigma_{0,2}$, MPa) and coercive force (H_C, A/cm) [10]. True

$$H_C \sim \frac{1}{d}, \quad \sigma_{0,2} \sim \frac{1}{\sqrt{d}},$$

where d – grain size.

Figure 3 shows the dependence of the coercive force of grain size for low carbon steel

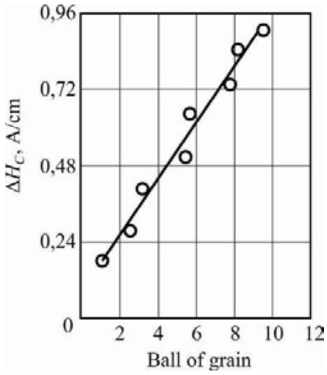

Fig. 3
Dependence of the coercive force (H_C, A/cm) the value of grain for low carbon steel

From Figure 3 shows that coercive force parameters in the same samples of metal, but with a different ball of grains will have different values. For example, two identical samples of metal mild steel with different grain size (ball of grain 6 and 10) have a difference in the coercive force shows ΔH_C = 0,36 A/cm. Larger shows coercive force will sample a smaller grain size.

In practice, quite often there are cases when metal construction crane with different thicknesses of elements made of a metal, but the size of grains in the metal elements are different. Usually, with increasing thickness of the metal – the grain size also increased.

As part of the steel is carbon (C), silicon (Si), manganese (Mn), chromium (Cr), nickel (Ni) and other chemical elements. They have different effects on indicators of coercive force. Increase the percentage of C in steel increases the coercive force; Si, Cr, Ni and other alloying elements also increase the coercive force; Mn – on the contrary reduces it. Table 2 shows the weight fraction of chemical elements in steels used in the crane.

Table 2
Weight fraction of chemical elements in steels used in crane

Mark steel	Regulations	Weight fate of the chemical elements,%					
		C	Mn	Si	Cr	Ni	Cu
Ст3пс USt.37-2	ГОСТ 380-2005 DIN17100	0,14…0,22	0,40–0,65	0,05–0,15	–	–	–
Ст3сп St.37-3		0,14…0,22	0,40–0,65	0,15–0,30	–	–	–
09Г2С 13Mn6	ГОСТ 19281 DIN17145	no more 0,12	1,30–1,70	0,50–0,80	no more 0,3	no more 0,3	no more 0,3

Table 2 shows that there is access to the content of chemical elements in steel. The question is how much this can affect access to the value of coercive force in a controlled metal? To answer this question, the Kharkov plant material handling equipment have been conducting the following studies: metal, which fed into production, the input control not only subjected to chemical analysis and mechanical testing, but metallographic study of primitive gaugings coercive force.

After metallographic studies 09Г2С metal steel (ГОСТ 19281-89) was divided into three groups according to the parameter – the value of grain. Therefore excluded the influence of this parameter on the statement Structuroscopes. Measurements H_C (A/cm) were conducted simultaneously by two devices КРМ-ЦК-2М (head number 542, 834) of 180 selected samples (10 samples of each thickness ball of grain 7, 8 and 9, with a ratio of pearlite to ferrite of 15/85 % to 20/85 %). Part of the consolidated results of magnetic coercivity of the method of NC for samples with ball of grain of 9 and 6 mm thick is shown in Table 3.

Table 3

Results of the magnetic coercive method of NC of metal samples of steel 09Г2С-12 with different chemical composition (grain size of 9 points (ГОСТ 5639-82), thickness 6 mm)

Chemical composition,%			H_C, A/cm	Value for pearlite to ferrite,% (ГОСТ 5639-82)	Mechanical properties[1]				
C	Mn	Si			Resistance to rupture, MPa	Yield strength, MPa	Elongation,%	Impact toughness at –40 °C J/cm^2	Shock viscosity at mech. aging, J/cm^2
0,90	1,58–1,62	0,60–0,65	3,51–3,59	15/85	540	435	28	75	60
0,10	1,53–1,59	0,61–0,68	3,61–3,72						
0,10	1,50–1,56	0,66–0,74	3,70–3,89						
0,11	1,48–1,53	0,70–0,79	3,82–3,96						
0,11	1,45–1,49	0,76–0,80	3,92–4,06						
0,11	1,43–1,46	0,80–0,84	4,03–4,17						

Table 3 shows that for steel 09Г2С-12 with a ball of grain 9 and 6 mm thick chemical composition of the change in coercivity to ΔH_C = 0,66 A/cm.

In prior studies [11] known dependence of coercivity (H_C, A/cm) of carbon in iron in granular form (1) and plate (2) cementite. Unfortunately, the portion of the schedule relating to crane steels was enough investigated. But, and existing data show that increased weight carbon content causes an increase in coercivity. Confirming studies at Charkov Plant "PTU".

[1] Reduced average values of the results of testing 10 samples

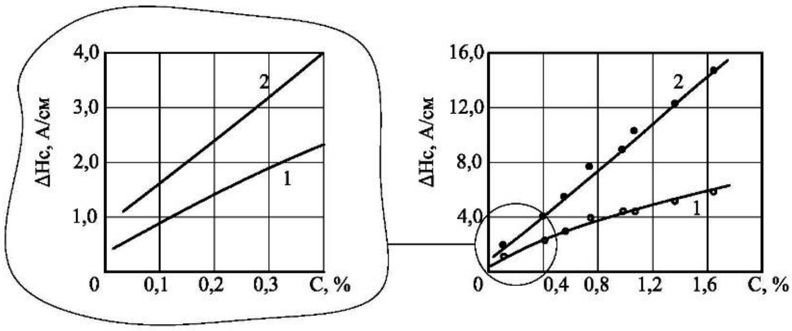

Fig. 4
Dependence of the coercive force (H_C, A/cm) of carbon in iron
in granular form (1) and plate (2) cementite

Thus, the effect of tolerances weight of particles of chemical elements in steels to show significant coercive force.

In [6, 12] described in detail methods of incorporation of error that occurs when the magnetic coercive method of NC metal with different thicknesses of elements. Suggested use certified samples with variable cross section with known mechanical properties and chemical composition of metal microstructure and coercive force values in each section of the sample (Figure 5). This eliminates the influence of grain size, chemical composition to show coercive force.

Fig. 5
Certified samples of metal with variable cross section

The algorithm method was taken as a basis for writing a computer program Metal v2.0 [12]. In the database program included more than 100 units of certified samples of various steel crane. This allows you to select the desired pattern is worked out from the base. Later in the program shell implemented the following functions:

– recalculation, taking into account the different thickness of metal elements controlled;

– construction of curves that clearly reflect the distribution of coercive force on the surface controlled metal;

– calculation of residual life of metal crane;

– the results generated in the reporting documentation for further printing.

Conclusions. Following the studies suggest that the formula for calculation, proposed in MB 0.00-7.01-05, is incorrect because it ignores the grain size, tolerances on weight of chemical elements in steels. Using it in practice can lead to significant errors in assessing the state-controlled steel.

Using methods of certified samples with variable cross section with known mechanical properties and chemical composition of metal microstructure and coercive force values in each section of the sample allows to take into account all the shortcomings of the first method transfer. Algorithm methods to automate in a computer program Metal v2.0.

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