ASSESSMENT OF MODE OF DEFORMATION OF BRIDGE CRANE METAL CONSTRUCTION WITH MAGNETIC (COERCIVE METRIC) CONTROL METHOD

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Abstract: The article supplies an alternative solution for the problem of unequal magnetization of different thicknesses of crane metal construction metal during nondestructive magnetic (coercive metric) control. The result enables us to assess more accurately the mode of deformation and to prognosticate the remaining life of crane metal construction with the thickness of elements over 10 mm.

Key-words: crane, deformation, magnetic control method

1. PROBLEM SETTING

Assessment of mode of deformation for metal constructions (MC) and prognostication of the remaining life of lifting gear with implementation of magnetic structure-scoping is finding a wider and wider application.

At the same time, nondestructive magnetic control of crane MC based on coercive force with the thickness of elements over 10 mm with the application of magnetic structure-scopes of KRM-TS-K2M type entails unequal magnetization of the metal under control. This is connected to insufficient separating power of the KRM-TS-K2M structure-scope. Therefore, we can obtain understated values for coercive force while assessing the controlled mechanic properties of the metal. That makes it impossible to assess accurately the mode of deformation for crane MC with magnetic (coercive metric) control method and to prognosticate further the remaining life.

At the Kharkiv Carrying and Lifting Equipment Plant I have researched 180

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samples of metal-roll coming into production (metallography, chemical analysis, mechanic testings and measurements of coercive force). Some of the research results are given in table 1, 2; figure 1 and in figure 2.

The figure shows that an increase in the metal thickness leads to a reduction in coercive force measurements. Therefore, it is not practically possible to implement magnetic control method based on coercive force for prognosticating mechanic properties degradation and for assessing the mode of deformation in MC without re-calculating coercive force values implementing KPM-TS-K2M type devices, depending on the thickness of the controlled element of MC.

Table 1. **Results of 09Г2С-12 steel metal-roll sample testing with grain-size of point 9 according to State Standard 5639-82**

Sample thickness, mm	**Chemical composition, %**			**Perlite to ferrite ratio, % (State Standard 5639-82)**	**Mechanic properties**				
	C	Si	Mn		Rupture resistance, MPa	Point of fluidity, MPa	Relative elongation, %	Impact resilience at -40°, J/см^2	Impact resilience at strain ageing, J/см^2
6	0,09-0,11	0,67-0,82	1,50-1,58	15/85	540	435	28	75	60
8	0,10-0,12	0,72-0,84	1,48-1,62	20/80	546	428	26	54	49
10	0,09-0,11	0,58-0,74	1,54-1,60	15/85, 20/80	538	430	28	70	58
12	0,09-0,12	0,61-0,82	1,52-1,64	20/80	548	424	26	64	52
16	0,10-0,12	0,68-0,72	1,48-1,56	15/85	532	420	28	52	48
20	0,09-0,11	0,70-0,74	1,52-1,58	15/85	510	398	26	48	50
30	0,10-0,11	0,66-0,82	1,46-1,58	15/85, 20/80	490	386	26	44	49

Table 2. **Dependence of coercive force value Hc (А/см) on metal-roll thickness (*d*, mm)**

Steel grade	**Metal thickness *d*, mm**						
	6	8	10	12	16	20	30
Ст3	2,80-2,90	2,19-2,23	1,71-1,79	1,50-1,56	1,24-1,30	1,17-1,25	-
09Г2С	3,82-3,87	3,08-3,12	-	2,05-2,11	1,62-1,69	1,51-1,60	1,40-1,50
10ХСНД	7,30-7,41	6,18-6,23	5,38-5,43	-	4,34-4,42	3,91-3,99	3,40-3,44

2. RECENT RESEARCH ANALYSIS

In 2005 Ukraine adopted «Guidelines for implementing the magnetic control of lifting construction mode of deformation and for determining their remaining life» (МВ 0.00-7.01-05) [1]. They are based on the Russian method in Guiding documents of the ECC “CRANE”-007-97/02 (РД ИКЦ «КРАН»-007-97/02) [2].

Research of magnetic control based on coercive force in MC of lifting equipment has been conducted in the works by V.S. Kotelnykov, V.A. Popov, B.Y. Popov, A.S. Lipatov, Y.A. Levin [3, 4, 5]. The problem of unequal values of coercive force depending on the metal thickness has been considered in the article [6, 7].

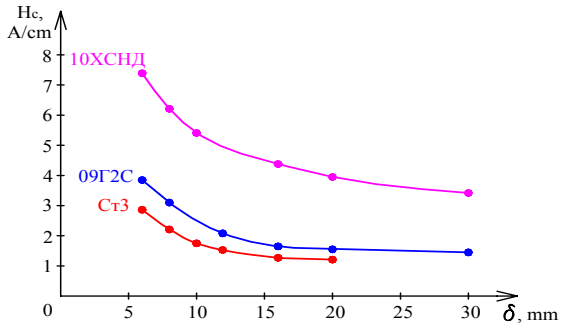

Fig. 1. - Dependence of coercive force value *Hc* (A/sм) on metal-roll thickness (*d*, mm) with grain-size of point 9 (State Standard 5639-82)

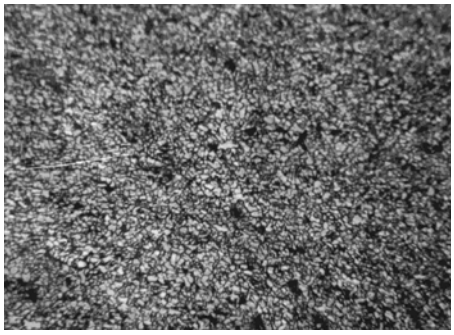

Fig. 2. Microstructure of 09Г2С steel sample (State Standard 19281-89), enlargement x 100, grain of point 9 (State Standard 5639-82)

Unsolved aspects of the general problem

Theoretical and practical basis of crane MC magnetic control based on coercive force with different metal thickness does not enable us to accurately assess mode of deformation and to prognosticate crane MC residual life.

The method of recalculating the KRM-TS-K2M structure-scope readings introducing the correcting coefficient, which is suggested in the techniques [1, 2], is not right as it does not take into account the perlite-ferrite ratio, the controlled metal grain point and shape, tolerance in chemical compositions of steels [8].

Objective of the article

This article gives a technique of assessing and prognosticating the residual life of the bridge crane MC with different element thicknesses using the magnetic control method based on coercive force and the method of final elements (MFE).

Basic material

To solve the problem of unequal metal magnetization in different thicknesses it is suggested to use a technique implementing certified experimental samples with variable cross-section (VES) with known mechanic properties and metal chemical composition, microstructure and coercive force values in each cross-section of the sample (figure 3). It is desirable to make a sample set from the metal of the controlled crane MC. However, if this is not possible it is acceptable to select steel with similar mechanic properties, chemical composition and microstructure to make samples. Samples are made according to the technique [7]. Then, coercive force measurements are conducted on these samples with variable cross-section. Coercive control is carried out on the operating parts (crosswise the sample) with a KRM-TS-K2M type magnetic structure-scope 4 or 5 times with a 5-hour interval.

Fig. 3. External appearance of certified experimental samples with variable cross-section (VES)

The obtained results of coercive force measurements are to be mathematically processed. According to the technique [9] and with the help of a software programme written in Delphi, the measurement approximation is carried out (fig. 4) and curve function is derived and given by a formula (1).

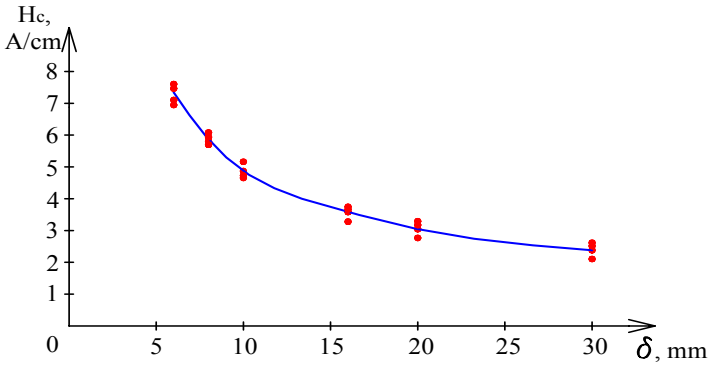

Fig. 4. Approximation of obtained results of coercive control in variable cross-section samples made of 10ХСНД steel

$$H_C(d)=A+B\cdot\exp(-C\cdot d) \quad (1)$$

where: $H_C(d)$, A/cm is coercive force value with the sample thickness of d (mm); A, B, C are coefficients that are derived according to the technique [9]; d, mm is the controlled metal thickness.

Experimental sample magnetic control certificate is composed based on the results of chemical analysis, mechanic testings, metallographic research and coercive force measurements [10].

For further analysis of the obtained results of crane MC magnetic control with different thicknesses it is necessary to reduce, by recalculating, all coercive force measurements to the one thickness. This metal thickness is 8 mm which is accounted for by the fact that KRM-TS-K2M structure-scope calibration before operation is conducted on the 8-mm-thick metal. This metal is supplied together with the structure-scope by the producer.

To recalculate the obtained results of the crane MC magnetic control for the 8-mm-thick metal (H_C^8, A/cm) we need to subtract formula (1) with the substituted actual thickness of MC element from the obtained measurement of coercive force (H_C, A/cm) for a certain thickness (d, мм). Then, we add formula (1) to the obtained number substituting the controlled metal thickness with 8 mm – formula (2):

$$H_C^8 = H_C - (A + B \cdot \exp(-C \cdot d)) + A + B \cdot \exp(-C \cdot 8) = H_C - B \cdot \exp(-C \cdot d) + B \cdot \exp(-C \cdot 8) \quad (2)$$

where H_C^8, A/cm, is the value of coercive force recalculated for 8 mm and for metal thickness d (mm).

A chart of prognosticating the residual life of bridge crane metal constructions with different element thicknesses with the help of magnetic control method based on coercive force is depicted in fig. 5.

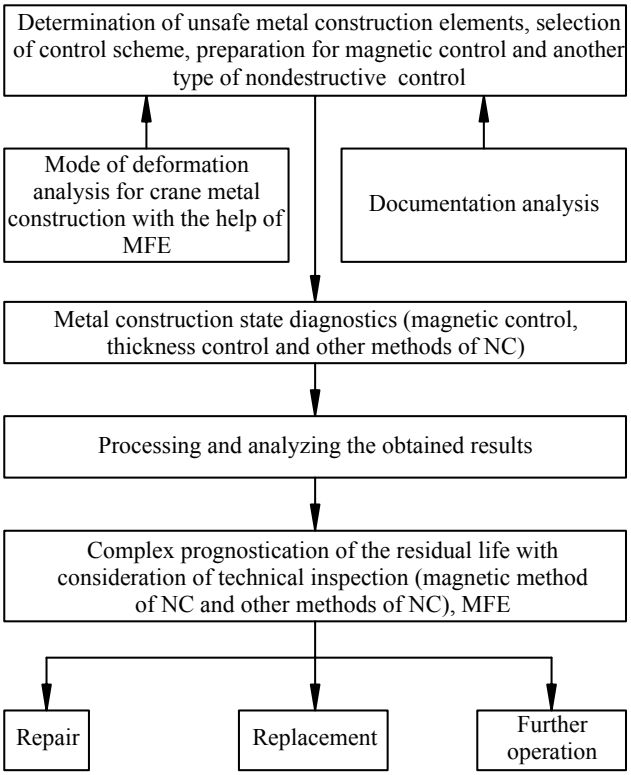

Fig. 5. Chart for prognosticating the remaining/residual life of bridge crane metal constructions with different element thickness with the help of magnetic (coercive metric) control method

Determination of unsafe metal construction elements, selection of control scheme, preparation for magnetic control and another type of nondestructive control (NC). At this stage it is necessary to single out crane MC elements which will be

primarily paid attention to while further diagnostics of the state of metal. This implies:

- mode of deformation analysis for crane metal construction with the help of MFE (software packages Ansys, SolidWorks).
- analyzing documentation, operating conditions of the crane, type and place of the crane operations.

To prepare for the magnetic (coercive metric) control it is necessary to select several VES with variable cross-section. The samples are selected according to the steel grade which the controlled crane MC is made of and to the MC elements thickness. Afterwards, according to these data (steel grade and metal thickness) we select several VES with different grain point. Then, it is necessary to calibrate the KRM-TSK-2M structure-scope according to Guidelines 0.007.01-05 (MB 0.007.01-05) and to make control measurements of the selected VES with this device. We have to ascertain that the obtained measurements correspond to the values in the certificate.

To carry out magnetic control of MC we only take documents (certificates) for the selected VES and the device with the calibration samples.

If need be, it is necessary to prepare other types of NC for implementation on the crane.

Metal construction state diagnostics (magnetic control, thickness control and other methods of NC). Metal construction state diagnostics is carried out according to NLALP 0.00-1.01-07 (НПАОП 0.00-1.01-07) [11] and to other valid normative legal documents with the help of magnetic control based on coercive force, thickness control and other methods of NC.

We need to select a zone on the crane where the metal has been under comparatively minimal effect of power loads while exploitation and to measure the coercive force H_C^0 (А/см). Based on the obtained values H_C^0 (А/см) we select one VES from the previously singled-out set of samples, using the sample certificates. Discrepancy between H_C^0 and the coercive force values in this VES (with the same thickness) must not exceed 10 %. If this requirement is not met it is necessary to select another slightly loaded zone and measure the coercive force. If we fail to find such a zone it means that VES have been selected incorrectly.

Afterwards, according to the chosen control scheme we need to measure coercive force in other zones where it is required to control the mode of deformation of metal. Those crane MC elements that have turned out to be the most dangerous after MFE implementation require special attention.

All the results of MC state diagnostics are to be recorded for further handling and analysis. If any departure from the crane exploitation norms under the valid normative acts has been detected; if the magnetic control has detected zones of a dramatic drop in coercive force (a drop to below 1,0 A/cm) [5], then the crane operation is stopped and is not renewed until the errors have been corrected. If a rise in coercive force values is observed, then it is necessary to increase the number of control points in this place.

If discrepancies between the certificate and the MC elements thickness control

have been found then we accept the thicknesses that have been obtained during measuring.

Processing and analyzing the obtained results. Based on the results of the thickness-metrics and on the crane documents (certificate) we need to take records of measuring the crane MC elements thickness.

Based on the results of the magnetic control of the crane MC state, a record of measurements is composed (according to Guidelines 0.007.01-05 (MB 0.007.01-05), that is, all the data are put into a separate table on every node (element) according to the control chart. If need be, additional measurements are conducted.

Basing on records of measuring the crane MC elements thickness and on the magnetic control of the crane MC state, we recalculate the results of the magnetic control in all the different thicknesses according to the afore mentioned technique.

Afterwards, we build curves of dependencies of coercive force distribution (Hc, A/cm) along the length of the crane MC elements (after the recalculation). We build curves of dependencies (plastic joints) of coercive force distribution (Hc, A/cm) along the height of the crane MC elements (after the recalculation). We record all the obtained values of coercive force (during measuring on the crane MC, during recalculating) as well as all the obtained curves of dependencies into the crane magnetic control certificate (which helps assess the load distribution in MC).

Complex prognostication of the remaining life with consideration of technical inspection (magnetic method of NC and other methods of NC). It includes:

- assessing the mode of deformation and prognosticating the remaining/residual life of the crane MC on the results of magnetic (coercive metric) control – Guidelines 0.007.01-05 (MB 0.007.01-05) technique, magnetic control certificate [12];
- prognosticating the residual life according to the rate of coercive force intensification [12];
- conclusions based on the results of other implemented types of NC;
- complex conclusion (prognosticating the residual life) based on all the results.

According to the obtained result of assessing the mode of deformation and prognosticating the residual life of the crane MC a conclusion (an expert conclusion) is drawn: *repair, replacement or further operation.*

3. CONCLUSIONS

The method of analyzing coercive force measurements of the crane MC with different thicknesses allows to:

- solve the problem of monitoring MC with different elements thicknesses using the KRM-TSK-2M structure-scope;
- objectively assess the mode of deformation of lifting machinery MC and to prognosticate their residual life.

As practical application shows, the suggested technique of assessing and

prognosticating the remaining life of bridge crane MC with different thicknesses of elements using the magnetic (coercive metric) control method and MFE, prognostication of the residual life of the crane MC reaches the 0,9 probability (the data have been collected and processed on 92 bridge cranes).

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