REMAINING LIFE DEFINITION OF CRANE METAL CONSTRUCTION ON VALUE OF COERCIVE FORCES

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Abstract: In this work, the condition definition of bridge crane metal construction and prognostication of its remaining life on the basis of nondestructive control method by using coercive forces is presented. Basic approaches and performance stages of the magnetic control for the purpose of metal condition definition and remaining life of its work are considered.

Keywords: bridge crane, nondestructive control method

1. INTRODUCTION

According to the information supplied by the State Department for Labour Protection of Ukraine [1] on 01.01.2009 in Ukraine there are 35692 bridge cranes in operation (28231 out of which have already exceeded the regulatory service life), and there are 3540 cranes in the Kharkov region (2720 out of which are past the regulatory service life). It is possible to prognosticate the remaining life of the bridge crane metal constructions using the magnetic method of nondestructive control (NC) based on coercive force [2].

In 2005 Ukraine adopted «Guidelines for implementing the magnetic control of lifting construction mode of deformation mode and for determining the residual life» (MB 0.00-7.01-05) [3]. They are based on the Russian method Guiding documents of the ECC “CRANE”-007-97/02 (РД ИКЦ «КРАН»-007-97/02) [4].

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2. UNSOLVED ASPECTS OF THE GENERAL PROBLEM.

Separate attempts to indirectly determine the strength properties of the produced wares date back to the end of the last century, specifically, to 1981 [5], and the application of magnetic and electromagnetic methods for controlling the strength properties of serially produced wares goes back to the beginning of the past century, to 1905 [6]. The first success in controlling the quality of thermally tempered steel wares led, in 1919, to precocious conclusions [7] about the existence of a definite link between the strength and the magnetic properties of steels. However, the appearance of new kinds of constructional steels and the expended range of the problems solved by nondestructive control method has led us to the conclusion that the interconnection of mechanical properties and magnetic properties traditionally used in nondestructive control is not always definite, and that is why, while elaborating the methods of control it is necessary to know the type of the connection which is most often found empirically. [8].

Systematic research of magnetic and electric properties of steels in as-received condition after diverse thermo mechanical, thermal and chemical mechanical kinds of processing began in the 30ies of the 20th century and has been carried out up to the present moment.

Objectives of the article:

- to consider the method of prognosticating the remaining life of the bridge crane metal constructions using the magnetic method of nondestructive control based on coercive force.
- to single out the nondestructive control method advantages and disadvantages as well as the peculiarities of its application
- to consider the solution to the problem of prognosticating the remaining life of the bridge crane metal constructions with above 12 mm thickness of elements.

3. BASIC MATERIAL

Magnetic properties of metal constructions at cyclic loading are formed in complex stressed condition under the effect of tensile and bending loads and twisting moments. It is accompanied by the process of accumulation of damages and microplastic deformation that leads to metal destruction with the following loss of the load-bearing quality of the construction. During the production of cranes, the assemblage and the consequent operation the coercive force H_c is increasing (ampere/centimeter) [9]. The rate of the coercive force increase is determined by the mode of crane loading.

The procedure of magnetic control result assessment in Guiding documents of the ECC “CRANE”-007-97/02 (РД ИКЦ "Кран" 007-97/02) and in Guidelines 0.00-7.01-05 (МВ 0.00-7.01-05) stipulates three modes of lifting construction operation: that of dependable service, of controlled service and of critical service.

The Guiding documents of the ECC “CRANE”-007-97/02 (РД ИКЦ "Кран" 007-97/02) and Guidelines 0.00-7.01-05 (МВ 0.00-7.01-05) provide three methods of prognosticating the remaining life of crane metal constructions on the results of magnetic control. But the simplest and the most available method of crane condition monitoring is the use of nomograms that generalize the experimental dependences of the residual number of load cycles N on the coercive force H_c (a/cm) (figure 1).

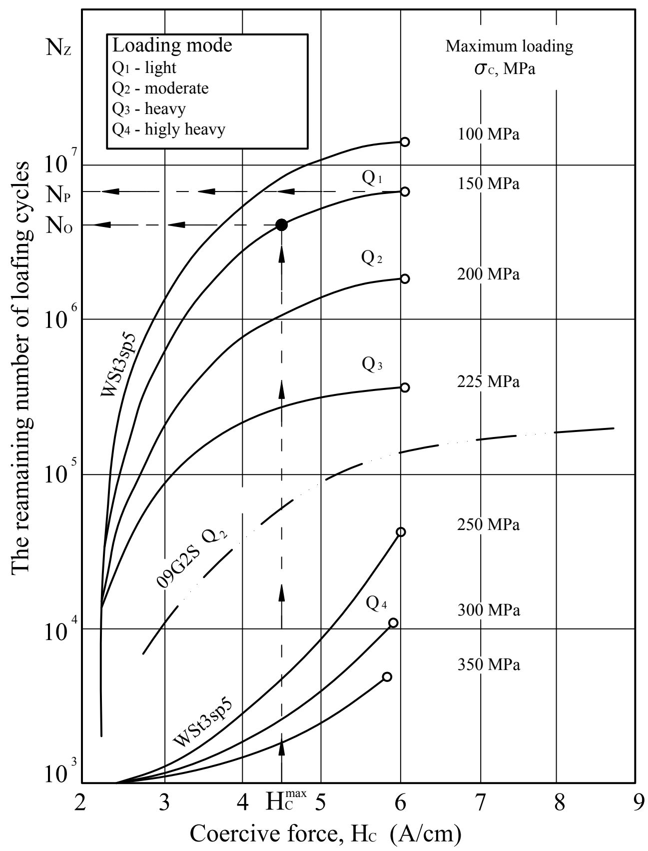

Fig. 1. Nomograms of dependences of remaining life of metal constructions (in fatigue) of ВСт3сп5 and 09Г2С steels on the coercive force H_C (A/cm)

In practical prognostication of the residual life of cranes past the regulatory service life it is considered indispensable first to determine the real mode of crane loading and the frequency of its use. Afterwards, having measured the H_c value (a/cm) with a magnetic structurescope KRM-TS-K2M (КРМ-Ц-К2М) as to the fatigue dependences H_c (A/cm) for the respective loading modes it is possible to assess the crane remaining life on the basis of nomograms generalizing the experimental dependences $N(H_c)$ (figure 2).

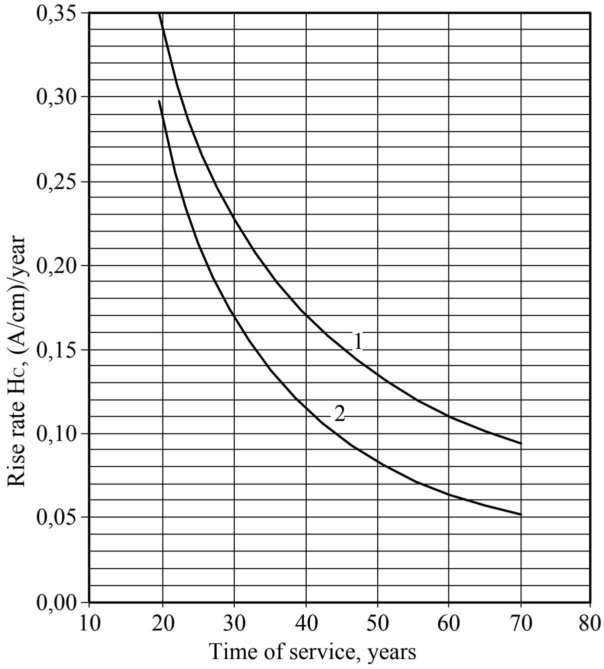

Fig. 2. Nomogram for controlling the remaining life of crane metal constructions from 09Г2С (1) and Ст3сп (2) steels

After determining the loading mode according to the certificate and the actual loading mode, magnetic control of the load-bearing constructions is carried out and sections with the maximum value for $H_c^{\max}$ are selected. The value for N_0 is acquired from the nomogram. The difference between the maximum number of cycles before the destruction N_P and N_0 for the given σ_a is the remaining number of crane operating cycles $N_{oct} = N_P - N_0$. The remaining life in sessions can be calculated knowing the expected crane loading and the frequency of loading in a session (C_{CM}) during operation:

$$P = \frac{N_p - N_0}{C_{CM}} \tag{1}$$

This method of assessing the remaining life of metal constructions is very simple but it has a significant drawback connected with determining the number of the cycles worked by a crane (N_0).

Besides, while implementing the magnetic NC method of mechanic properties of the metal based on coercive force it is obligatory to take into account the situation described in the article [10] when the magnetic structure-scoping of the crane detects not only zones of maximally acceptable rise in H_C but zones with a sudden fall of the coercive force down to 1 – 1,1 A/cm (for the 09Г2С steel). Consecutive defectoscopy detects flaws in these zones, for instance, fatigue metal exfoliation.

Another method of prognosticating the remaining life (durability of crane metal constructions) was offered in the article [11]. Using the data from the magnetic control certificate (MCC) and the magnetic control technique H_C for recurrent inspection of lifting constructions it is possible to put 0.9 probability on the prognostication of the remaining life of metal constructions from *09Г2С* and Ст3сп steels based on nomograms connecting the rate of damage accumulation in the state of fatigue to the time of crane operation (figure 2). The dependences are similar to the low-cycle fatigue curves (LCF) and replicate, up to a considerable degree, the nomograms for controlling the remaining life based on the coercive force H_C in Guiding documents of the ECC “CRANE”-007-97/02 (РД ИКЦ "Кран" 007-97/02) and Guidelines 0.00-7.01-05 (МВ 0.00-7.01-05).

Special attention should be paid to diagnosing bridge cranes in foundries [12], when elements of the crane metal construction are exposed at each technological cycle to scorching high-temperature gases discharged by the liquid metal. The heating-up temperature in the lower layers, while casting, reaches minimum 700-750 ^{o}C , that is, the temperature of steel heating is approaching the Curie point (which is T=768 ^{o}C for iron). Approaching this temperature point results in a decrease of coercive force and in a deterioration of mechanical parameters ($\sigma_{0,2}$ is the range of steel fluidity, MPa; σ_B is the limit point of steel strength, MPa) - figure 3.

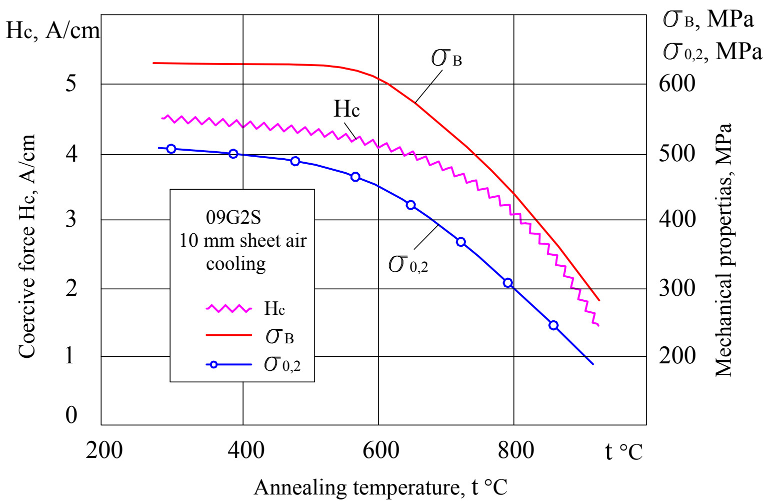

Fig. 3. Effect of annealing temperature on the magnetic and mechanic properties of steel 09Г2С sheets

Chemical composition influences the coercive force in metal. For instance, a rise in carbon concentration leads to a rise in coercive force, in electrical resistance and to a reduction in saturation of magnetization. Doping elements in steel also result in an increase (Cr - chromium, Si - silicon, Ni - nickel, Al - aluminium, Cu - copper) or a decrease (Mn - manganese) of coercive force.

A considerable drawback of the magnetic method of NC based on the coercive force H_C (A/cm) is its sensitivity to local alterations in the wall thickness that creates additional problems for interpreting the results of the control. The method, offered in Guidelines 0.00-7.01-05 (MB 0.00-7.01-05), of the coercive force recalculation depending on the metal thickness do not produce expected results in practice.

That is why while assessing the mode of deformation of load-carrying crane metal constructions according to the alterations in the coercive force the specialists in nondestructive control have to overcome obstacles while prognosticating the remaining life on nomograms of magnetic control (figure 1) in the elements with the metal-roll thickness of 12 mm and beyond [13, 14]. It is explained by the fact that the existing technology of metal-roll producing (with the sheet thickness of over 12 mm) presupposes a coarse-grained structure of the metal with the grain size of 7 points and below (according to the State Standard 5639-82).

An increase in the grain size leads to a reduction in the metal strength properties and, consequently, the coercive force decreases as well due to a reduction in the length of grain boundaries in the ferromagnetic structure [8].

Because of the insufficient resolution capability of coercimeters of the КРМ-ЦК-2М type (if applied to metal-roll with the sheet thickness of 12 mm and more) values for the coercive force (H_C, A/cm) are somewhat understated as compared to values for the coercive force in the standard check samples with the thickness of 8 mm that are provided with the coercimeter.

For ladle cranes, pick-and-place systems, cranes of great load-carrying capacity the thickness of the metal construction elements is over 12 mm. For a more accurate prognostication of the remaining life of their metal constructions with the help of the magnetic control method we can recommend (in addition to Guidelines 0.00-7.01-05 (MB 0.00-7.01-05) to implement variable cross-section samples with the known mechanical properties, chemical composition of the metal microstructure and values of the coercive force (H_C, A/cm) in each cross-section of the sample [14].

4. CONCLUSIONS

It is necessary to derive by way of experiment dependences (formulas) that will allow to recalculate the coercive force H_C on the basis of not only the thickness of the checked metal but of the chemical composition and the grain point in the complex.

The most accurate result in the prognostication of the remaining life of the crane metal construction can be obtained by application of the metal construction certificate (MCC) that is set up at the stage of the crane production.

Prognostication of the remaining life of the metal construction using the magnetic method of nondestructive control of mechanical properties of metal based on the coercive force is a highly promising method. Guidelines 0.00-7.01-05 (MB 0.00-7.01-05) have already been approved in Ukraine. However, coercimeter control should be applied for obtaining better results in conjunction with other NC methods (naturally, together with visual and measuring control and, for instance, with ultrasonic NC method) [15]. It will allow to exclude the drawbacks of one NC method, to compliment the NC methods and thus to realize the superfluity principle to enhance the reliability of load-carrying machinery construction control.

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