USAGE OF BARKHAUSEN EFFECT FOR HARDENING QUALITY CONTROL OF NEAR-SURFACE LAYERS OF TRANSPORT MACHINE PARTS

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Abstract: Some patterns of magnetic noises electromotive force (EMF) - Barkhausen effect - depending on change of ferromagnetic materials strength characteristics, static loading conditions and level of plastic deformation with the purpose of this factor usage enhancement for mechanic hardening non-destructive control, have been studied. Practicability of EMF and magnetic noises usage in order to control the stated factors and their place among other methods of non-destructive control was evaluated.
By methods of non-destructive control the impact of Barkhausen effect patterns on value and sign (strain - compression) of static loading in elastic and elasto-plastic domain for 65G and 38CrSi steel was studied. The character of graded magnetic noises EMF change at compression differs from the same change at strain, and that is evidence of magnetic noises method sensitivity to deformation sign.
The experimental research results of correlation dependencies between characteristics laser-hardened near-surface cast-iron layers with lamellar graphite grains and factors Barkhausen effect have been quoted. Correlation between laser-hardening depth, that is determined metallographically, and the value of graded magnetic noises EMF has been stated, and that permits to use the results of these measurements for laser-hardening depth non-destructive control on important parts of diesels and similar plants.

Introduction: Application of progressive methods of metallic materials manufacturing with purpose of increase of serviceability and safety of the machine heavy-loaded critical elements needs steady manufacture improvement control method. It also needs more wide usage of non-breaking control methods, development of new methods of such control using wide range of physical effects in solid body.

Now it is quite perspective to use the magnetic noises method for non-breaking control. This method is based on usage of Barkhausen effect. It is known [1] that Barkhausen effect index (EMF MN) is a structurally sensitive index. This index depends on quantity and character of defect pattern of crystalline construction, on presence of residual stresses and on other factors.

The opportunity of strong localization of the material value, which is subject to control with help of Barkhausen method, makes usage of analysis of the thin near-surface material layers (which were subject to surface thermal and deformation treatment) quality analysis expedient.

The opportunity of Barkhausen method for control of steel and cast-iron elements surface hardening quality by methods of plastic deformation (ППД) and of laser hardening (ЛТО) has been studied in this work.

Examination of ППД influence on EMF magnetic characteristics of magnetic noises (EMF MN) and on coercive force (H_c) was held on medium carbon alloyed structural 30XGSN2A steel in high strength state. Pins 30mm in diameter and 100mm long, thermally strengthened by quench of low-temperature tempering and hardness support of49-52HRC_E were used. ППД was executed by bowl rolling (bowls are 100mm in diameter and with profile radius of 5mm). Energies of rolling ranged from 0 to 1300kgf. At larger value of the effort, an intensive destruction such as surface layer bursting can be observed. Rolling was executed with help of 2-bowl hydraulic device with advance speed of 0.3 mm/turn.

Results: For examination of magnetic characteristics of H_c and EMF MN, coercitimeter KRM-Ts and "PION-1" device were used. The results of the measurement are given in figure 1.

The received data indicate that dependence of EMF MN and H_c on running in effort at relief effect has a view of saturation curves. At increasing running in effort to 600kgf one can observe H_c increase and EMF MN decrease; at further increase of running in effort the subjected to research magnetic data practically do not change.

Thus the pattern of change of EMF MN at increase of running in effort (hence material rate of deformation in near-surface seam) to 60kgf corresponds to the existing conception (1), according to which EMF MN should decrease depending on material inhomogeneity, in particular depending on dislocation density growth. Ceasing of EMF MN decrease with the following increase of running in effort can be explained as following: at rolling efforts of more than 600kgf the relaxation of attached inner tensions goes not due to dislocation density increase, but by micro- and than macrocracks forming. So that at rolling efforts of 1200kgf and more cracks and shelling can be observed on the rolled surface [2].

Conformity detection shows that the method of magnet noises the same as coercimeteric method, can be offered as quality control for upper coating of steel parts strengthening by PPD method. At this it should be remembered, that such type of control according to value EMF MN will have more sensibility, than according to H_c, as changes in EMF MN with increasing of value of effort at running in has more intensive character, than changes of value H_c, i.e. graphic chart E=P is higher than, graphic chart of H_c=P.

Considering the return character of value changing E and H_c (see fig.1) it becomes reasonable to offer new characteristic for surface control of deformed coatings-relation E/H_c. We can consider that usage of such combined characteristics should improve sensibility of the control.

Actuality and importance of such development in this area is connected with the point that at present time there is no reliable method of quality control of the parts which were strengthened by surface deformation.

Discussion: Lately parts laser thermostrengthening methods are of more wide usage in industry. Rather an effective measure of surface strengthening for increase of service life of parts, which work in intensive wear-out conditions, is laser chilling.

The surface laser chilling efficiency mostly depends on characteristics of the phase composition and parameters (depth, firmness, structurally-stress condition) strengthened with laser irradiating of the layer. Keeping of the optimum relationship between chilling phases of high-carbon heterogeneous alloy, which is cast iron with observance of the given technical conditions of strengthened layer characteristics, which are determined by depth and hardness. This keeping is a complex technologic problem to solve which, it is impossible without methods of non-breaking physical parameter control of strengthened layer.

In this connection the usage of non-breaking control method, which is based on Barkhausen effect is perspective because of high sensitiveness of surface layers.

Experimental research results of correlation relationships between characteristics of strengthened by laser chilling of cast iron near layer and of Barkhausen effect parameters are given in the work.

Measuring of magnet noises characteristics were held with help of cylindrical type changer with usage of special capping, which provides the persistence of clearance and of state of changer relatively to the controlled surface by pointwise scanning in direction, which is perpendicular to laser strengthening "track" with increment of 0.5mm. Within one measuring scanning of 3-5 laser tracks is being conducted. In the process of scanning max (approximately in the center of the track) and min (among laser tracks) device readings are recorded as standard units.

It was necessary to carry out pointwise scanning to learn the characteristics of laser hardened case depending on the hardening mode and the way of their section building. For that a mock-up was fixed tightly on the stand with micrometer travelling, and the converter was installed completely perpendicular to the mock-up surface and was pressed to its surface. By means of the micrometer screw the mock-up traveled with regard to the converter and recorded device readings point to point.

Laser hardening changes the structural-phase composition of iron. The characteristics of the samples under research of iron parts in cast condition are perlite structure of matrix and platelet shape of graphite insertion with even partition in matrix. Laser quenching at current 12.0…14.5A leads to typical iron surface fusing and to creation of hardened layer for the depth of 0.6 mm. As a result the layer of laser thermal hardening represents a hardened zone because of high temperature (fusing temperature on the surface). Different structural components are in thermal hardened zone, such as: pig iron of dendritic structure, martensite austenite and graphite. The modes of laser hardening to receive samples with different rate of hardening are stated in the table.

Mode	Quenching modes	
	Voltage, V	Discharge, A
1	1400	14.5
2	1400	13.5
3	1400	12.7
4	1400	12.0
5	1400	11.5
6	1400	11.0
7	1400	10.5
8	1400	10.0

The results of EMF MN definition by means of point to point scanning with regard to the width of laser track by means of converter of PION-1 device depending on quenching modes are stated on figure 2.

The following appears from the data received:

- EMF MN amplitude changes evenly with regard to the width of laser track from min value on the track frontier to max value on its center;
- For modes with stronger radiation power (1-4 modes) one can observe the plate of 4 mm width in the middle of the hardened track, that is characteristic for max signal stabilization of the device, hence magnetic qualities of the material;
- At weakening of radiation power the difference between max and min E value within laser track under research lowers steadily, mostly because of min signal value rise.

The character of magnetic noise signal change within laser track pints to the fact that this magnetic characteristics reflects changes of laser-strengthened layer characteristics and can be used to control it.

Curves of laser chilling depth distribution on the strengthened track edgewise, which are measured pointwise on metallographic samples, are shown in figure 3. The given distributions are obtained at laser chilling conditions, which correspond to the table.

The figure results in:

- Laser beam power decrease causes strengthening depth reduction from 0.6 to 0.2mm;
- Strengthening depth is unevenly distributed edgewise on laser track – together with laser beam power decrease this unevenness increases. More even strengthening depth distribution edgewise on laser track is characteristic for 1-4 conditions. For 5-8 conditions such distribution with two maximums is characteristic. It is connected with the following: laser processing power reduction results in increase of beam energy distribution unevenness along the section, it causes the chilling unevenness increase. By the same reason the power reduction results in the track becoming noticeably smaller: from 8mm for 1-4 conditions up to 6mm for 7 and 8 conditions;
- 3 and 4 conditions generate satisfactory strengthening depth distribution edgewise on laser track and provide the given strengthening depth (at least 0.35mm) and track width (8mm) and due to this they are considered to be optimal.

The dependence of magnetic noises signal on strengthening depth is shown in figure 4. Curve 1 reflects changes of signal maximum index (I_1), curve 2 reflects changes of signal minimum index (I_2), and curve 3 is Δ index $\Delta = I_1 - I_2$. As far as the Δ value changes depending on the strengthening depth almost acrwise, it was recommended for non-destructing laser chilling depth control in working environment.

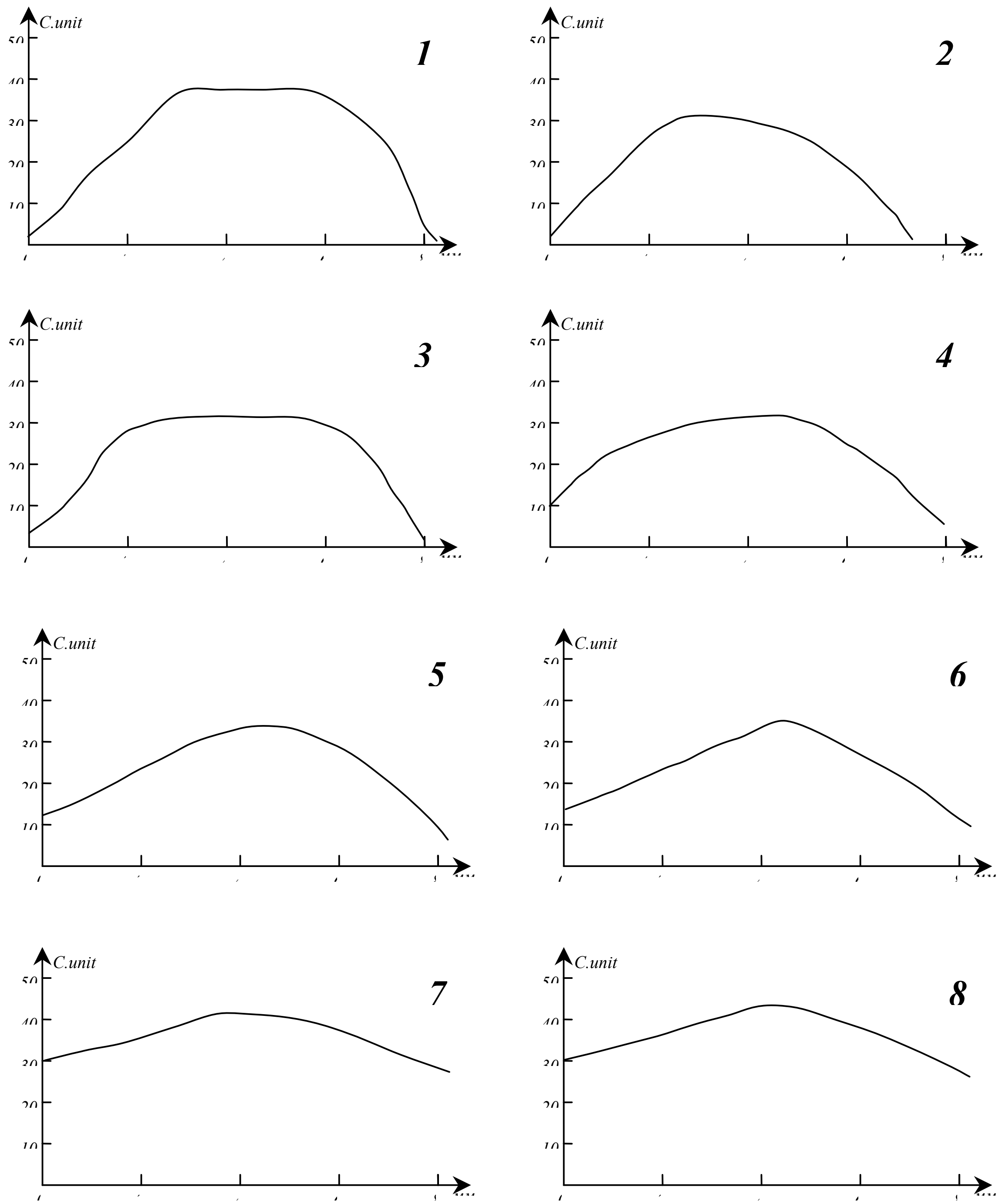

Fig.1. Dependence of EMF MN (curve 1) and H_c (curve 2) on the rolling effort value at ППД strengthening.

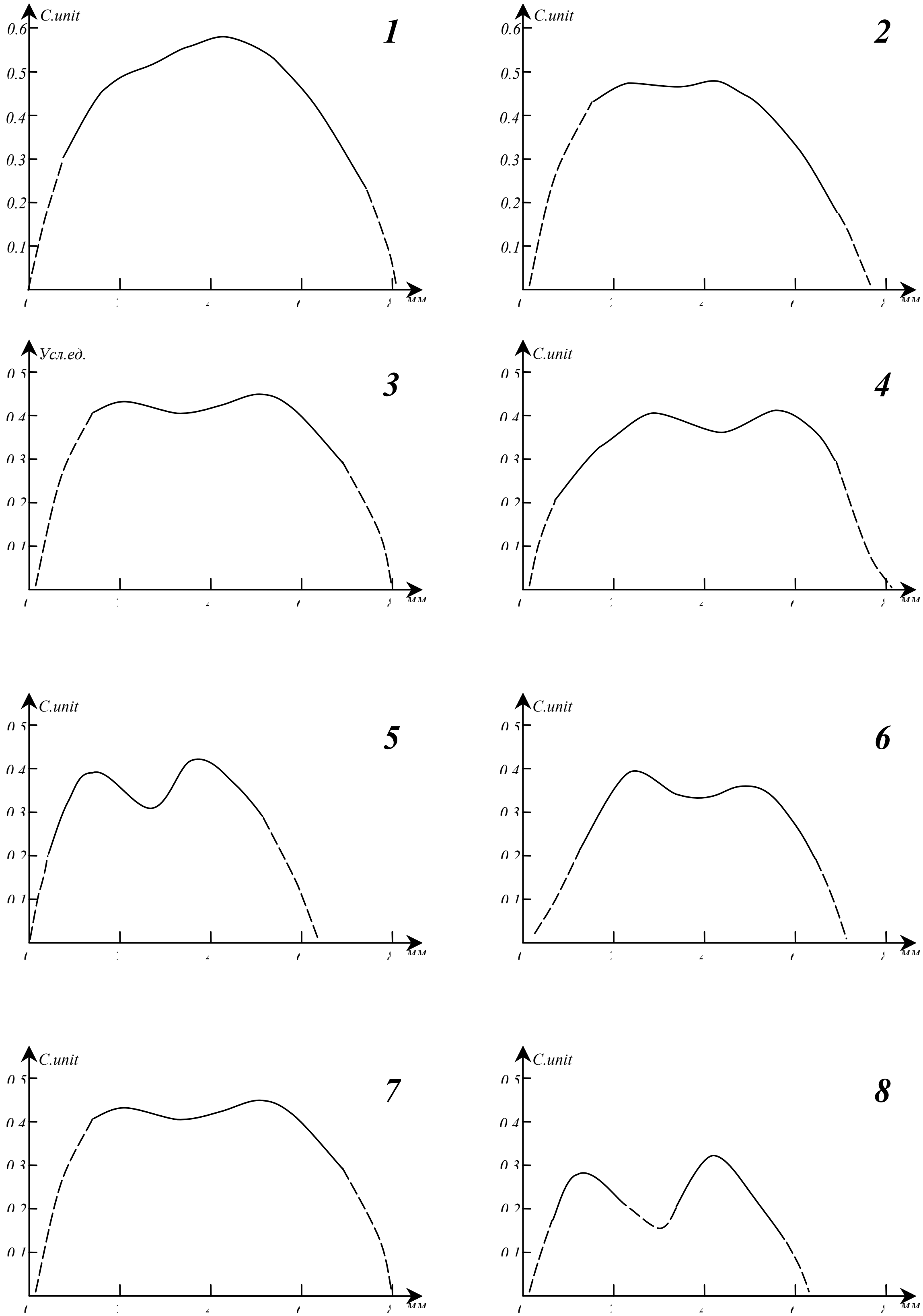
C.unit
0.6
0.5
0.4
0.3
0.2
0.1
1
2
Усл.ед.
3
4
5
6
7
8

Fig.2. Dependence of chilled layer depth within the laser track on the irradiation power (1-8 are ## of the conditions according to table 1).

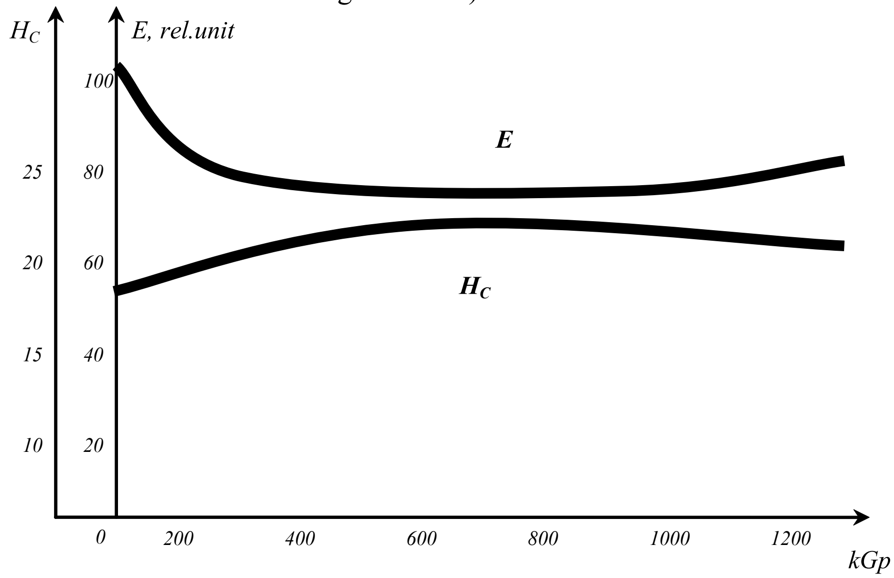

Fig.3. Dependence of EMF MN within the laser track on the irradiation power (1-8 are ## of the conditions according to table 1).

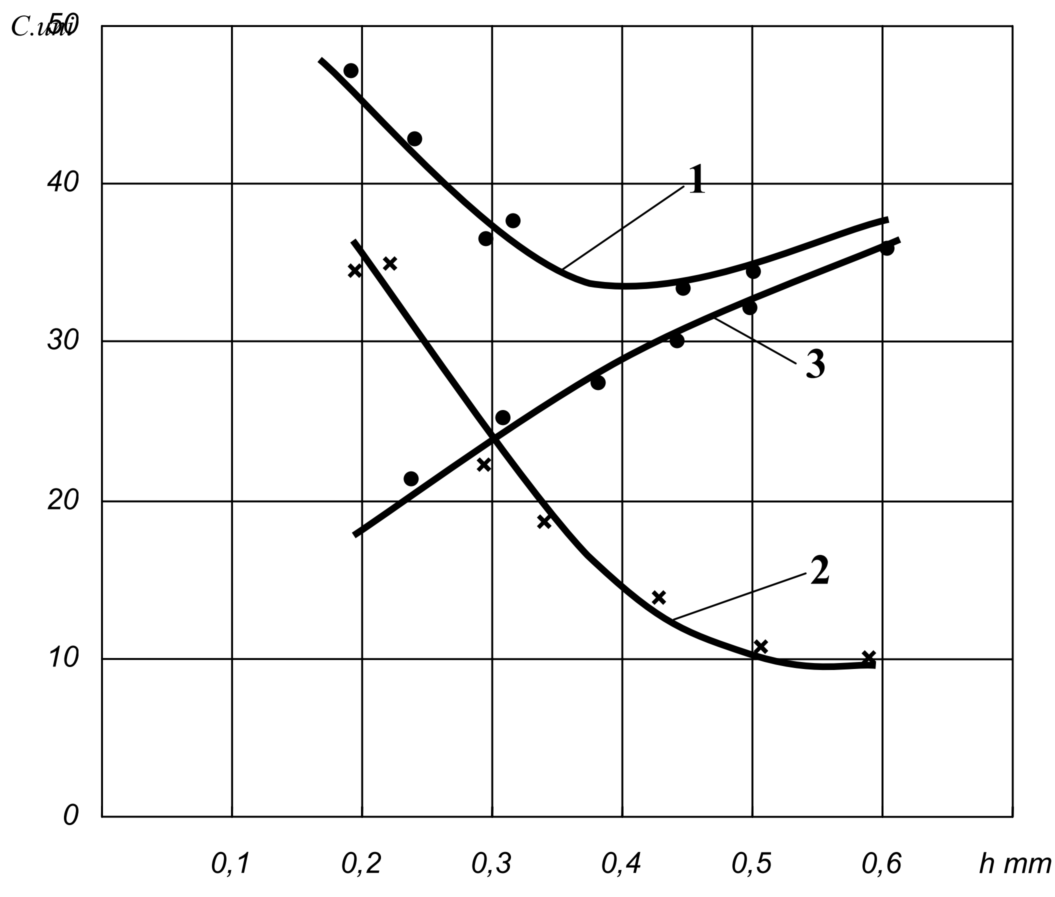

Fig.4. Dependence of magnet noises signal value on strengthening depth.

Conclusions: The displayed correlation dependence between parameters of surface layers, which were strengthened with help of surface plastic deformation and laser chilling methods, and magnetic characteristics indicates the opportunity of usage of magnet noises method to control the quality of surface strengthening in steel and cast iron parts.

References:

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