NANOAMPLITUDE RESONANCE VIBRATIONS OF SAMPLES IN A STRONG UNIFORM MAGNETIC FIELD

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Abstract: The paper presents the results of studies of the effect of nano-amplitude vibrations of steel samples in a constant and uniform strong magnetic field on some of their physical and mechanical characteristics. Various technological schemes are considered, in which broadband excitation of samples is applied using piezoelectric exciters that convert an electrical signal of constant amplitude in the range from 20 Hz to 20 kHz in the form of "white noise" into a resonant spectrum of natural mechanical vibrations of the samples. The results of such impacts on samples in laboratory conditions are confirmed by standard tests for the hardness of samples, their chemical composition and metallography. These studies confirmed the possibility of volumetric action on the material of the samples for various variants of technological schemes and made it possible to draw conclusions about the prospects of using nano-amplitude resonance oscillations of the samples in a strong uniform magnetic field of permanent magnets for strengthening the samples. It is shown that for samples of eutectoid steel with a carbon content of 0.8%, magnetic resonance treatment of the samples with an electric signal source with a power of only 3 watts for 50 minutes made it possible to achieve a change in Brinell hardness up to 35%. In this case, the formation of a mesh of a reinforcing nature made of lamellar pearlite in the bulk of the sample material was observed. An increase in the amplitude of oscillations of the piezoelectric resonator and, consequently, of the samples leads to an increase in the hardness of the material and the duration of reaching the steady-state value of its hardness, however, the nature of such changes is extreme. An increase in the amplitude of oscillations of the piezoelectric resonator and, consequently, of the samples leads to an increase in the hardness of the material and the duration of reaching the steady-state value of its hardness, however, the nature of such changes is extreme. The results obtained allow us to conclude that such processing is promising for increasing the wear resistance of non-regrowth cutting tool plates, for increasing the durability of elements of mechanical parts and structures. Also, it becomes possible to expand the list of technological influences on the working surfaces of machine parts, along with surface plastic deformation and heat treatment.

Keywords: volumetric hardening, uniform magnetic field, resonance, vibrations, piezoelectric elements, metallography.

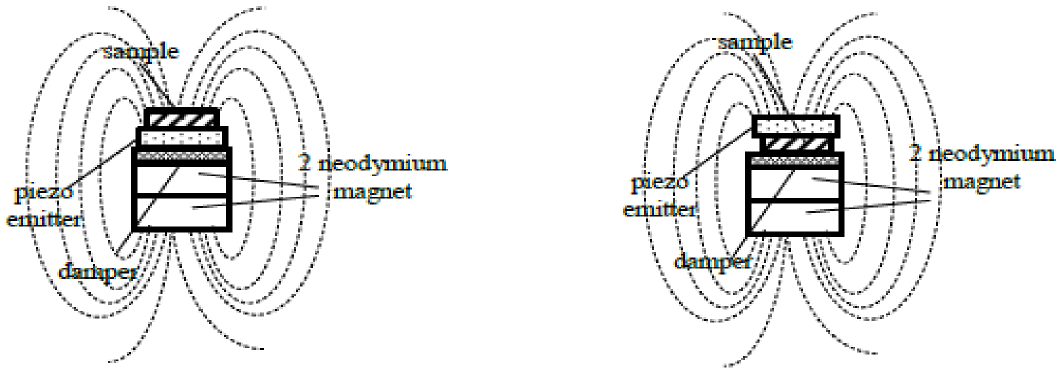
INTRODUCTION.

Thermal (heating or cooling) and force (surface-plastic deformation), implemented with different speed modes [1,2,3], remain traditional technological methods of influencing the working surfaces of products made of known materials. Their use is accompanied by significant expenditures of energy, time, material and labor resources. Many of these types of resources are non-renewable, and therefore, it is relevant to search for other possibilities of changing the physical and mechanical properties of materials with a multiple reduction (up to exclusion) of the use of the above resources. These possibilities include the use of quantum technologies based on quantum mechanics, capable of affecting materials and substances on an atomic and subatomic scale [4,5,6]. However, the implementation of known approaches to the impact on materials at the atomic and subatomic levels also requires significant, often exceeding the scale, costs of thermal and force effects.

BASIC PART.

In connection with the above, of particular scientific interest is the study of the effect on the atomic and subatomic levels of materials whose particles are vibrated in a strong uniform magnetic field at natural resonant frequencies with nanometer range amplitudes [7].

The study of the use of a uniform flux of the magnetic field generated by powerful permanent magnets was performed to influence the material volume of non-grinding plates of the cutting tool CNMG_120508E-M. The effect of a uniform magnetic flux is initiated as a result of resonant oscillations of the sample caused by a broadband effect of equal amplitude using a “white noise” generator and a piezo emitter (Figs. 1a and 1c).



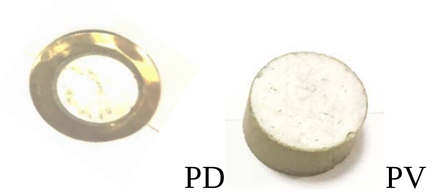
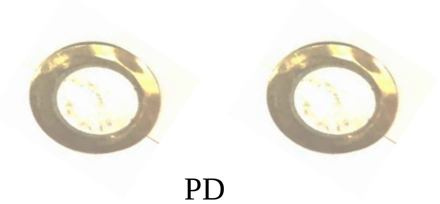
a) b)

Figure 1 - Schematic diagrams of devices for strengthening the samples with the upper (1a) and lower (1b) position of the sample relative to the piezoelectric agent

Adding mechanical oscillations to the samples in a uniform constant magnetic field allowed to achieve volumetric hardening of the samples from 150 HB to 240 ÷ 250 HB, ie by 60 ÷ 65% in 10-12 minutes, which is the hardening of the samples by 5-6% in one minute. hard alloy grooves placed in the magnetic field of a permanent magnet, subjected to resonant oscillations caused by a broadband effect of constant amplitude - "white noise", change the hardness and reach the maximum value after 10 minutes of magnetic resonance imaging.

Other schemes of mutual arrangement of assembly elements for experimental researches of magnetic resonance processing of eutectoid steel with chemical composition: C = 0,8%; Si = 0.15%; Mn = 0.15%; P = 0.012%; S = 0.017%; Cr = 0.10%; Al = 0.009%; Cu = 0.10%; are presented in table.1.

Table 1 - Schemes of technological adjustments for magnetic resonance processing of samples

№	Piezoelectric Elements - Emitters and Sensors	Loading scheme
1	2	3
1	 PD PV	NM-PD-S-PV-NM
2	 PD	

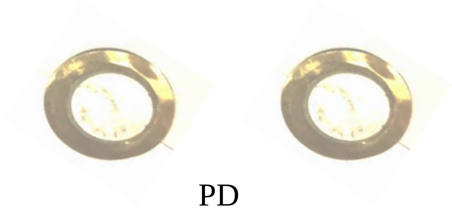
	PV	
3	 PD PV	
4	 PD PV	PD-S-PV-NM

Table 1 shows: column 1 - the number of the technological adjustment; column 2 - the appearance of the piezoelectric elements used as a vibration exciter (PV) and sensors (PD); Column 3 - diagrams of the sequence of connection of elements of technological adjustments during the processing of samples. The comparative efficiency of magnetic resonance treatment of samples according to the schemes presented in Table 1, lasting up to 50 minutes with a broadband piezoelectric exciter with a power of up to 5 W, is shown in Fig. 2.

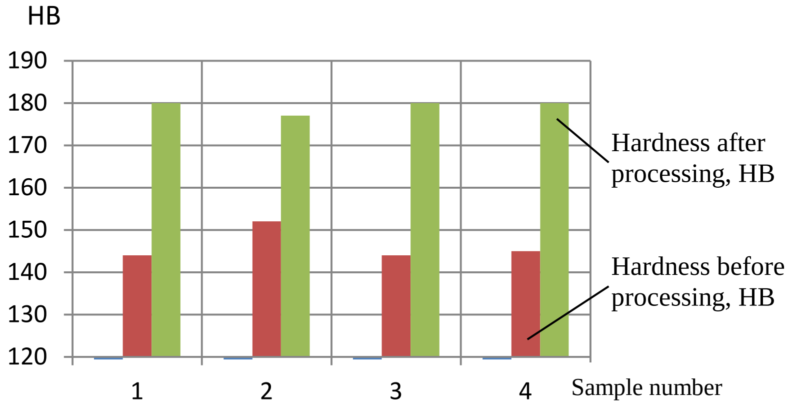
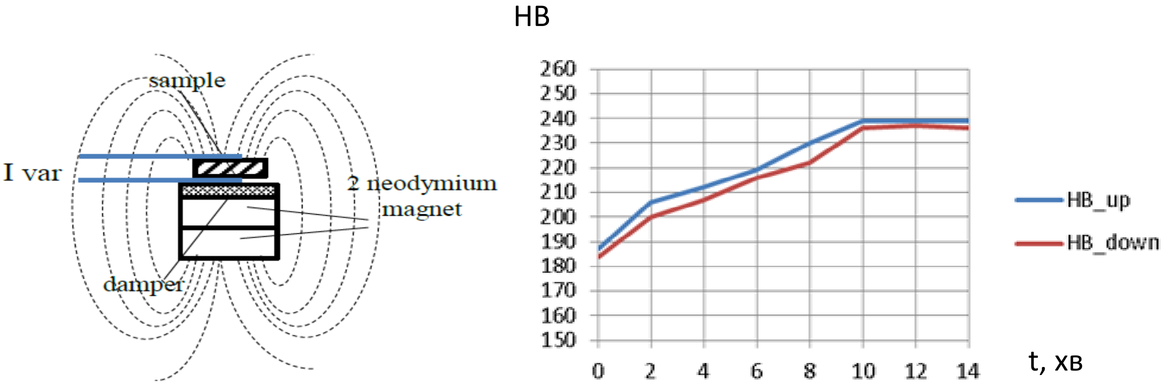


Figure 2 - The results of increasing the hardness of the sample materials for different samples and the corresponding processing schemes shown in table 1.

Samples 1-4, subjected to resonant vibrations and placed inside a uniform magnetic field created by neodymium magnets, increased the hardness of the material and after 30 minutes stabilize the hardness values.

Based on the obtained result and applying the Bio-Savar-Laplace law, it is possible to cause the interaction of the sample material with a uniform magnetic field of a strong permanent magnet [8,9]. In this case, when passing through the conductive material of the sample broadband multi-frequency alternating current with the characteristic "white noise" in the sample can also form a resonant vibration of the sample with an amplitude in the nanometric range. In comparison with cases 1 and 2, in the scheme of the experimental setup there is no piezoelectric element for creating vibrations of the sample with nanometric amplitude. Figure 3 shows: the schematic diagram (a) of the device for studying the behavior of the sample for the above conditions and the results of changes in the hardness of the sample over time according to this variant of the processing scheme.

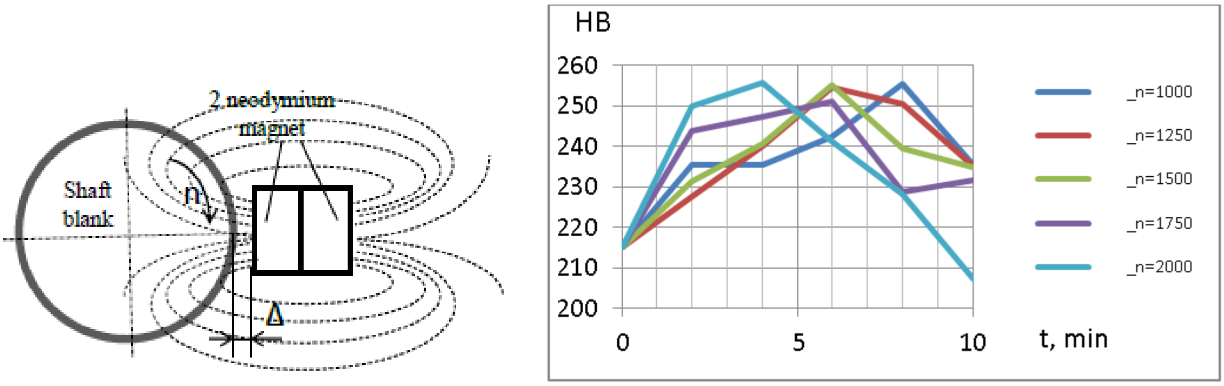


a) b)

Figure 3 - Schematic diagram of the device for strengthening the sample using the action of the law of Bio-Savar-Laplace (a); the results of the study of the change of HB sample from time t (b) for its top (HB_up) and bottom (HB_down).

A sample of a hard alloy placed in a magnetic field of a permanent magnet, when passing alternating current in the form of "white noise", can be strengthened by 30-40% after only 10 minutes of continuous exposure. In this case, the current consumption does not exceed 3 watts.

The search for alternative ways to affect the working surfaces of machine parts, such as the working necks of loaded shafts is an urgent problem, because such surfaces are subject to force (surface-plastic deformation) or temperature and, at the same time, receive, while strengthening, residual stresses [10, 11]. At the same time, such actions require the use of powerful energy sources, if there is a need to provide a three-dimensional impact on the material of the part. Using a powerful uniform magnetic field created by neodymium magnets to provide a three-dimensional effect on the sample, a scheme (Fig. 4a) and its implementation on a research device (Fig. 4b) are proposed.

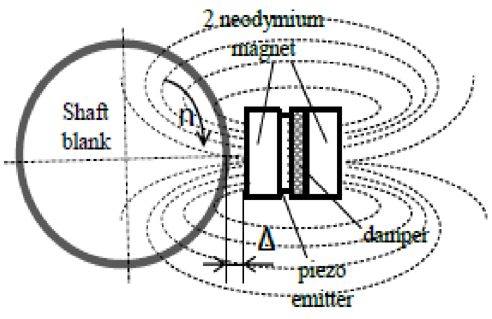


a) b)

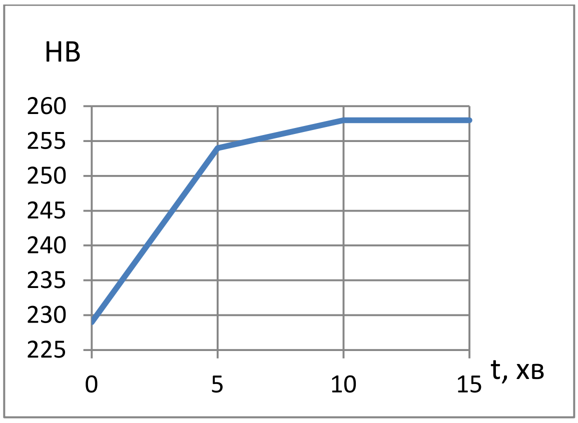
Figure 4 - Device for magnetic strengthening of the working surface of the shafts: a) schematic diagram; b) the dynamics of strengthening the HB working surface from time t to the influence of the magnetic field for different values of the spindle speed of the machine; $\Delta = 0.1$ mm.

As a result, the quantitative dependences of the hardening of the working surface on the time of exposure to the magnetic field for different values of the speed of the machine spindle. The use of the considered scheme makes it possible to increase the hardness of the material of the working surfaces of parts such as rotary bodies made of Ck45 steel (in accordance with the DIN standard) from 215HB to 255HB. The dynamics of changes in the hardness of the treated surfaces has the same character as in magnetic resonance processing of stationary samples and depends on the rotation frequency of the part. The shift of the maximum hardness towards a decrease in the duration of the treatment with a magnetic field of a permanent magnet with an increase in the rotation frequency of the part is explained by an increase in the rate of change of the magnetic flux relative to the surface to be hardened.

In the development of this scheme is proposed (Fig. 5a) and its implementation on a lathe, the difference of which is the provision of vibration to a magnetic field with an amplitude within 5-10 nanometers and $\Delta = 4.0$ mm. The value of Δ is directly proportional to the magnetic flux.



a)



b)

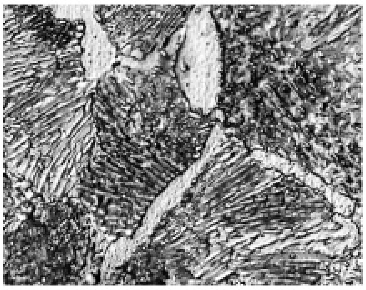
Figure 5 - The device of magnetic resonance hardening of the working surface of the shafts:
a) schematic diagram of the technological adjustment; b) the dynamics of hardening HB of the working surface from time t to the influence of broadband vibration of the magnetic field with the amplitude of the manometric range.

The results of tests to qualitatively assess the effect of a uniform magnetic field of a powerful permanent magnet with superimposed vibration of this magnet caused by a piezoelectric element, excited by a broadband effect within 20 Hz ÷ 20.0 kHz and a power of 3 W and 2000 rpm of the lathe spindle are presented in Fig.5b. Stabilization of surface hardness values after 10 minutes of treatment with a vibrating magnetic field of a permanent magnet indicates the commonality of physical processes at the atomic subatomic levels during magnetic resonance processing of materials. The relatively low hardening index of 10-12% is due to the smaller, compared to previous cases, the effect of the magnetic field due to the protrusion of the neodymium magnet from the hardened surface of the part by 4.0 mm.

Metallographic studies of the results of the considered principle of material hardening can be illustrated in Fig. 6.

Photographs of the structure were obtained by etching with a 4% alcohol solution of HNO_3. The grain boundaries appear after etching along the broken ferrite mesh in the longitudinal direction. In this case, the formation of a mesh of a reinforcing nature made of lamellar pearlite in the bulk of the material of the samples was observed. An increase in the amplitude of oscillations of the piezoelectric resonator and, consequently, of the samples leads to an increase in the hardness of the material and the duration of reaching the steady-state value of its hardness, however, the nature of such changes is extreme. The results obtained allow us to conclude that such processing is promising for increasing the wear resistance of non-regrowth cutting tool plates, for increasing the durability of elements of mechanical parts and structures. Also, it becomes possible to expand the list of technological influences on the working surfaces of machine parts, along with surface plastic deformation and heat treatment.

a)



b)

Figure 6 - structure of steel samples: (a) - before magnetic resonance treatment, HB = 145; (b) – after magnetic resonance treatment, HB = 197.

CONCLUSIONS.

The paper presents the results of studies of the effect of nano-amplitude vibrations of steel samples in a constant and uniform strong magnetic field on some of their physical and mechanical characteristics. Various technological schemes in which broadband excitation of samples is applied using piezoelectric exciters that convert an electrical signal of constant amplitude in the range from 20 Hz to 20 kHz in the form of "white noise" into the resonance spectrum of natural mechanical vibrations of samples are confirmed by standard tests for hardness of samples, their chemical composition and metallography. These studies confirmed the possibility of volumetric action on the material of the samples for various variants of technological schemes and made it possible to draw conclusions about the prospects of using nano-amplitude resonant oscillations of the samples in a strong uniform magnetic field of permanent magnets for strengthening the samples. An increase in the amplitude of oscillations of the piezoelectric resonator and, consequently, of the samples leads to an increase in the hardness of the material and the duration of reaching the steady-state value of its hardness, however, the nature of such changes is extreme. The results obtained allow us to conclude that such processing is promising for increasing the wear resistance of non-regrowth cutting tool plates, for increasing the durability of elements of mechanical parts and structures. Also, it becomes possible to expand the list of technological influences on the working surfaces of machine parts, along with surface plastic deformation and heat treatment.

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