UDC 621.785.532

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INFLUENCE OF TECHNOLOGICAL PARAMETERS OF COMPLEX BORATING ON THE PERFORMANCE OF COATING SURFACE OF MACHINE ELEMENTS

The influence of both the complex borating and temperature-temporal parameters of the process on microhardness of coating surface of logging machinery is examined. Roughness and stability of the dimensions in the strengthened machine elements are considered.

Introduction. The operating conditions of several logging machinery elements under complex load involve considerable friction, as well as vibrations of a wide amplitude-frequency range. All these factors contribute to heavy wear of the working surfaces of elements and to other "types" of destruction, including fatigue damage.

Manifold research and experience in the field of operating different machines and mechanisms show that fatigue and wear resistance is dependent on a number of factors, including surface hardness of the material. The higher the hardness is, the greater the allowable contact and bend stress and wear resistance are.

However, logging machinery, especially tractors, working under the maximum load, the hardness of loaded parts, in particular transmission gearwheels, is inadequate. For the above mentioned reason, a technique for hardening of the materials is relevant to be developed since it will enable to achieve greater surface hardness of the elements with minimum time and power consumption.

To improve wear resistance of the machine elements, different surface hardening techniques are employed such as cementation, nitriding, cyanidation, etc. [1–3].

The technological process of borating and borosiliconizing of machine elements involves shorter saturation time as compared to other diffused saturation methods (e.g., cementation). This advantage along with equal saturation temperatures (920–950°C) caused the analysis of these techniques as they can be applied to strengthen the transmission parts of logging tractors at repair shops of timber enterprises.

The hardening of teeth surfaces of transmission gearwheels of logging tractors brings up the problem of the effect which the applied technique has on the dimensional stability and roughness of the surfaces.

Therefore the paper dwells upon the analysis of the influence of complex borating technological parameters upon surface hardness, roughness and dimensional stability of the hardened surfaces of the elements.

1. **Study of microhardness of the hardened surface layer**. The analysis of the microhardness depth distribution of the hardened layers by borating and borosiliconizing was carried out at the ПМТ-3М microhardness tester. Fig. 1 shows the microhardness depth distribution in the sample surface layers made of 25 ХГТ steel and hardened by borating and borosiliconizing. The results obtained at different temperature-time parameters of the processes show that hardness decreases gradually in all samples under test. It has been determined that both borating and borosiliconizing allow to obtain the peak hardness of the surface layers which gradually decreases in-depth.

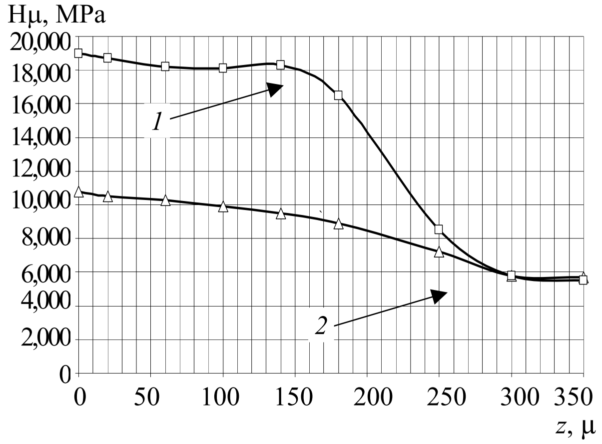

Fig. 1. Microhardness depth distribution over borated and borosiliconized layers in 25 ХГТ steel samples of various thickness: *1* – borating; *2* – borosiliconizing (200–220 μ layer thickness)

The microhardness depth distribution of the borated and borosiliconized layers is related to their phase composition. It has been stated that borating causes sharp decrease of hardness where the hardened layers adjoin the metal basis with additional stress in the bordering area. This can be explained by the formation of FeB in the hardened layer. Borosiliconizing processes provide a smoother transition to the metal basis, therefore do not cause sharp microhardness differences and less hard phases of Fe_2B and FeSi are formed. Three zones of microhardness can be distinguished when borosiliconizing: boron- and silicon-saturated zone

(11,200–11,800 MPa), transition zone (7,800–9,000 MPa) and core zone (5,000–5,600 MPa).

This microhardness describes formation and depth layout of the hardened layers which have different structure and chemical phase composition. Different compositions of saturating mixtures reveal similar microhardness changes what can be proven by the data quoted by other authors [2].

As mentioned above, the logging tractor operations are carried out under heavy dynamic load on the transmission parts which can result in shear fractures of the hardened surface layers off the teeth contact parts in case the surface impregnation has not been done in a proper way. Therefore the hardened layer should possess both improved surface hardness and low fragility.

The obtained results on the distribution of microhardness over the depth of the hardened layer made it possible to determine that by means of borosiliconizing the increased hardness at 200–250 μ depth leads to increasing of allowable contact stresses. These help to avoid plastic strain not only on the surface but in the indicated depth and prevent the hardened layer from deep contact spalling as well. These factors allow this hardening technique to be applied for transmission gearwheels of logging tractors.

As noted above, wear resistance of the surface and performance of the transmission elements are dependent on the surface roughness and dimensional stability which can change through surface impregnation.

2. **Study of roughness and dimensional stability of the hardened surface**. The roughness was determined by *Ra* parameter using profilograph-profilometer. The study involved samples made of 45, 40X and 25XГТ steel grades with different surface finish. The samples were then borated and borosiliconized at impregnation temperature of 950°C, curing time being 3 hours (Fig. 2).

The study results reveal that the surface state after diffusion saturation becomes inferior for both borating and borosiliconizing procedures.

The hardening of the items results in changing of their linear dimensions which can be explained by active surface adsorption of alloy atoms and formation of solid interstitial solutions on the hardened layer. At the same time after gearwheels have been subjected to surface impregnation, the linear dimensions should not go beyond allowable margin of tooth profile error.

The study tests were carried out using cylindrical 25XГТ steel samples of 20 mm diameter and 10 mm length that were borated and borosiliconized at temperature of 950°C for 0.5–5.0 hours. The changing of samples diameters was registered by vertical ИКВ type optimeter with 0.001 mm division value. The increase (Δl) in dimensions proved to be proportional to increasing curing time and hardened surface layer thickness.

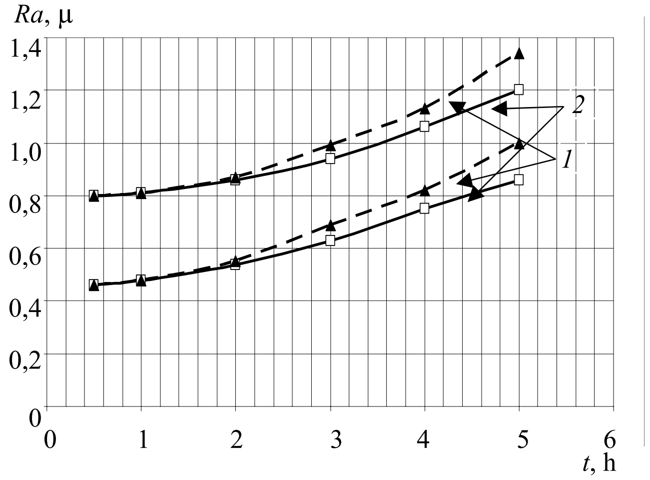

Fig. 2. Effect of saturation time on the surface roughness at different initial *Ra* values for borating and borosiliconizing:
1 – borating; *2* – borosiliconizing

The increase in dimensions makes up about 18–22% of the thickness of both borated and borosiliconized layers. The total thickness of the borosiliconized layer of the transmission parts of logging tractors being 200–250μ, the dimensions will be increased about 36–55μ.

The close-to-linear pattern of the dependence of the dimensional increase from the saturation time makes it easier to determine corresponding correlation dependences (Δl from t) and thus optimal allowances for machining. In some cases the machining errors can be eliminated by the corresponding surface saturation time.

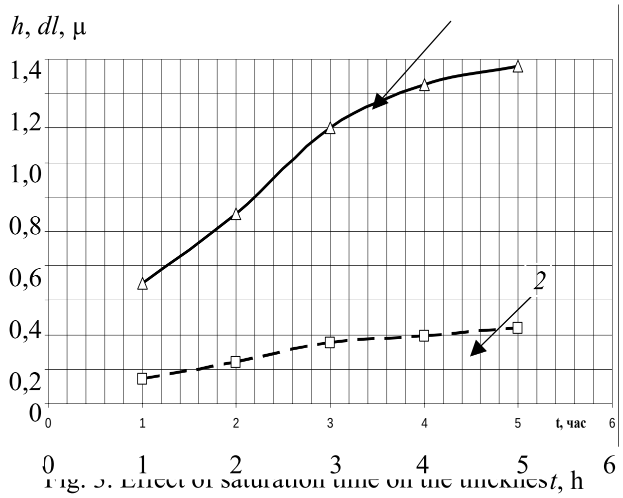

Fig. 3. Effect of saturation time on the thickness of borosiliconized layer (*h*) and dimensional increase (*dl*) of 25XГТ steel samples

The conducted study has shown that the dimensional increase in borosiliconizing does not exceed the margin of error of the bevel gear tooth profile. This does not assume additional machining for reducing the dimensions. To diminish the roughness of the hardened bevel gear wheels of TTP-401 logging tractor transmission parts, honed finishing is to be carried out after borosiliconizing.

Conclusion. The analysis of changes in roughness and linear dimensions of the impregnated transmission parts made it possible to determine the following factors: after borating and borosiliconizing the increase in dimensions is within 18–22% of the hardened layer thickness (200–250µ), i.e. about 36–55µ. The increase does not exceed the margin of error of the gearwheel tooth profile.

A minor increase of roughness *Ra* parameter (Ra = 1.6µ before hardening, Ra = 1.72–1.94µ after surface impregnation) can be observed in both borating and borosiliconizing, thus hone finishing is recommended for hardened gearwheels.

The research results show that in spite of high surface microhardness (18,000–20,000 MPa), borating is not appropriate for hardening of logging machinery parts since this kind of impregnation provides a quite fragile hardened layer.

The studied parameters of hardening by borosiliconizing meet the demands placed on the machine parts operating under heavy load, in particular transmission gearwheels of logging tractors.

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Received 15.03.2012