Ti-coating by method III: $w^{IV}_{950} = 5 \cdot 10^{-9}$ g/cm²·sec. Experiments with evaporation of Cr—Ni steel 316 at 835°C under high vacuum (10 μPa) showed that, similar to the Cr—Mn steel ÉP838 the specimen weights did not change. Because of this, the vacuum conditions were deliberately lowered. Tests of the titanium-coated steel 316 in 100 μPa vacuum at 835°C are shown in Fig. 1c. The Ti layer absorbs gas molecules from the residual atmosphere in the working chamber, which causes a weight gain of the specimens at 835°C. That weight increase is insignificant in absolute terms, however it must be remembered that the molecular weights of the absorbed gases (oxygen, carbon dioxide, water vapor, etc.) are low. Therefore the absorption even of a large amount of gases does not result in a significant weight gain of the specimens. Gas absorption of titanium coatings on austenitic steels at high temperatures can be a very important factor for their application in various vacuum systems.

It is concluded therefore that the titanium coating of austenitic Cr—Mn steel ÉP838 and Cr—Ni steel 316 can be recommended as a protective coating for high-temperature applications. It is also worthwhile to test the heat resistance of titanium coatings in thermocyclic conditions, as well as to experiment with other coating methods, for instance, plasma coating, etc.

The application of TCT-formed aluminium and titanium protective layers on Cr—Mn (ÉP838) and Cr—Ni (316) austenitic steels decreases the evaporation rates of volatile components from these steels in vacuum at 800-950°C. Titanium coating has an additional advantage: high absorption of gas molecules which can be used as a method of improving the vacuum conditions.

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METHOD OF IMPROVING THE HEAT RESISTANCE OF PARTS WORKING UNDER CONDITIONS OF DISCONTINUOUS LUBRICATION

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In the present work the possibilities are studied for using thermochemical treatment methods (TCT) to improve the heat resistance of parts working under conditions of discontinuous lubricant supply. The main aim of the study is to produce rubbing surfaces, the microstructure of which would possess high antifriction as well as antigalling properties.

Boriding produces a friction-resistant layer. The borided layer retains a high hardness (H1400-2000 at a load of 0.5 N) up to 850-900°C. However, because of low galling resistance, such layers cannot be used without lubrication.

Sulfiding is the most promising method for improving galling resistance. However, the hardness of sulfide layers is so low that even a quenched steel abrades it, and consequently, that process cannot be used as a treatment for working parts [1].

Simultaneous boron and sulfur saturation of steels failed to improve their galling resistance. This can be explained by the fact that such processes do not produce, on the steel surface, dispersed phases of iron sulfides which would at high temperatures form, due to their melting point, sulfide films between the rubbing surfaces.

Boron and silicon impregnation was used to produce microstructures at the steel surface containing boride and sulfide areas [2]. The studies were carried out using steel 20. Im-

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TABLE 1

Thermochemical treatment	Wear, g		Load, MPa
	roller	block	
Boron/silicon impregnation at 1000 deg C for 4 h + sulfidation at 560 deg C for 2 h	0.0055	0.0072	15.0
Boron/silicon impreg. at 900 deg C for 4 h + sulfidation at 560 deg C for 2 h	0.0021	0.0027	15.0
Boron impregnation at 900 deg C for 4 h	0.0019	0.0035	8.0

Footnotes: 1) The SMTs-2 machine's maximum permitted load is 15 MPa; 2) the block was made out of steel 45, while the roller was made out of coated steel 10.

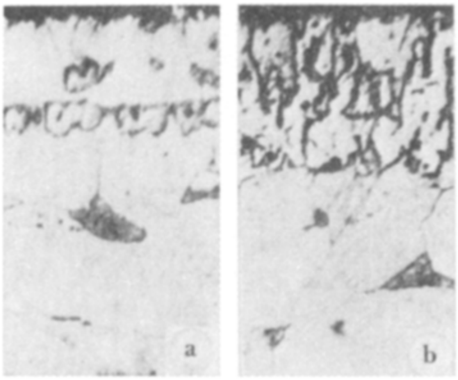

Fig. 1. Microstructures produced by boron/silicon impregnation followed by sulfidizing on steel 20 (270×): a) impregnation at 1000°C for 4 h; b) at 900°C for 4 h.

pregnation was carried out in powder mixtures made from two components: a boriding component (84% boron carbide and 16% borax) and a siliconizing component (50% silicon, 45% aluminum oxide and 5% ammonium chloride). Each component was prepared separately before they were mixed in the ratio 70% boriding to 30% siliconizing component.

The parts and the impregnating mixture were placed in a container as is usually done for carburization. The container was made air-tight. Then the container was placed into a furnace heated to the impregnation temperature. The temperature of the processes was 900 or 1000°C, impregnation time was 4 h.

Coatings of two types are formed depending on the temperature. The microstructure of the first-type coating (Fig. 1a) is produced by impregnation at 1000°C. According to x-ray analysis, the outer layer consists of α'-phase, the next layer is composed of α-phase, then come spheroidized iron borides, Fe_2B. After boron/silicon impregnation, the parts were subjected to sulfidizing in fused salts at 560°C for 2 h. As a result of sulfidizing, the α'-phase disappears and Fe_2B phases and α-solid solution of silicon in iron are formed. The surface microhardness is H 310-350, while the microhardness of the boride area is H 1400-1600. The total thickness of the coating was 0.1 mm (measured at the ends of borides).

The microstructure of the second-type coating is produced by impregnation at 900°C (Fig. 1b). The outer layer consists of borides Fe_2B scattered in a matrix of α-iron silicate. Unlike the first-type microstructure, borides in the second-type microstructure persist through the whole coating. After boron/silicon impregnation, the parts were also subjected to sulfidizing in molten salts. The coating produced consisted of boride phase Fe_2B with H 1300-1600 microhardness and α-iron silicate containing S in solid solution as well as in the form of scattered particles of iron sulphide.

The coatings produced were tested in the friction device SMTs-2 using the roller-block method. Tests were conducted for 2 h at a speed of 2 m/sec. The lubricant, "industrial oil 20," was supplied to a limited extent. Running-in prior to the tests was conducted to the point when the friction moment reached a constant value. The friction moment was continuously recorded. For comparison purposes boride coatings were also tested. Specific pressure on the blocks was 6 MPa.

Galling tests were carried out in the following way: the lubricant supply was cut off and the load was increased by 5 MPa every 10 min. Then the specimens were blast-cooled in air. The galling point was identified by an acute increase in the friction moment.

Wear was measured by weighing the specimens using a balance of the VLA-1 system, with accuracy of 1 mg. The specimens were thoroughly degreased prior to weighing. Results are shown in Table 1. It can be seen that boron-impregnated coatings and coatings of the second type (where the iron borides are located at the friction surface) have the higher wear resistance. Coatings of the first type have the lowest coefficient of sliding friction. Coatings of the first and second types have higher galling resistance, which can be explained by the presence of iron sulfides in their surface layers.

Gears equipped with the coatings described here were subjected to industrial tests under conditions of limited lubrication. The test results indicated that the wear resistance of gears with the second-type coatings is 1.6-2.1 times higher than that of conventional gears (made out of steel 45, after high-frequency heating and quenching).

CONCLUSIONS

1. Diffusion impregnation of steel with boron and silicon followed by sulfur impregnation produced two types of coatings. Coatings of the first type are formed at 1000°C when silicon forces iron boride off the surface, while coatings of the second type are formed at 900°C when silicon to some degree hinders boron diffusion to the surface. Sulfur diffusion does not affect the surface microstructure.

2. The wear-resistance and galling-resistance of parts subjected to diffusion impregnation with boron, silicon, and sulfur are 1.6-2.1 times higher than for parts subjected to boron impregnation alone.

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