УДК 621.9.048 DOI 10.36910/775.24153966.2023.75.7

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THE RELIABILITY OF THE GEARS OF THE PRESSURE BLOOMING MECHANISM

The operations of strengthening of cantilever intermediate and central gears, which are constantly in engagement, are considered, and methods of forming a protective layer obtained using composite saturating charges.
Keywords: *cantilever gear, reliability, surface hardening, hardness, wear resistance*

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ПІДВИЩЕННЯ НАДІЙНОСТІ ЗУБЧАСТИХ КОЛІС НАТИСКНОГО МЕХАНІЗМУ БЛЮМІНГУ

Розглянуто операції зміцнення консольних, проміжних та центральних шестерень, що постійно знаходяться в зачепленні, намічені методи формування захисного шару, отриманого з використанням композиційних насичуючих середовищ.
Ключові слова: *консольна шестерня, надійність, поверхневе зміцнення, твердість, зносостійкість*.

Statement of the problem.

Strengthening of parts of machines and mechanisms in industrial engineering for metallurgical production is to ensure the reliability and durability of parts of the blooming press mechanism. The wear resistance of the gears was increased using composite saturating media, which provide minimal hardening costs and significantly reduce energy consumption.

The design and principle of operation of the high-speed pushing mechanisms shown on the blooming consists of: screw drive and is driven by two flanged vertical electric motors with a capacity of 640 kW each. The cantilever gears are mounted on the motor shafts. The intermediate and center gears are constantly engaged, which ensures synchronized movement of the screws. In order to improve the reliability of gears, it is necessary to strengthen their surface layer, which is obtained with minimal thermo-kinetic load and increased surface hardness, which directly affects their wear resistance.

Analysis of the latest research and publications.

It is possible to change the properties of the surface in the necessary direction by various methods [1–4]. The existing methods of hardening can be divided into two kinds:

– application on the surface of a new material with the necessary properties;

– changing the composition of the surface layer of the metal, alloying with boron, titanium, tungsten and other elements that provide the desired change in properties.

In the first case, well-known coatings such as galvanic, chemical and others are used. Non-metallic materials are also applied to the surface of metal alloys.

In the second case, the surface layers of the metal are subjected to diffusion chemical heat treatment (CHT), which results in the formation of a new alloy composition on the surface of the product, different from the core of the product [5].

Purpose of the work is to process gears with minimal time for the formation of protective layers and thermo-kinetic load on the part to increase their reliability.

Materials and research results

The study was carried out on the samples of technical iron and steel (AISI/ASTM) 3140, C102,1045 and W108 in diameter of 20 mm and width of 10 mm. The composition of complex functionally active charge consisted of: energy composition, technical boron, aluminum ASD-1, aluminum oxide, silicon Cr1, titanium of ПТХ5-1 brand, tungsten powder and gas-transport agent, which was composed of ammonium chloride – NH_4CI and sodium fluoride – NaF.

Study of wear resistance of protective layers. conducted on the machine friction SMT-1 conducted according to GOST 23.224–86, DSTU 336–96 (GOST 30431–96) in terms of sliding friction with lubrication with automotive tractor oil (GOST 858 –78 without the additive) the scheme roller – pad, at

speed of counterbody (roller) 500 rpm. Counterbody was made of U8A steel with subsequent hardening and low tempering to hardness of 61 ... 63 NRC. The coatings were applied to the test piece.
After coating, the sample was quenched from temperature t_z = 820 ^{0}C in water and tempered at t_p. = 180 ^{0}C. The load on the test specimen, which remained stationary during the tests, was: P = 500N. During the first 30 minutes, the specimens were preconditioned and then tested for 5 hours.

The type and design of the pressing mechanisms depends on the purpose of the rolling mill [6]. For example, crimping and heavy plate mills are equipped with high-speed pressing mechanisms that lower or raise the top roll at speeds ranging from 10.0 (TLS sheet stands) to 300 mm/s (large blooms) during pauses between passes. On thin strip mills, in addition to setup, the pressing device regulates the gap between the rolls, preventing the rolls from being of different thicknesses along their length, which requires high accuracy of roll positioning during rolling. For this purpose, such mills are equipped with low-speed NMs. The speeds of the pressure screws do not exceed 0.1–1.0 mm/s for hot rolling quarto stands, 0.05–0.15 mm/s for cold rolling, and 0.005–0.8 mm/s for multi-roll mills. The high-speed pressing mechanism is designed to provide a large movement of the top roll up to 1600 mm.

On the 1300 blooming machine, the screws are driven by two flanged vertical electric motors with a capacity of 640 kW each. The cantilever gears are mounted on the motor shafts. The intermediate and central gears are constantly in gear, which ensures synchronized movement of the screws that move in the nuts mounted in the cage frame. To ensure that the cushion can be moved with one screw if necessary, for example, to eliminate roll skew, a hydraulic cylinder is used to disengage the satellite gear from the pinion gear. The advantages of the considered designs compared to worm gears are higher efficiency and ease of manufacturing gears and reliability in operation; the disadvantage is an increase in the height of the stand.

The blooming mill 1500 is equipped with a quick-acting pressure mechanism. Each pressure screw is driven by a 640 kW DC motor (700 rpm) through a gear i = 3.08, the speed of the pressure screw to 180 mm/s. The maximum force on the screw when rolling 12 MN. The total weight of pushing mechanisms of the working stand is 88.7 tons [7].

Synchronization of rotation of both pressure screws is provided by the presence of parasite gears, which are in meshing with the work gears; when adjusting the position of the upper roll one of the parasite gears is disengaged from the meshing by means of a hydraulic cylinder. At the top end of the pressure screw installed device for measuring wear on the thread of the pressure nut, parasite gears that are meshed with the work gears; when adjusting the position of the upper roll one of the parasite gears is removed from the meshing with the help of a hydraulic cylinder.

Powders of chromium oxide, aluminum oxide, silicon oxide, boron powder, aluminum powder, crystalline silicon, ammonium chloride, sodium fluoride were used to obtain siliconized coatings, alloyed with chrome, aluminum and boron.

The use of the silicon component (CrS) leads to a double ignition due to the beginning of the reaction of reduction of aluminum, silicon oxide. The use of CrS leads to higher tmax, the optimum is the introduction of 7.5% wt. of silicon or 25% wt. of CrS.

Пр With up to 8% wt. of crystalline silicon in the mixture, the coatings consist of iron borides (Fe, Cr, Al, Si) B and $(Fe, Cr, Al, Si)_2B$ doped with silicon.

As the silicon content in the mixture increases, above 15%, iron silicides appear in the layer, and the amount of high boride phase in the total layer thickness decreases. The formation of a borated layer begins due to the formation of a solid solution of boron, silicon, aluminum, and chromium in iron (α-phase).

The silicon content on the surface is 0.3–0.42%, and in the Fe_2B phase 6.7–7.3%. Carbon is pushed deep into the sample, which leads to the formation of boron carbide phase - boride cementite type $Fe_3B_{0,2}C_{0,8}$.

During borosilicification of 3140 and W108 steels a solid boride layer is formed that has practically no needle structure; below it equiaxed grains of Fe_2B evenly distributed in the layer of siliceous ferrite are located. As the amount of boron in the SHS mixture increases, the continuity of the layer decreases.

Eutectic silicized layers doped with chromium, aluminum, and boron were obtained at temperatures above 1250 ^{0}C. The change in the layer structure occurs due to the different cooling rate of the reactor. Changing the value of Vi obtained coatings, the microstructure of which has a characteristic honeycomb structure. At Vi = 15 the microstructure has a dendritic shape of herringbone type. The direction of the dendrite branches has a radial character, which is connected with the direction of the cooling flow. The chromium is predominantly located in the surface zone, aluminum along the needles of the Fe_2B boride. This arrangement of chromium and aluminum allows the coatings to resist well the effects of corrosive and oxidizing environments.

The microhardness of multicomponent siliconized layers alloyed with aluminum and chromium on technical iron and steel C102 is in the 7100–8200 MPa range, on steel 1045 and W108 it reaches 15000–16800 MPa, which is due to the formation of chromium carbide phases like $(Cr,Fe)_3C_2$

The surface microhardness of multicomponent boron-alloyed silicified layers is 20000–22000 MPa, which is associated with the presence of the FeB phase. Microhardness of the alloyed Fe_2B phase is 15000–16000 MPa. The obtained results indicate that silicon is displaced from the boride zone into the α – phase sublayer, doping only the Fe_2B phase. It has a stepped character that can be explained by the phase composition of the layer determined by the type of borides.

Microhardness of the multicomponent silicized layer alloyed with chrome, aluminum and titanium on technical iron and steel C102 changes from 1800–2700 MPa; on the surface of steel 3140, 1045 and W108 from 19000–21000 MPa. Microhardness of silicide $(Fe, Ti, Al, Cr,)_5Si_3$ is 9500–10500 MPa, and α-hard solution of titanium, silicon, aluminum and chromium in α – iron 2500–3700 MPa.

The microhardness on the substrate with high carbon content has a step character, which is determined by the phase composition of the layer in which the titanium carbide is observed. While on the substrates with lower carbon content it has smoothly decreasing character.

Microhardness of the multicomponent siliconized layers alloyed with chrome, aluminum and tungsten on the surface of technical iron and steel C102 makes 2500–3000 MPa, on 3140, 1045 and W108 12500–14000 MPa. The microhardness on a substrate with high carbon content has not so pronounced step character as at alloying with chromium, aluminum and titanium that is determined by lower hardness of tungsten carbide. On substrates with lower carbon content, the curve does not have pronounced gradient drops.

Wear resistance tests were carried out on specimens made of steel 3140, 1045 and W108 (t_n = 1000 ^{0}C, τ_v = 60 min) subjected to quenching (820–850 ^{0}C in water) and low tempering (200 ^{0}C) after saturation. For comparative analysis we used samples from those subjected to chemical treatment under steady-state isothermal conditions.

Tests on friction machine SMT-1 (sliding friction) showed that the best wear resistance of the considered coatings have siliconized layers, alloyed with boron, chromium and aluminum. Their wear resistance is 1.8 times higher than that of the samples with the base coating. The siliconized layers alloyed with Cr, Al have wear resistance 1.3 times higher, titanium 1.6 times higher and tungsten 1.1 times higher. As it is visible, wear resistance for the considered pairs of a friction and test conditions depends on microhardness of a surface layer.

Tests on the MT-5 friction machine (friction with impact) showed that the best wear resistance has siliconized layers, alloyed Cr, Al and W, which wore 1.6 times less than the base coating. Alloyed Cr, Al 1.5 times, Cr, Al and W 1.1 times, and alloyed Cr, Al and Ti 1.2 times less. As can be seen, under this test scheme, the wear resistance of contacting pairs is determined by the reduced total score of brittle fractur.

Conclusions.

1. The microhardness of multicomponent silicized layers obtained under conditions of thermal self-ignition on the gears of the pressure mechanism increases with increasing carbon content in the substrate material, which is associated with the formation of carbide phases like Cr_3C_2, (Ti,Fe)C. So at alloying of siliconized layers with boron the surface microhardness makes 20000–22000 MPa that is connected with formation of phase FeB.

2. It was established that alloying of siliconized layers with chrome and aluminum increases their wear resistance 1.3–1.5 times; with chrome, aluminum and boron – 1,1–1,4 times in comparison with a base article. Wear resistance when tested on the CMT-1 friction machine for the friction pairs under

consideration depends on the microhardness of the surface layer. Under impact test conditions on the MT-5 friction machine the wear resistance is determined by the brittleness of the layer.

3. In a series of studies, the highest value of total brittle fracture score Z_{100} is observed for multicomponent siliconized layers alloyed with chromium, aluminum and boron. In comparison with the basic coating, the reduced total brittle fracture score Z_{100} of the developed coatings is 1.3–1.5 times lower, which is explained by a shorter time of temperature influence and complex alloying of the formed phases.

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