Methods of improvement of exploitation features of carbon and low-alloyed steels.

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Abstract. Wear resistance is the main characteristic that can define detail’s endurance in application environment. To assess the endurance capability of layers strengthening by low-temperature cyanide carburizing, the methods that replicates friction and load conditions, typical for exploitation of details strengthened by cyanide carburizing, were applied.

Introduction
The basics of metal thermal processing technology - electro physical and electrochemical processing, require close research of internal and external processes at the stage of developing strengthening technologies, especially on the creating of physical and mechanical features with taking into account real machine's details' and technical equipment’s exploitation conditions.

Present practical guidelines for choosing strengthening technologies are separated. Therefore, junior specialists are not able to recommend a defined expedient strengthening technological process that can successfully compete in the world markets [6].

Moreover, there is no entrenched algorithm to make this. There are different sizes of details, different received loads, working environment and exploitation temperatures.

Lack of efficient technologies forces leading Russian oil, gas-producing, oil refining, chemical and transport manufactures to deny low-quality products in order to use foreign manufactures' products.

Russian manufacturers establish factories outside the Russian Federation's territories because of special features of Russian government politics concerning the machine industry sector.

National and foreign experience of manufacturing and exploitation of various machine's types shows extensive use of methods of surface strengthening treatment of machine details by carbonization, nitriding, nitrocarburizing, laser and plasmatic processes, high frequency current tempering, surface plastic deformation, using endurance coverings, etc.

Every well-known method has its own advantages and disadvantages that is why the current choice becomes difficult. Taking into consideration above-mentioned, there is the necessity of discovering a method that will increase exploitation characteristics of problem surfaces.

Results and Discussion
As a result of electric current and pressure impact, depending on friction and loss conditions, metal surfaces' endurance capability is rising 2-6 times. In addition, the 30-70% percentage point increase in fatigue resistance and total running time of working under cyclic load details is observed. Back-to-back endurance is rising too, for example, the 52100 steel has this characteristic 1.8 - 2 times higher in comparison with the steel strengthened by nitro carburizing.
This method allows one to get the strengthening of external and internal layers of steel details' cylindrical and plain surfaces to a depth of 0.2 mm with surface's microhardness 4-time increase and simultaneous improvement of undulation in 1-2 levels. It also allows the strengthening of details' surface layer to a depth of 0.2-5 mm with subsequent surface grinding and reeling onlay, the strengthening of toothed gearwheels, castellated shafts, internal combustion engines' sleeves, piston rings group, worm gears' thread, large shafts' journals. Electromechanical reactivation of treated surface sizes occurs due to plastic hot heading of some metal volume from the workpiece range. Combined treatment of voltage concentrators includes electromechanical stress relieving and subsequent surface deformation. Plasmatic surfaces' processing forming amorphous and nanostructure of strengthening elements and adhesion and cohesive coverings' endurance increase till the level of solid materials.

Such specifications as long life, reliability, constant functional features, readiness for use in given conditions are required for the machine details.

At the same time details, connection joints, and products themselves made from metals and alloys are required to have necessary physical mechanical features for providing above-mentioned and other exploitation characteristics.

The best conditions for diffusion of nitrogen and carbon into steel and for forming a zone of this carbonitride several times as thick result from the external zone of cyanided and nitrocarbonized layers that represent hexagonal carbonitride $\varepsilon$ with the increased homogenic area compared with all others nitrides and carbonitrides in the Fe-C-N system. [7]

That is why, only a deep layer made from the carbonitride is important and matched for practical use. For example carbonitride with 0.050 mm depth was made in 2 hours at 650°C, but the cementite type carbonitride and $\gamma'$-depth phase — approximately 2 times faster. Phase's $\varepsilon$ microindentation hardness is $(1000...1200) \text{ H$\mu$}$. 

There is a nitrogen-carbon layer under the carbonitride layer with the depths of 0.015...0.020 mm, the microindentation hardness of which decreases to 300...450 H$\mu$. Due to higher plasticity of austenite, mainly the austenite structure under the carbonitride layer $\varepsilon$ levels inner forces and promotes good connection between the solid carbonitride layer and the basic layer [2].

Endurance is the important characteristic that defines machine details' longevity. To assess the endurance capability of layers, strengthened by low-temperature cyanide carburizing, the testing methods that replicate friction and load conditions typical for exploitation of details, strengthened by cyanide carburizing, were applied.

Mainly there are carbon and low-alloyed steel details that are used without lubricants; as a result, oxidation processes on friction surfaces are appearing. Produced carbonitride structures isolate details' friction surfaces and prevent from hot holding the metal of details with or without any lubricant materials [1].

In real life exploitation, solid abrasive bits get in the friction zone because of non-effective isolation of machine friction joints from external environment that contains abrasives (dust, grain, etc).

Wear products of friction surfaces - oxidized and hammer-hardened fragments of surface metal layers, destructed during friction and having sufficiently high hardness, can act as abrasive particles. In the process of steel samples' probation under dry sliding friction conditions, unit loads are set on contacting surfaces of such dimensions, which would provide free relative transition of the sample and the counterbody (without drawing in). And, at the same time, it would provide intensive wear-out of the sample's surface that can be precisely defined for a relatively short time of probation.
Figure 1. Wear of cyanided steel 5135 under small unit loads: cyaniding temperature: 1-560°C; 2-600°C; 3-760°C

Figure 1 illustrates the dependence between small unit loads and wear intensity. In the small unit load zone, the wear increases when pressure rises and such situation is well-noticeable by the example of steel, cyanided at 760°C.

When increasing unit loads by more than 0.15 MPa, in all cases there is the reduction of wear intensity what typical for loads up to 0.35...0.40 MPa. With further pressure increase, the wear intensity remains constant at a relatively low level. The discovered wear reduction of the cyanided surface under the conditions of increased unit loads in the range of 0.05...0.15 MPa can be explained by self-hardening of the friction surface when in the considered range of pressures, the reserve of metal plasticity is retained.

Figure 2. Wear of cyanided steel 5135 under large unit loads: cyaniding temperature: 1-560°C; 2-600°C; 3-760°C
The wear rate under these conditions is defined by hardening sensibility. Surface metal layers lose their plasticity fast, and the ultimate hardening is achieved fast and wear reduces.

The load increase has no influence on the strengthening process of the already hardened surface layer in the high pressure area. Frictional force causes fatigue phenomena, which entail cracks in the surface layer and separation of its fragments from the main metal body (figure 2) [4].

Conclusion
In these conditions, dependence of wear on unit loads on the friction surface is of practically directly proportional character. The wear tests of cyanided layers of 1042 and 5135 steels' samples have the qualitative similarity. However, the endurance of the cyanided 1042 steel on average is lower than that of the cyanided 5135 steel. Relatively low cyaniding temperatures (550...650°C) provide minimal wear of cyanided layers both in the 5135 steel and in the 1042 steel. Increasing the cyaniding temperature higher than 650°C causes an intensive increase in the wear, reaching the 6-10-fold value at the cyaniding temperature of 800°C. Such course of dependences of wear on the cyaniding temperature is explained by creating hard antifriction-able carbonitride cover ε on the surfaces of 1042 and 5135 steels making wear intensity decrease under conditions of dry friction. The depth increase of the carbonitride cover, obtained at cyaniding temperatures (600...650) °C, promotes wear minimization of the diffused layer. The increase of the cyaniding temperature up to 700°C and higher results in the fact that in diffused layers replacing of both steels, the carbonitride is replaced by the cement-type carbonitride and the martensite-austenite matrix [3].

Constant and rather high wear resistance of cyanided steels is retained in a wide range of pressures, but with the increase of pressure over (4...5) MPa, the wear increases intensively, reaching catastrophic intensity while scuffing [10].

Details made of steels 1042 and 5135, cyanided at different temperatures, show that the cyaniding temperature has great influence on resistance of surface layers to scoring and seizure, although, it is necessary to note that cyaniding improves significantly scoring resistance properties in all cases. Samples of steels 1042 and 5135 without cyaniding (after heat hardening and low-temperature tempering) obtained first traces of scoring under a pressure of about (1.5...2.5) MPa. While in cyanided samples, the value of this characteristic at low temperatures does not descend below 4 MPa. Samples of both steels, cyanided at 650°C, have the best scoring resistance properties. The maximum thickness of carbonitride cover ε on the surface, and the maximum hardness of the cyanided layer correspond to this temperature. Therefore, it is obvious that high resistance of cyanided samples to seizure is conditioned by the presence in the surface layers structure of a big amount of carbonitrides (particularly ε-carbonitride).

Good abrasion resistance and resistance to seizure of carbonitrides under dry friction conditions allow one to recommend cyaniding at the temperature of (640...650)°C for strengthening details, operating in the most unfavorable conditions of wear-and-tear.

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