Method of thermal treatment of saw disk teeth of fiber-processing machines by laser quenching

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Abstract. The article covers the increase of hardness of the surface layer (h=25 microns) with a soft core (h=100-300 microns) of the teeth of the saw blades of the cylinders of fiber processing machines. Assigned task of hardening the surface layer of the teeth of the disc saw of the cylinder of fiber-processing machines is solved by thermal and chemical-thermal treatment of the teeth of the disc saw in a vacuum chamber by pulsed electron beams, laser processing after ion nitriding.

1. Introduction
One of common thermal treatment techniques is laser-quenching technology. The main point of the method chosen for this work is that a highly concentrated energy source – the laser beam as a source of local thermal hardening (quenching) has significant technological and technical-economic advantages in comparison with traditional technologies of volumetric or furnace thermal and chemical-thermal treatment.

Considering this method from a scientific point of view, laser surface hardening significantly eliminates the disadvantages inherent in volumetric thermal quenching, chemical-thermal treatment, and at the same time opens up new potential technological possibilities in hardening the surface layers of machine parts and mechanisms [1].

The state-of-the-art level of development of laser technique and laser technologies allows to consider lasers as a convenient, economical and reliable tool for surface heat hardening of a wide range of mechanical engineering parts.

The effect of the laser beam on the surface of steels leads to a comprehensive improvement in the physical-chemical and mechanical properties of the surface layer, which can be seen in a higher dispersion and isotropy of the structure of the hardened surface layer, an increase in micro-hardness, heat resistance, corrosion resistance, and endurance [2].

The advantages of laser hardening can be classified into several types: technological, energy, operational, environmental.

The laser thermal hardening (quenching) method of surface layers has a number of technological advantages compared to traditional heat treatment technologies, which can be seen in the following properties [3]:

- After laser hardening, a technological operation of tempering is not required;
• Absence or minimal residual deformation;
• Retention of geometric dimensions of the part within the tolerance zone during laser quenching;
• Increasing the hardness of the hardened layer;
• Increased endurance;
• Minimum heat input into the work piece;
• Local impact on the hardened surface;
• Lack of coolants;
• Easy to automate and robotize;
• The duration of the thermal hardening cycle is reduced.

2. Materials and methods
A number of methods of heat treatment of plate products, in particular teeth of saw discs are known [4]. At the same time, quality of cutting surface of saws (teeth) depends both on heating of surface and on quenching liquid.

There is also a method of quenching the teeth of saws in industrial oil [5]. However, the use of oil leads to the risk of fire, smoke content of workplaces, environmental pollution, the possibility of cracking on the surface and different structure in the work piece, which reduces the resistance of saws, as well as increases (expands) operating costs during heat treatment.

A method of heat treatment of the teeth of disk saw, including heating the teeth for quenching and tempering, cooling, while heating the teeth of the saw for quenching and tempering is carried out by high frequency currents supplied from the generator to the inductor, while heating under hardening is carried out at certain values of the grid current and the anode current strength is 1.6 A and 7.5 A, respectively, the anode and loop voltage are 9.0 V and 0.48 V, respectively, to 820-850°C and cooled in a polyacrylic iron salt at a temperature of 20-40°C, tempering carried out at current values of the grid and the anode, respectively 0.5 A and 2.5 A, the voltage of the anode and the circuit, respectively, 3.5 V and 0.18 V at 260-270°C, the depth of tooth entry into the inductor is 2.0-2.5 mm and the peripheral speed of rotation of the disk is 13.75 mm/s [6].

3. Results and discussion
The main disadvantage of the known methods of processing disk saws is the inability to provide the required hardness of the surface layer at the softer core of the teeth of the cylinder disks of fiber-processing machines.

The objective of the research is to increase the hardness of the surface layer (h = 25 microns) at a soft core (h = 100-300 microns) of the teeth of the disk saw of the cylinders of fiber-processing machines [7].

The task of hardening the surface layer of the teeth of the disk saw of the cylinder of fiber-processing machines is solved by thermal and chemical-thermal treatment of the teeth of the disk saw in a vacuum chamber by pulsed electron beams, the teeth of the disk saw by laser processing after ion nitriding [8].

The main point of the method of heat treatment of teeth of disk saw is that the surface layer of the saw blade is subjected to ion nitriding in a vacuum chamber, heating to 6500°C in argon atmosphere at a pressure of 0.4 Pa with simultaneous ion surface cleaning, ion-plasma nitriding is carried out at a temperature 620-690°C in pure nitrogen for 1 hour in a gas medium of N2 80% and Ar 20% P=0.3 Pa with arc current of Ia=80 A and additional current of the anode Ias=75 A, while the table with the disk saw is supplied with a bias voltage of U = −700 V. After nitriding, the disk saw is slowly cooled to room temperature in the chamber, the teeth of the disk saw are processed along the entire length with a continuous laser beam along the side surface (around the perimeter), 8 full turns with a pitch of 0.5 mm, with a power of 100 W, the speed of feed and processing 1.6 m/min from a distance from the laser head to the surface of the saw 5-6 mm [9].

The aimed technical result is achieved by the fact that after ion nitriding the highly concentrated energy source – the laser beam as a source of local thermal hardening (quenching) has significant
technological and technical-economic advantages compared to traditional technologies of volumetric or furnace thermal and chemical-thermal treatment. Considering this method from a scientific point of view, laser surface hardening largely eliminates the disadvantages inherent in volumetric thermal hardening, chemical-thermal treatment, and at the same time opens up new potential technological possibilities in hardening the surface layers of machine parts and mechanisms. This method, in addition to hardening the teeth themselves, allows getting high hardening of the crown of the disk. In the zone of laser heating after cooling, a highly dispersed martensite with increased hardness is formed. The hardness varies insignificantly with respect to the depth of the light zone h=25 microns and amounts to 925-990 HV 0.05 kgf/mm², and at a depth h=100-300 microns amounts to 890-905 HV 0.05 kgf/mm². The hardness of the light hardened zone is slightly lower than with laser hardening without nitriding. This is explained by the presence of nitrogen, which lowers the point of martensitic transformation and increases the amount of residual austenite. The hardness in the heating zone at a depth of 10 microns was 1015 HV 0.05 kgf/mm², and at a depth of 50 and 100 microns 1009 HV 0.05 kgf/mm² and 970 HV 0.05 kgf/mm² respectively. A needle-like structure of apparently troostite is fixed below the light zone [10].

Figure 1 shows the hardening of the teeth themselves, allowing obtaining high hardening of the crown of the disk. In the laser heating zone after cooling (light zones), highly dispersed martensite with increased hardness is formed. The hardness varies insignificantly with respect to the depth of the light zone h=25 microns and amounts to 925-990 HV 0.05 kgf/mm², and at a depth h=100-300 microns amounts to 890-905 HV 0.05 kgf/mm². The hardness of the light hardened zone is slightly lower than with laser hardening without nitriding. This is explained by the presence of nitrogen, which lowers the point of martensitic transformation and increases the amount of residual austenite. The hardness of the dark etching zone is in the range of 320-350 HV 0.05 kgf/mm². This is also lower than in the case of the hardening method by laser hardening without nitriding, but at a sufficiently high level. This is explained by the presence of nitrogen in this zone and the formation of a sorbitol structure due to a change in the critical rate of steel cooling.

Figure 1. Nitrided surface of a disk saw of a fiber-separation machine type 5DP-130. a) the sample with a nitrided cover and laser quenching, b) with a nitrided cover and subsequent laser quenching, c) with a nitrided cover without laser quenching.
Figure 2 shows the image after laser quenching, where the zone heated with a laser beam (light areas) with a depth of 200 microns and a length of 400-450 microns is clearly identified. At a relatively large magnification, the structure of extremely dispersed martensite typical to laser quenching is visible. This indicates a cooling rate of the heating zone, sufficient for the formation of martensite after exposure to a laser beam. Cooling is carried out by quickly removing heat to the underlying areas of the disk saw.

![Figure 2. The structure of the crown of the disk saw after laser quenching.](image)

Figure 3 shows the hardness of martensite in the heating zone at a depth of 10 microns - 1015 HV 0.05 kgf/mm², and at a depth of 50 and 100 microns is 1009 HV 0.05 kgf/mm² and 970 HV 0.05 kgf/mm², respectively. Below the light zone (dark-etching zone), a needlelike structure of apparently troostite is fixed. This is indicated by the measurement of the thickness of the disk (see table 1).

![Figure 3. The needlelike structure of troostite after laser quenching.](image)

**Table 1.** Distribution of micro-hardness of disk saw manufactured according to the recommended method before laser quenching.

| The distance from the surface, microns | Hardness HV 0.05 kgf/mm² |
|---------------------------------------|--------------------------|
| 150                                   | 478                      |
| 200                                   | 440                      |
| 300                                   | 440                      |
| 400                                   | 420                      |
| 500 (core)                            | 400                      |
4. Conclusions
Required hardening of disk saw in surface layers after laser treatment is achieved without loss of hardening in thickness of disk due to formation of troostite. This also indicates the heating of the inner layers through the thickness of the disc after laser heating of the surface.
Method allows obtaining required hardness of surface layer up to required depth of teeth of disk saws at sufficiently viscous (less strong) core of saw teeth.

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