WAYS TO INCREASE THE WEAR RESISTANCE OF WORKING SURFACES OF GEAR TRANSMISSIONS.

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ARTICLE INFO

ARTICLE HISTORY:
Received:09.06.2025
Revised: 10.06.2025
Accepted:11.06.2025

KEYWORDS:
Gear, wear, surface treatment, heat treatment, nitrocarburization, hardness, strength, friction, contact stress, surface coating.

ABSTRACT:

This article studies methods for increasing the wear resistance of gear surfaces. Methods for increasing surface strength through surface coatings, heat treatments, chemical-thermal treatments, and modern technologies are analyzed. The contact forces, friction, and wear processes occurring on the surface of teeth under the influence of heat are covered based on a scientific approach. Optimal processing methods are determined based on experimental results.

Login: In mechanical transmission systems, gears are one of the main elements for transmitting motion and torque from one shaft to another, and their reliable and long service life determines the efficiency of the entire mechanism. One of the most common problems in gear transmissions is the intensive wear of the working surfaces. Wear is the gradual loss of part of the substance from the surface of the material under the influence of friction, contact pressure, vibration and temperature. The loads that arise in gear transmissions are local in nature, especially in the contact zone of the tooth tip and the working surfaces, sharp stresses and high temperatures appear. This leads to material fatigue, cracking of micro-coatings, loss of smoothness and, as a result, failure of the entire transmission system. To solve this problem, various materials, design solutions and surface strengthening technologies have been developed in mechanical engineering. In particular, in the production of gears, high-strength and high-strength steels, induction heating, carburizing, cementation, nitrocarburizing, surface coating, laser and plasma processing are used.

By increasing the surface hardness, it is possible to slow down the wear process and increase the service life of gears. In particular, modern technologies such as laser hardening, ion plasma coatings, nanocomposite coatings are used to increase wear resistance several times. Such treatments not only increase the surface hardness of the material, but also improve its microstructure, friction coefficient and thermal stability. Studies conducted in recent years have shown that if the tooth surface treatment technology is not chosen correctly, even the best material can quickly fail. Therefore, it is necessary to provide high-tech processing of the working surfaces of gears in production, ensuring optimal geometry and mechanical properties. The type, depth, heat treatment, accuracy of the processing method and changes in temperature-state significantly affect the quality of the final product.

Among the methods for increasing surface strength, chemical-thermal treatments (for example, cementation, carburization, nitrocarburization) are widely used. With the help of these methods, only the working surfaces of the gears are hardened, while the internal structure remains flexible without becoming brittle. This contributes to optimal stress distribution. On the other hand, vacuum coatings such as TiN, CrN, AlTiN, as well as modern surface engineering methods such as laser and electron beam processing play an important role in surface strengthening. Such technologies create very thin, but very hard and wear-resistant layers on the surface of gears. These layers have the properties of reducing friction, improving temperature distribution, and slowing down oxidation and corrosion processes.

It is worth noting that the operating conditions of gears (speed, load, vibration, temperature), the material used, the processing technology and the quality of the lubrication system directly affect the level of wear resistance. Analyses show that it is the condition of the surface, its structure, hardness and friction coefficient that determine the service life of the teeth. Therefore, the article analyzes the existing technological solutions for increasing the wear resistance of gear surfaces, their effectiveness, advantages and disadvantages, based on the results of experimental tests. The goal is to identify effective, economically acceptable, high-quality processing methods that can be used in practice and identify opportunities for significantly increasing the wear resistance of gears.

Research and method: During the research, anti-wear treatments were studied on samples of gears made of 20X and 40X steels, which are widely used in automotive and industrial transmissions. The following treatments were applied to the samples:

- Normal grinding (control group);
- High-frequency induction heating;
- Nitrocarburizing;
- Laser hardening;
- TiN-based vacuum coating.

Wear tests were carried out on the samples prepared in each group on a special tribometric stand. A shaft made of tempered steel was used as a friction pair. The test duration was 10 hours, the pressure was 400 N, and the rotation speed was set at 1000 rpm.

After the test, the surface condition of the samples was analyzed using a microscope. The surface hardness was measured by the Vickers method, and the wear depth was measured using an optical microscope.

Below is a summarized table of test results:

Processing type	Surface hardness	Wear depth
Polished	220	18,2
Induction heated	560	9,4
Nitrocarburized	720	6,8
Laser hardened	640	5,2
TiN coated	840	3,1

Table -1. Wear depth and surface hardness by type of processing.

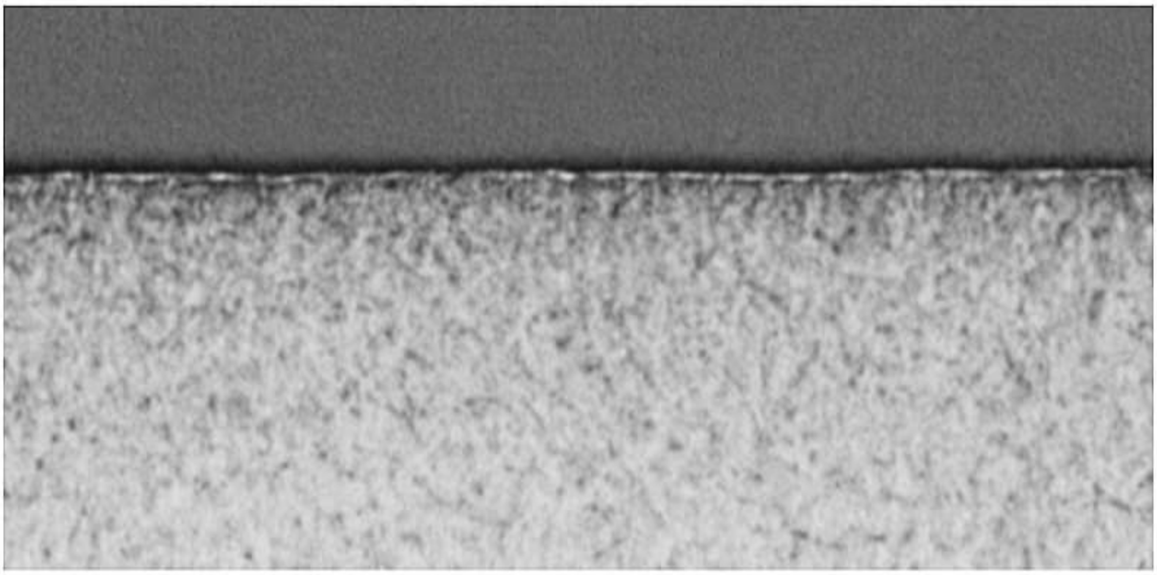

Figure 1. Microstructure of tooth surfaces subjected to various treatments.

Note: The figure shows the precision and uniform structure of the TiN coated surface layer.

Results and discussion: The test results showed that the simply ground samples wore out quickly and had a low hardness index. A martensite structure appeared on the surface of the samples that underwent induction treatment, and their hardness increased significantly. Nitrocarburization formed a diffusion layer on the tooth surface, which showed good resistance to abrasive forces. Laser processing increased the structural density of the surface and created a smooth structure. TiN coating showed high hardness and the highest wear resistance.

The analysis shows that with the help of modern surface treatments, the service life of the working surfaces of the gear can be increased several times. In particular, with the help of vacuum coatings, the friction resistance and corrosion resistance of the metal surface also increase at the same time. TiN coating and nitrocarburization can be recommended as the most effective methods against wear. However, the application of each method should be selected depending on technological capabilities, cost and operating conditions.

The analysis shows that, although traditional methods (induction heating, nitrocarburization) give certain results, their effectiveness depends on the density, depth of the surface layer and its adaptability to operating conditions. In addition, their environmental safety, energy consumption and technological complexity are also important factors. Therefore, it is necessary to choose a technologically and economically optimal solution in production. TiN coating, while having high efficiency, requires expensive technological equipment. Laser technology is very convenient for automated lines, but is not always universal. This emphasizes the need to choose the appropriate surface treatment for each case based on the results of the research. In general, in order to increase the service life of gears and reduce wear, it is necessary to ensure the harmony of material selection, surface treatment and experimental control.

Conclusion: As a result of the conducted research, it was found that modern surface treatments play an important role in increasing the wear resistance of the working surfaces of gears. The analysis showed that, although traditional treatments (induction heating, nitrocarburization) significantly increased the hardness of the tooth surface, laser treatment and vacuum coatings based on TiN were able to increase the wear resistance of the surface even more effectively. In particular, the TiN coating was distinguished by the highest hardness (840 HV) and the lowest wear depth (3.1 microns). Laser treatment, on the other hand, provided a dense structural state of the surface, increasing the level of strength and temperature stability. These results mean that increasing the surface hardness alone is not enough - the microstructure of the surface, the coefficient of friction and heat distribution are also important factors. The correct choice of surface treatment technology, its adaptation to the load and operating conditions are very important in increasing the service life of gear elements. At the same time, it is worth noting that high-performance technologies - laser processing, ion-plasma coatings, vacuum coatings based on TiN, CrN - are widely used in industrial production. These treatments increase the service life of gears, ensure transmission efficiency, reliability and technological stability. Also, these technologies are suitable for use in modern automated production systems and are environmentally friendly. It follows that the use of modern surface treatments to increase the wear resistance of gears is the most optimal way not only technologically, but also economically and environmentally. Future research should continue in the direction of developing combined versions of these technologies, further extending the service life of microcoatings and maximizing surface adaptation to real operating conditions.

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