# Characteristics of Titanium Nitride (Tin) in Increasing the Wear Resistance of High-Carbon Steel Alloys

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Abstract: In this article, the effect of titanium nitride (TiN) compound on the wear resistance of high carbon steel alloys is studied. In this case, TiN is added into the alloy as a microparticle modifier, based on improved technology, for improving the wear resistance of the high-carbon steel alloys. During the research, periodic heat treatment was also carried out to further improve the mechanical properties of wear resistance alloys obtained by casting. The device IS.1053-PLMi metallographic microscope was used to analyze the images of the microstructures in the selected alloy. In the technological process of melting the alloy, the resulting wear resistance and hardness tests of samples with 0, 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6% of TiN added to the alloy and subjected to periodic heat treatment were conducted. In particular, samples containing 0.3% and 0.5% TiN, which showed austenite-trostite at the beginning of the experiment and pearlite-ferrite, pearlite-martensite and a small amount of bainite at the end of the experiment, achieved high wear resistance and hardness. Mechanical wear resistance tests were performed on a tribometer. The main goal of the research process is to introduce the technology of obtaining wear resistant wheel details in a casting method, which improves the internal and external transportation capabilities of large production enterprises, and as a result, the annual economic value of the enterprise is increased by increasing the stagnation period of the wheel detail operating under friction conditions in the enterprise. The stagnation period of the detail has been increased by 2.59 times.

## 1 INTRODUCTION

Among the FeC alloys, one of the most widely used alloys is the high carbon steel alloy, which is generally valued for its mechanical properties such as long-term wear-resistance and hardness. Such steel alloys contain on average C 0.60 - 1.4%, and in extremely high (extreme) cases C is 1.4 - 1.8% and 0.90 - 1.20 % Mn will be available up to. Such an alloy is thermally and thermomechanically processed to form microstructures consisting of uniformly dispersed grains of spherical ferrite, continuous proeutectoid solid carbides evenly distributed throughout the volume. Such microstructures form a superplastic, but also provide high wear resistance, hardness and low ductility. Chromium, manganese and titanium elements and their ferroalloys are used in many ways to improve the mechanical properties of high-carbon steel (Cr, Mn and Ti). These, in turn, positively affect the alloy's mechanical properties, such as hardness, wear resistance, and corrosion resistance (Chidi et al., 2022). Although high-carbon

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steels have good wear resistance, the demand for this property has increased. This led to the advancement of research aimed at improving the wear resistance of steel alloys around the world to a new stage, and scientists of all leading countries of the world conducted research for the same purpose. In particular, the well-known British metallurgical scientist R.W. Bebbington studied the effect of some ferroalloys, especially ferroboron and ferrotitanium on steels and the methods of adding them, and made the following suggestions for improving wear resistance. In the production of wear-resistant steel castings, titanium is highly reactive with elements such as carbon (C), oxygen (O), nitrogen (N) and sulfur (S) when introduced independently, and no any difficulty in enriching the alloy composition when introduced as a ferroalloy (FeTi). Initially, ferrotitanium was converted into a eutectic alloy consisting of FeTi40 (40% titanium) and FeTi70 (70% titanium) obtained in aluminothermic processes, and the influence of the amount of titanium in FeTi on the casting was studied. It was found that ferroalloy has the lowest melting point of all alloys when titanium is exactly 70% (Bebbington, 1992, Ernest, 1995). According to kazakh metallurgical scientists V.A. Golubtsov, L.G. Shubya, R.G., during out-of-furnace processing of the alloy, after segregation of the alloy, S was in the range of 0.001-0.003%. At the lowest cost of machining, it was achieved when S in the alloy was 0.009-0.012%, and the damage of S, P was neutralized by modifying the alloy with hard compounds in the form of carbides and nitrides. In this process, the sulfur content was reduced, thereby shortening the alloy's machining time. By treating with inert gas in the furnace, by accelerating the diffusion of the alloy, sulfur in the alloy decreased the solubility of hydrogen and prevented the appearance of cracks in the casting. A quality structure was formed in the alloy by modifying the alloy in the cavity. In this case, the influence of modifiers (WC, TiC, TiN, CrC,) main element on steel casting was studied in advance (Golubtsov et al., 2006; Bykov et al., 2006).

## 2 MATERIALS AND METHODS

The Scientific and practical research work was carried out on high-carbon steel 65Г (ГОСТ 14959-2016) alloy. This steel alloy is analogous in composition to steel 1066, 1566, G15660 alloys according to international ASME and AISI standards, and to 65Mn alloy according to JUDE, and such alloys are usually used for various wheels, springs, gears, thrust devices, brakes parts that require wear resistance and rigidity, such as friction discs, bearing housings, are manufactured using casting and pressure treatment methods (Kholmirzaev et al., 2024). In this case, TiN was introduced in the form of microparticles in the form of microparticles at intervals of 0.1-0.5% to the alloy with the usual composition by means of modification outside the furnace (Rao et al., 2022).

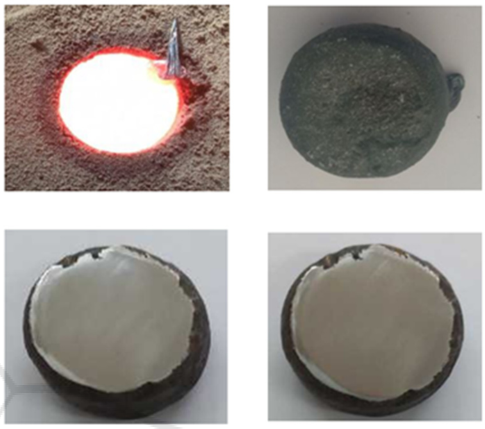
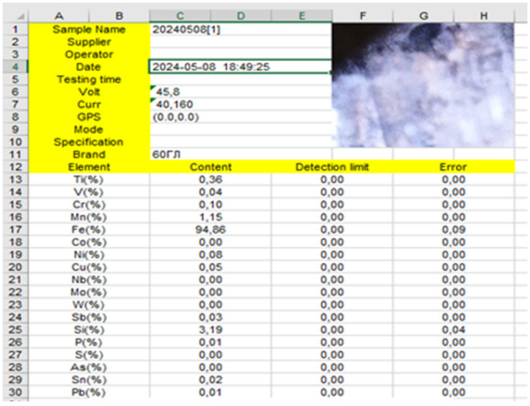


Figure 1: Modified and recast samples.

Titanium nitride is a hard and wear-resistant material with strong crystallinity and is commonly used as a modifier in various mechanical alloys, steel, cast iron and aluminum components to improve the alloy's volume and surface strength properties. Titanium nitride is yellow-brown in appearance, but when compressed under pressure or mechanically treated, it turns golden.

The density is 5.44 kg/cm3, and the hardness index of individual parts of the microstructure of the material is 2050 kgj/mm2, and the melting temperature of the material is 2930 ˚C. In the study, steel 65Г alloy was melted in an induction furnace. CaCo was used as flux during melting. In the last 15 minutes of liquefaction, Mn 1.2 % was added, taking into account the burning indicators. Out of the furnace, 5 different amounts (0.1-0.2; 0.2-0.3; 0.3-0.4; 0.4-0.5; 0.5-0.6 ) modified with microparticles of TiN. Modified and conventional samples were cast in the same sand-clay molds for comparison. The overall obtained chemical composition is shown in Figure 2. The chemical composition was determined on the Explorer 5000 device. Grinded and polished samples are shown in Figure 1.



| Element | Content | Detection limit | Error |
|---|---|---|---|
| Sample Name | 20240508[1] | | |
| Supplier | | | |
| Operator | | | |
| Date | 2024-05-08 18:49:25 | | |
| Testing time | | | |
| Volt | 45,8 | | |
| Curr | 40,160 | | |
| GPS | (0.0,0.0) | | |
| Mode | | | |
| Specification | | | |
| Brand | 60ГЛ | | |
| Ti(%) | 0,36 | 0,00 | 0,00 |
| V(%) | 0,04 | 0,00 | 0,00 |
| Cr(%) | 0,10 | 0,00 | 0,00 |
| Mn(%) | 1,15 | 0,00 | 0,00 |
| Fe(%) | 94,86 | 0,00 | 0,09 |
| Co(%) | 0,00 | 0,00 | 0,00 |
| Ni(%) | 0,08 | 0,00 | 0,00 |
| Cu(%) | 0,05 | 0,00 | 0,00 |
| Nb(%) | 0,00 | 0,00 | 0,00 |
| Mo(%) | 0,00 | 0,00 | 0,00 |
| W(%) | 0,00 | 0,00 | 0,00 |
| Sb(%) | 0,03 | 0,00 | 0,00 |
| Si(%) | 3,19 | 0,00 | 0,04 |
| P(%) | 0,01 | 0,00 | 0,00 |
| S(%) | 0,00 | 0,00 | 0,00 |
| As(%) | 0,00 | 0,00 | 0,00 |
| Sn(%) | 0,02 | 0,00 | 0,00 |
| Pb(%) | 0,01 | 0,00 | 0,00 |

Figure 2: Chemical composition determined in the Explorer 5000 device.

## 3 RESULTS AND DISCUSSION

The wear resistance tests were carried out on the samples obtained by the casting method (Tursunbaev et al., 2023a; Tursunbaev et al., 2023b). Wear resistance was determined based on the weight of the sample and the formation of geometric dimensions within the unit of time. A Micron-tribo wear testing device was used for wear testing (Fig. 3a.).

a b

Figure 3: a) Micron-tribo; b) Scheme of testing on the Micron-tribo device.

Wear-resistance of the samples was determined in two different procedures. In forward and back and circular motions (Fig. 3b.). The results of the test for resistance to wear are shown in Table 1.

After the wear test, the samples were polished using a grinding and polishing machine to prepare polished section. Microstructural analysis of the polished samples was carried out by observation using an optical metallographic microscope. Optical images and analysis of the microstructures are presented in Figure 4.

Table 1: The results of the test on resistance to wear.

| № | Sample alloys | The total amount of wear of samples (g/100 hour) |
|---|---|---|
| 0 | Steel 65Г | 5,55 |
| 1 | Sample 1, TiN 0,1 % | 3,70 |
| 2 | Sample 2, TiN 0,2 % | 3,01 |
| 3 | Sample 3, TiN 0,3 % | 2,20 |
| 4 | Sample 4, TiN 0,4 % | 2,16 |
| 5 | Sample 5, TiN 0,5 % | 2,14 |

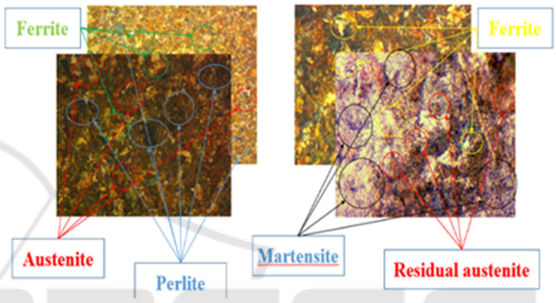



Figure 4: Alloy microstructures.

## 4 CONCLUSIONS

Analyzing the results of practical studies, the following final conclusion can be drawn: TiN, like all carbon steels, has a positive effect on the mechanical properties of high-carbon steel alloys, especially wear resistance and hardness indicators. In this case, the nitrogen contained in TiN introduced in the form of micro-powder at a high temperature in the furnace formed a three-phase solid layer with Fe, Cr, Mn, and a small amount of Al, which are the main components of the alloy. Titanium nitride created new centers of crystallization in the alloy by itself, and ensured that the alloy had finer grains. In this case, TiN improved the connection of crystal lattices with neighboring crystals. That is, the crystal branches spreading from the newly formed core serve as the core for the neighboring crystal. As mentioned above, the addition of Ti promoted the crystallization of titanium nitride (TiN) during the crystallization of steel. The TiN particles formed in the liquid phase have a cubic shape and relatively large (1-20 mkm) dimensions compared to those formed in the solid state at the next process stages. Although it has specific metallurgical functions in controlling the growth of subsequent crystals, the strength of the material is improved by promoting the dispersion of initial crystallization centers. When microstructures of samples modified with TiN were observed after polishing, the hardness and wear resistance of the samples modified with TiN showed a relatively positive difference from the previous indicators due to the formation of new crystallization centers and the increase in the number of crystals and the strengthening of each monocrystal.

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