THE INVESTIGATION OF PROPERTIES OF THE BALL PINS OF THE STEERING ROD OF THE CAR

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Abstract: Investigations are made of the properties of alloy steels used for car ball pins of the steering rod subjected to various methods of surface hardening. The choice of the material and technology of hardening processing for the detail "the ball pins of the steering rod" of the KAMAZ automobile is substantiated. The results of studies of the microstructure, hardness, microhardness of 40X steel and bench tests of parts are presented. The microstructure of the core of the ball of the part is a ferritocarbide mixture - sorbitol and ferrite in the form of a torn mesh along the grain boundaries. The microstructure hardened by high-frequency currents of the component layer is troostomartensite, consisting of 50% martensite and 50% troostite. corresponds to the norms of the fracture of the part during its long-term operation.

Keywords: steel, hardening, cementation, microstructure, hardness, strength, fracture.

1 Introduction

The ball pins of the steering rod are ones of the most important parts of the steering wheel of a truck. A steel rod with a ball head and a threaded tip for mounting, playing the role of the hinge axis, is the main fastener. The finger connects the rods and other parts of the steering gear, forming a ball joint. The presence of a hinge of this type provides the mobility of the mating parts of the steering gear in both longitudinal and transverse planes. Ball fingers operate under severe conditions of alternating impact loads and abrasive wear. Therefore, the following requirements are imposed on the spherical fingers: high rigidity, ensuring minimal deformation during operation; high resistance to cyclic shock loads; sufficient mechanical strength, the high wear resistance of the working surface (Kartashevich, 2013; Galiev, 2018). The choice of material for the manufacture of engineering parts depends on numerous factors affecting the possibility and expediency of their use in a particular product. The general requirements for the choice of material include compliance with standards and norms, cost, manufacturability of parts, ensuring operational reliability, durability. Currently, a large number of materials are used for car parts. One of the main is steel, the properties of which can be varied through various types of processing (Lakhtin & Leontyeva, 1990; Calner, 1984).

An effective direction for improving the operational properties of many products is their surface hardening. The choice of the most effective hardening technology is based on identifying the fundamental parameters of the operational properties that affect the service life of the part, evaluating the spectrum of its loading and determining the quality indicators of the surface layer that affect the performance of the part. To impart a high complex of properties to the surface layer of a part, various types of chemical-thermal treatment are widely used in engineering: cementation, nitrocarburizing, nitriding, boronation and other hardening methods (Borisenok et al., 1981; Walter et al., 2014; Astashchenko et al., 2017; Kaufmann et al., 2014; Astaschenko et al., 2016; Mukhametzyanova et al., 2019).

In this work, comparative studies of the properties of the ball pins of the steering rod of a KAMAZ automobile made of improved steel 40X and alloy steel 12XH3A, subjected to various methods of surface hardening, were carried out.

The choice of the material and technology of hardening processing for the detail “The ball pins of the steering rod” of the KAMAZ automobile is substantiated.

2 Methods

Steel 40X - structural alloyed steel, as a result of hardening treatment acquires high strength while maintaining sufficient ductility. After machining a billet made of 40X steel, the ball pin undergoes improvement (hardening + high tempering), followed by surface hardening with heating by high-frequency currents and low tempering. Hardening treatment of 40X steel is carried out according to the scheme shown in Fig. 1.

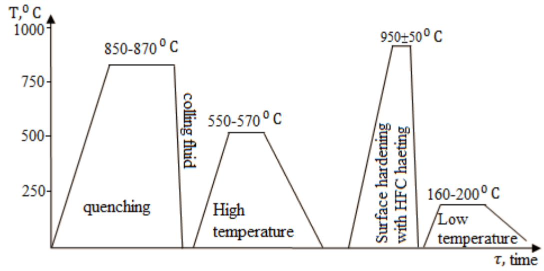


Figure 1. The heat treatment diagram of the part “The ball pins of the steering rod” from 40X steel.

Steel 12XH3A structural alloyed chromium-nickel. After machining the workpieces, the ball fingers are subjected to chemical-thermal treatment. The microstructure of steel 12XH3A before chemical-thermal treatment consists of sorbitol-like perlite and ferrite. Chemical-thermal treatment of steel, including cementation, hardening, and low tempering, is carried out according to the scheme shown in Figure 2.

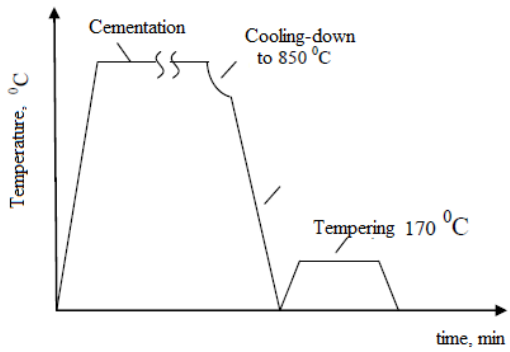


Figure 2. The heat treatment diagram of the part “The ball pins of the steering rod” of 40X steel.

Studies of the chemical composition of the metal of the part were performed according to GOST 54153-2010 on a SPECTROMAXx emission spectrometer. The microstructure of the part was studied on longitudinal microsections using a MEIJI MT 7530 optical microscope. Assessment of metal contamination of parts by non-metallic inclusions was assessed by the "SH4" method according to GOST 1778-70. Hardness measurements were carried out on the surface of the spherical part of the parts according to the Rockwell method GOST 9013-59 at a load of 150 kgf on a TR 2140 instrument. The thickness of the surface hardened high-frequency hardening layer of the part in the fillet region was measured according to the Vickers method GOST R ISO 6507 - 1 - 2007 on a Durimet microhardness meter at a load of 100 gs. The experimental data were approximated according to the procedure using Microsoft Excel software. Bench tests were carried out at an ambient temperature of 15 - 17^{o}C, atmospheric pressure 736 - 765 mm. Hg. and humidity 46 - 51%. For testing, the certified universal testing machines ZD-100 and Hofmann-

212 were used. The test program included testing the ball fingers for strength at temperatures close to 20°C and cooled to minus 60°C, as well as an assessment of their cyclic durability. For strength tests, the ball finger was mounted on the stand in a special device that simulates the operating load on the car (Zotkin, 2008).

3 Results and Discussion

As hardening treatment for steel 12XH3A, an expensive chemical-thermal treatment is used (cementation followed by heat treatment). To achieve the required mechanical properties, it is sufficient to use heat treatment with surface hardening with the heating of high-frequency hardening as a hardening treatment for steel 40X, which significantly reduces the cost of the manufacturing process of the part. The mechanical properties of steel 40X and 12XH3A are shown in table 1.

Table 1 - Mechanical properties of steels

Steel	Mechanical properties					
	Yield strength, kG / mm^2	Tensile strength, kG / mm^2	Percentage of elongation,%	Percentage of reduction,%	Impact resistance, J / cm^2	Hardness, HB
12XH3A	>70	>95	11	55	88	217
40X	>80	>100	11	45	59	217

According to the main indicators, the mechanical properties of the 40X and 12XH3A steels are comparable, which allows them to be used for the KAMAZ automobile's "The ball pins of the steering rod". Table 2 shows the hardenability of steels 40X and 12XH3A.

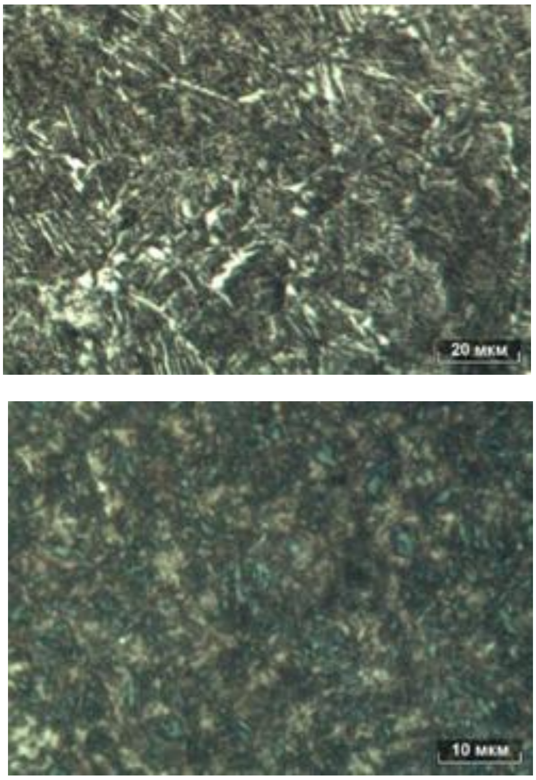
Table 2 - Hardenability of steels 40X and 12XH3A

Steel	Hardness (HRC) at a distance from the hardened end, mm										
	1.5	3	4.5	6	8	10	14	16	19	21	24
12XH3A	38.5-43	37-42.5	35-42	31.5-41	25-39.5	22-35	32	29	27.5	26	23
40X	51.5-60.5	50-59.	48.5-58	45-57.5	39.5-56	36.5-53	33-50.	32-47.5	28-43	26-42	25-40

As can be seen from table 2, steel 40X has hardenability and hardness higher than steel 12XH3A, which allows appropriate heat treatment to obtain greater strength and maintain viscosity at the level of steel 12XH3A.

As a result of the studies, it was found that the chemical composition of the metal of the parts "Steering finger ball" corresponds to the steels 40X and 12XH3A specified in GOST 4543 - 2016.

The microstructure of the core of the ball of a part made of 40X steel is a ferritocarbide mixture (FCM) - sorbitol and ferrite in the form of the remains of a broken mesh along the grain boundaries (Fig. 3, a). The microstructure of the layer of parts hardened by HFrC corresponded to troostomartensite, consisting of 50% martensite and 50% troostite (Fig. 3, b).



a *b*

Figure 3. The microstructure of the part made of steel 40X: *a* – the core of the part, x 500; *b* – the layer of the part hardened by high-frequency currents, x 1000.

The contour of the hardened high-frequency layer of parts is shown in Figure 4. The thickness of the layer hardened by high-frequency currents is: on the surface of the ball - 2.45 mm; on the fillet surface - 2.75mm; on the surface of the cone - 3.30 mm. Assessment of metal contamination of parts by non-metallic inclusions corresponds to: for sulfides - point, 1b, for point oxides - point, 1a.

Figure 4. The contour of the layer of a part made of steel 40X hardened by high-frequency hardening.

The hardness of a part made of steel 40X, after quenching with the heating of the high-frequency alloy on the surface of the sphere, is 58HRC, in the core of the part of the ball is 275HB. The microhardness of the core of the part is 271 - 276 HV_1. The distribution of microhardness in the longitudinal section in the region of the part fillet is shown in Fig. 5. The experimental data were approximated according to the procedure using Microsoft Excel software.

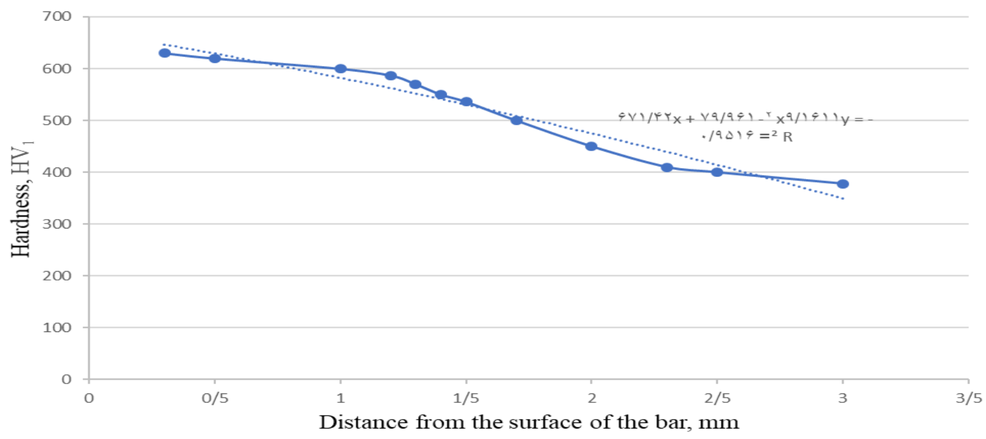


Figure 5. Microhardness distribution in the longitudinal section of a part made of 40X steel.

During bench tests, a smoothly increasing load (F_{load}) was applied to the center of the ball part of the finger from zero to the moment of its destruction with simultaneous registration of the finger deformation diagram in the coordinates "Load, kN - finger deflection, mm". The strain diagrams determined the loads corresponding to the yield strengths (F_T) and strength (F_B) of the parts. The scheme of fastening and loading of ball fingers is shown in Figure 6. The results of bench tests are presented in Fig. 7.

Figure 6. The scheme of fastening and loading of ball fingers during bench tests.

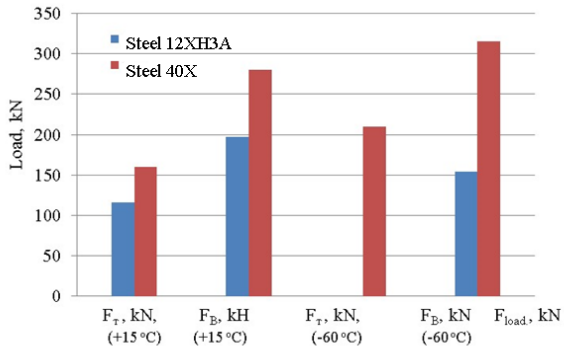


Figure 7. A comparative analysis of the strength characteristics of ball fingers made of steel 40X and 12XH3A.

All parts, both having room temperature and cooled to - 60°C collapsed after significant plastic deformation. The destruction occurred along the conical part of the part, in accordance with Figure 8. A fractographic analysis of the fracture surface showed that the fracture of the part is mixed - ¼ the fracture adjacent to the fracture has a brittle structure, ¾ of the fracture is the dolom zone, has a viscous structure, which corresponds to the norms of the fracture of the part during its long-term operation. The destruction center is located on the surface of the conical part of the part, in accordance with Figure 9.

Figure 8. The appearance of the destroyed parts made of steel 40X.

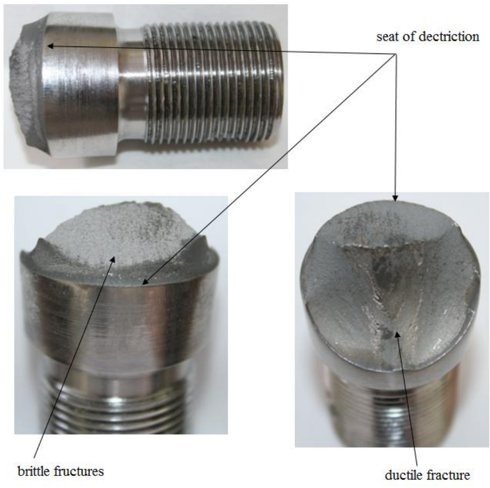


Figure 9. The fracture surface of a part made of steel 40X.

A comparative analysis of the strength characteristics of ball fingers made of steel 40X and 12XH3A.

The results of tests of ball fingers for cyclic durability are shown in table 3.

Table 3 - the results of tests of ball fingers for cyclic durability

Load swing, kN	100	95	93	90	90
Operation time before the destruction, of cycles	138 000	500 000	490 000	$1.06 \cdot 10^6$	$2.23 \cdot 10^6$
Fracture mode	On conical portion	On bar surface	On conical portion	On conical portion	Without distruction

The data given in table 3 allow us to conclude that the fatigue limit of ball fingers made of 40X steel submitted for testing is about 90 kN.

4 Summary

Thus, in the course of the studies, it was found that it is most advisable to use the improved 40X steel as the material for the steering tie rod fingers. The required steel characteristics are achieved as a result of improvement (hardening + high tempering) followed by surface hardening with heating by high-frequency currents and low tempering. The temperature of heating for quenching is 860^0C, tempering - 560^0C followed by cooling in air. During tempering, hardness decreases, internal stresses arising during hardening are removed, and ductility and toughness increase significantly. When surface hardening is carried out, the surface layer of the finger is heated using high-frequency current to a temperature of 900^0C followed by rapid cooling with water. Low tempering is carried out at a temperature of 160 - 200^0C followed by cooling in air.

5 Conclusions

The search for effective hardening technologies is a multivariate solution that should be based on the operating conditions of the product, its configuration, steel grade, and other factors. For the manufacture of ball pins of a vehicle's tie rod, preference is given to 40X improved steel with surface hardening of a part after heating with high-frequency currents.

Acknowledgments

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

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