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Study of Truck Spring U-Bolt Properties

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Abstract

They presented the studies of the chemical composition, microstructure and the properties of carbon and alloy structural steels, used for spring ladders of a truck, subjected to various heat treatment methods. Improvement and normalization are used as heat treatment. They provided the study results of the chemical composition, microstructure, hardness and cyclic durability in tension of parts made of steels of the following grades: 40, 40X, 30G2 from various manufacturers. The study of the microstructure of the part was carried out on longitudinal microsections cut from the threaded part using an optical microscope via the program - analyzer of the solid SIAMS 800 microstructure fragments. During the study of the microstructure, they evaluated the depth of the decarburized layer, the presence of nonmetallic inclusions, and the grain size. They provided the results of cyclic tests and fractographic studies of parts. They substantiated the choice of material and the technology of hardening treatment for the ladders of a truck spring. After the study, it was found that it is recommended to use high-quality alloy structural steel 40X for the manufacture of ladders of a truck spring, normalization is used as a hardening treatment, which significantly reduces the cost of manufacturing part technological process and increases their durability.

Keywords

Steel; Stepladder; Hardening; Normalization; Microstructure; Hardness

Introduction

The step-ladder is the connecting link between the truck suspension and the spring, and it must meet the following requirements: the thickness and strength of the step-ladder must correspond to the loads that will fall on it; the thread of the stepladder edges and its bends must fully match the car model; the ladder should be made of high strength steel that will not break or deform under stress. The step-ladders of automobile springs are usually made of structural carbon and alloy steels (for example, the steel 40, 45, or 40X, 30G2), as a heat treatment they are subjected to normalization or improvement. The choice of steel for the manufacture of a part and the method of its hardening is primarily determined by the working conditions of the part, the magnitude and nature of the stresses arising in it during operation, the size and shape of the part, etc. The combined effect of heat treatment, which changes the structure, and alloying is an effective way to increase the complex of mechanical characteristics of steel. The choice of material and technology of hardening types of processing should be considered in relation to specific production conditions, since the same heat treatment process in different production conditions can lead to different economic results. The efficiency of technological processes is influenced by the type of product, the use of appropriate blanks and energy resources, the possibility of creating or using specialized equipment, and other organizational and economic conditions, especially in the case of mass production. Usually, the possibility of using several grades of steel and hardening methods is considered, which makes it possible to choose the most rational option, which, along with high operational properties, also provides good manufacturability at all stages of the route technology of its manufacture in accordance with the drawing. This approach denotes a very practical principle of combining the necessary with the sufficient, when there is a need to combine opposite properties in one material, that is, the achievement of a normalized level of the required property while ensuring a sufficient level of other, less important properties. However, at present there are no universal methods to choose a material and technologies for their strengthening [16; 22; 18; 3; 4; 21; 2; 17; 1; 19; 20].

In this work, they performed comparative studies of automobile spring ladder properties of various types, made of carbon and alloyed high-quality steels, subjected to various heat treatment methods. The purpose of the work is to substantiate the choice of material and technology of hardening processing for truck spring ladders.

Methods

The studies of the part metal chemical composition were carried out in accordance with GOST 22536.1 - 88, GOST 22536.2 - 87 and GOST 18895 - 97 [9] on a multichannel atomic emission spectrometer DFS-71, designed for the simultaneous determination of carbon and sulfur in steels, cast iron, and nonferrous alloys [10]. 1988; GOST 22536.2 - 87 [11]. The study of the part microstructure was carried out in accordance with the GOST 8233 - 56, the GOST 1763 - 68, the GOST 1778 - 70 and the GOST 5639-82 on longitudinal microsections cut from the threaded part using an OLYMPUS GX53 optical microscope at 50 and 500 time magnifications using the "Fragment Analyzer" software for the microstructure of SIAMS 800 solids. The microstructure of the microsection was evaluated after chemical etching in a 4% solution of nitric acid in ethyl alcohol, cut out of the part without local heating [14; 7; 8; 13]. Hardness measurements were carried out according to the Brinell method GOST 9012 - 59 on a TSh - 2M hardness tester [15], the indenter diameter was 5 mm, and the load was 750 kgf. The studies were carried out under the following environmental parameters: air temperature - 22.3 C; relative humidity - 46.6%; atmospheric pressure - 755 mm of mercury column. Bench tests were carried out in laboratory conditions, at the ambient temperature of (25 ± 10) 0C, relative air humidity (45-80)% and atmospheric pressure (84.0 - 106.7) kPa, i.e. in compliance with the requirements of the GOST 15150-69 [6] to ensure normal climatic conditions for testing products on the servo-hydraulic test bench MTS 322.31 in accordance with the program No. R180.CP-2018ПМ at the load from 4.735 to 94.7 kN. At least three specimens were used for tensile cyclic fatigue tests. During the tests, the installation scheme of the tested spring ladders on the test equipment corresponded to their installation on the vehicle. The object of the study was truck ladders with differences in design. The tests were carried out on the samples of various grades of steels used for the manufacture of step-ladders for truck springs: for step-ladders of the first type - steel 40X and steel 30G2; for the stepladder of the second type - steel 40 and steel 40X from different manufacturers, subjected to various types of hardening treatment (Table 1).

Table 1: The Samples of Various Grades of Steel Used for the Manufacture of Truck Spring Ladders

U-bolt type	Grade of steel	Country	Heat treatment
I	Specimen №1 (40X)	Russia	hardening 840-850°C, oil, tempering 580°C
	Specimen №2 (40X)	Russia	hardening 840-850°C, oil, tempering 580°C
	Specimen №3 (40X)	Russia	normalization 850-860°C, air
	Specimen №4 (30Г2)	Russia	hardening 880 °C, oil, tempering 600°C
II	Specimen №5 (steel 40)	Russia	hardening 820-860 °C, oil, tempering 500°C
	Specimen №6 (steel 40)	Iran	hardening 820-860 °C, oil, tempering 500°C
	Specimen №7 (40X)	Russia	normalization 820-860°C, air
	Specimen №8 (40X)	Belgium	hardening 840-850°C, oil, tempering 580°C
	Specimen №9 (40X)	Russia	hardening 840-850°C, oil, tempering 580°C

Results and Discussion

The results of the chemical analysis of the part material after various processing methods are presented in Table 2.

Table 2: The Results of the Material Chemical Analysis of the Truck Spring Ladders after Various Processing Methods

Specimen №	The content of chemical elements, wt. %							
	C	Si	Mn	Ni	S	P	Cr	Cu
Specimen №1	0,38	0,22	0,73	0,04	0,005	0,013	1,01	0,03
Specimen №2	0,41	0,32	0,82	0,05	0,004	0,008	1,08	0,013
Specimen №3	0,37	0,23	0,67	0,05	0,007	0,011	0,89	0,04
Specimen №4	0,30	0,15	1,38	0,14	0,008	0,013	0,30	0,17
Specimen №5	0,44	0,23	0,62	0,17	0,011	0,009	0,18	0,26
Specimen №6	0,44	0,23	0,70	0,05	0,004	0,016	0,02	0,001
Specimen №7	0,37	0,25	0,80	0,05	0,007	0,014	1,00	0,05
Specimen №8	0,38	0,19	0,61	0,05	0,004	0,011	0,96	0,07
Specimen №9	0,37	0,28	0,77	0,04	0,009	0,012	1,05	0,03

After the studies, it was found that the chemical composition of the metal parts of the spring ladders corresponds to the declared steel grades: 40X, 30G2, 40 according to the GOST 4543 - 2016 [12] and the GOST 1050 - 2013 [5]. The microstructure of an etched section in a 4% solution of nitric acid in ethyl alcohol, the part made of 40X steel after improvement (sample 1): oriented and represents a uniform ferrite-carbide mixture - temper troostite (Fig. 1).

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Fig. 1: Microstructure of the Part made of Improved Steel 40X (sample 1), x 500.

The assessment of part metal contamination with nonmetallic inclusions was performed by the "SH4" method according to the GOST 1778-70 [8] - it corresponds to 2a points for point oxides and 1a point for sulfides. There is no decarburized layer.

The microstructure of an etched section in a 4% solution of nitric acid in ethyl alcohol, the part made of steel 40X after normalization (sample 3): weakly striped and is a lamellar pearlite, sorbitol-like pearlite and ferrite in the form of a mesh and grains (Fig. 2, a). The size of the actual grain corresponds to No. 7, 8, the sections No. 6 according to the GOST 5639-82 [13]. Partial decarburization with the depth up to 0.20 mm is observed on the thread surface. The assessment of metal contamination of the part with non-metallic inclusions was performed by the "SH4" method according to the GOST 1778-70 [8] - it corresponds to 4b point for line oxides and 3a point for point oxides, and 1a point for sulfides (Fig. 2, b).

a) b)

Fig. 2: The Microstructure of the part made of Steel 40X, Subjected to Normalization (sample 3), x 100:
a) Weakly Striped, Lamellar Pearlite, Sorbitic Pearlite and Ferrite in the form of a Mesh and Grains;
b) Non-Metallic Inclusions in the Microsection Plane.

The microstructure of an etched section in a 4% solution of nitric acid in ethanol, the part made of steel 30G2, subjected to improvement (sample 4) is a uniform ferrite-carbide mixture - temper troostite (Fig. 3). There is no decarburized layer.

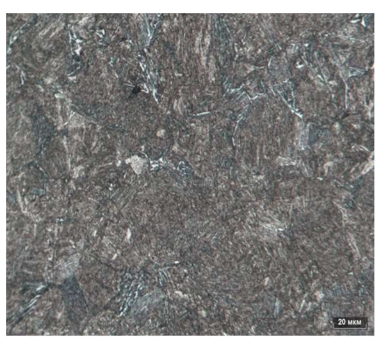

Fig. 3: The Microstructure of the part made of Improved Steel 30G2 (sample 4), x 100.

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The assessment of metal contamination of the part with non-metallic inclusions was performed by the “SH4” method according to the GOST 1778-70 [8], corresponds to 1a point for point oxides and sulfides.
The microstructure of an etched section in a 4% solution of nitric acid in ethyl alcohol, a spring ladder made of steel 40 after improvement (sample 6): temper sorbitol and significant amount of ferrite inclusions in the form of grains (Fig. 4). Contamination of the part metal with non-metallic inclusions was assessed by the “SH4” method according to the GOST 1778-70 [8] and does not exceed 1a point for sulfides and point oxides. There is no decarburized layer.

a) b)

Fig. 4: The Microstructure of the part made of Improved Steel 40 (sample 6): a) x 100; b) x 500.

The microstructure of an etched section in a 4% solution of nitric acid in ethyl alcohol, the part made of steel 40X after normalization (sample 7): banded and made of a lamellar pearlite, granular pearlite and ferrite in the form of mesh and grains (Fig. 5). The size of the actual grain corresponds to No. 6, the 7 GOST 5639-82 [13].

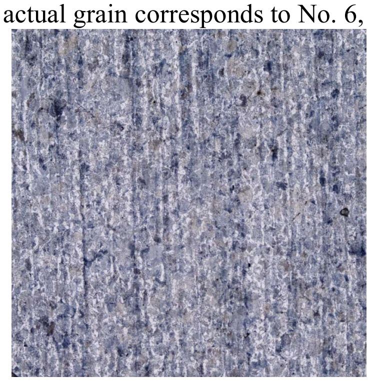

Fig. 5: The Microstructure of the part made of Steel 40X, Subjected to Normalization (sample 7), x 100.

The assessment of the part metal contamination with non-metallic inclusions was performed by "SH4" method according to the GOST 1778-70 [8] and does not exceed 1a point for point oxides and sulfides. There is no decarburized layer.
The microstructure of an etched section in a 4% solution of nitric acid in ethyl alcohol, the part made of 40X steel after improvement (sample 8) is a uniform ferrite - carbide mixture - temper troostite (Fig. 6).

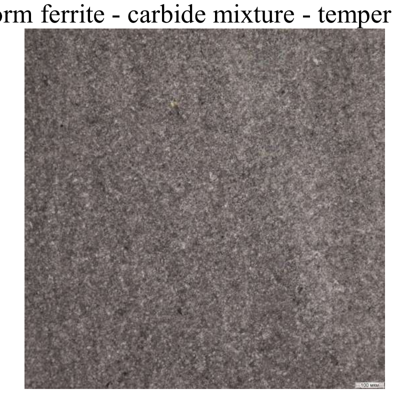

Fig. 6: The Microstructure of the part made of Improved Steel 40X (sample 6), x 100.

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The assessment of the part metal contamination with non-metallic inclusions was performed by the "SH4" method according to the GOST 1778-70 [8], corresponds to 1a point for point oxides and sulfides. There is no decarburized layer.

Table 3 presents the study results of the sample material microstructure used for the manufacture of truck spring ladders.

Table 3: The Study Results of the Material Sample Microstructure used for the Manufacture of Truck Spring Ladders.

Material	Microstructure
Specimen №1 (40X)	ferritic-carbide mixture – temper troostite
Specimen №2 (40X)	ferritic-carbide mixture – temper troostite
Specimen №3 (40X)	Weakly banded and it represents lamellar perlite, sorbitic pearlite and ferrite in the form of a grid and grains. The value of the actual grain corresponds to sections No. 6, 7, 8
Specimen №4 (30Г2)	ferritic-carbide mixture – temper troostite
Specimen №5 (steel 40)	ferritic-carbide mixture – temper sorbite, small amount of ferrite
Specimen №6 (steel 40)	ferritic-carbide mixture – temper sorbite and a significant quantity of inclusions of ferrite in the form of grains
Specimen №7 (40X)	Striped structure, lamellar perlite, granular perlite and ferrite in the form of a grid and grains. The value of the actual grain corresponds to No. 6, 7
Specimen №8 (40X)	ferritic-carbide mixture – temper troostite
Specimen №9 (40X)	ferritic-carbide mixture – temper troostite

In the course of the microstructure studies, it was found that all the samples meet the requirements of the drawing.

The hardness was measured by the Brinell method, the GOST 9012 - 59 on a TSh - 2M hardness tester [15], the indenter diameter was 5 mm, and the load was 750 kgf. The results of measuring the part hardness after different methods of hardening are presented in table 4.

Table 4: Measuring Results the Spring Ladder Hardness after Different Methods of Hardening

Specimen №	Hardness Measurement Site							
	Threaded hardness, HB 5/750				Inflection point hardness, HB 5/750			
	1	2	3	Half value	1	2	3	Half value
Specimen №1	346	350	354	350	354	352	356	354
Specimen №2	345	345	345	345	329	329	329	329
Specimen №3	184	184	184	184	205	206	204	205
Specimen №4	345	345	345	345	345	345	345	345
Specimen №5	272	272	272	272	275	274	276	275
Specimen №6	260	260	260	260	260	260	260	260
Specimen №7	205	210	206	207	175	176	180	177
Specimen №8	345	345	345	345	345	345	345	345
Specimen №9	345	345	345	345	345	345	345	345

The hardness of part samples (the stepladder of type I) meets the requirements of the drawing, except for sample No. 3 (underestimated). The hardness of the part specimens (the stepladder of type II) No. 8, 9 corresponds to the requirements of the drawing, the hardness on the specimens No. 5, 6, 7 is underestimated.

The results of cyclic tests for durability and fractographic analysis of spring ladders after various methods of strengthening are presented in Table 5.

Table 5: Results of Cyclic Durability Tests and Fractographic Analysis of Spring Ladders after Various Methods of Strengthening

U-bolt type	Material	Cyclic tests, cycle	The appearance of the fracture	The point of fracture
I	Specimen №1 (40X)	110 th.	high density fibrous fracture	on the threaded part
	Specimen №2 (40X)	79 th..	High-density fibrous fracture with traces of plastic deformation in the	on the threaded part

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			form of scars emanating from the fracture site	
	Specimen №3 (40X)	231 th.	crack defect	on the threaded part
	Specimen №4 (30Г2)	87 th.	Brittle ductile fracture	on the threaded part
II	Specimen №5 (steel 40)	152 th..	on the threaded part of the "U-bolt" along the thread cavity, a defect in the form of a crack is observed	on the threaded part
	Specimen №6 (steel 40)	649 th.	loose fibrous fracture with traces of plastic deformation in the form of scars	on the threaded part
	Specimen №7 (40X)	664 th.	The fracture is fibrous, high density, dark gray with traces of plastic deformation in the form of scars coming from the centers of destruction	on the threaded part
	Specimen №8 (40X)	208 th..	The fracture is fibrous, high density, dark gray with traces of plastic deformation in the form of scars coming from the centers of destruction	on the threaded part
	Specimen №9 (40X)	600 th.	The fracture is fibrous, high density, dark gray with traces of plastic deformation in the form of scars coming from the centers of destruction	on the threaded part

The best durability for the stepladders of type I springs is represented by 40X alloy steel with an operating time of 231 thousand cycles, for the stepladders of type II springs - the alloy steel 40X with an operating time of 664 thousand cycles - supplied by Russia; and the carbon steel 40 with an operating time of 649 thousand cycles supplied by Iran.

Conclusions

During the study, it was found that 40X alloy steel is recommended as the material for the truck spring ladders. The required characteristics of steel are achieved after normalization at the temperature of 820-860 °C, which ensures high durability of parts.

Summary

The choice of materials and effective hardening technologies for part processing is a difficult task, which depends on the operating conditions of the product, its configuration and many other factors. Preference is given to 40X steel and normalization to manufacture the truck spring ladders.

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