

Heat treatment of steel 30KhGSA on the specialized equipment

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Abstract. This article presents the results of the developed technology for the production of the part “striker” made of steel 30KhGSA with the use of vacuum heat treatment. It was established that application of vacuum heat treatment for critical parts can significantly increase the percentage of yield of good products, reduce the number of technological operations by 2.5 times and the cost of manufactured products by 30%, and also obtain high repeatability of the result, which is an important indicator in the production of serial products .

1. Introduction

Modern industry in Russia includes many dynamically developing directions of production of metal products. At many stages of production a large number of defective products are produced. If the part is critical and needs to meet strict requirements for mechanical properties, in most cases thermal treatment should be applied to it. At this stage, a fairly large percentage of the output of defective products is observed.

If we consider a modern plant, then it will have quite a lot of modern high-precision equipment for mechanical treatment, i.e. automated lines, machining complexes with CNC, etc. In the heat treatment section, old thermal furnaces or salt baths are usually in a very worn condition.

Differences in temperature in these units reach 70 °C, which is unacceptable for the manufacture of critical parts. In most cases, enterprises take into account the high percentage of rejects in the production of critical parts and simply overstate the prices for them without conducting any work to improve the technological process of production. In this paper we will consider the method of vacuum heat treatment on modern high-precision equipment, describe the advantages of using innovative technologies, as well as the economic effect of their use.

Heat treatment of steel is a very important final operation in the manufacture of parts and tools. It is responsible for giving the final mechanical properties to the material, on which the performance of the part will depend [1, 2]. The vacuum heat treatment, although described in the literature of the 80s, was mainly used at enterprises that produce parts for the defense industry, thus, vacuum heat treatment for Russia is a new direction, and enterprises are not fully aware of the possibilities and the advantages of using this process in modern production [3].

One of the main advantages of vacuum heat treatment is the absence of decarburization (oxidation) of the surface during the heating and cooling of the part, as well as the reduction of shrinkages and deformations due to uniform heating and cooling. The vacuum furnace B63 used in this work is shown in figure 1.





Figure 1. Vacuum furnace BMI B63 for heat treatment.

2. Results and discussion

The paper considers the use of vacuum heat treatment for steel 30KhGSA. Structural alloy steel 30KHGSA is one of the numerous steels used in the aviation industry. The main alloying elements in the steel are chromium, manganese, silicon. The chemical elements manganese and chromium sharply increase the hardenability. A feature of this high-quality steel is its relatively inexpensive cost and good weldability [4].

Analyzing the results of scientists in the field of aviation materials, it can be concluded that the standard thermal treatment for the material in question is the improvement: hardening from the temperature of 900 ± 10 °C in the oil with a subsequent high-temperature tempering. This mode of heat treatment is designed to obtain certain mechanical properties, namely, high fatigue strength [5].

The technology was tested on cylindrical samples 25 mm in diameter made of steel 30KhGSA, the chemical composition of which meets the requirements of GOST 4543- 71. We used ARL optical emission spectrometer. The chemical composition of the steel is shown in table 1.

Table 1. Analysis of the chemical composition of two batches made of steel 30KhGSA, %.

Batch	C	Mn	Si	P	S	Ni	Cr	Cu	Fe
1	0.28	0.89	0.95	0.01	0.01	0.13	0.89	0.08	res.
2	0.31	0.89	0.96	0.01	0.01	0.13	0.98	0.09	res.
GOST	0.28-0.34	0.8-1.1	0.9-1.2	0.025	0.025	0.3	0.8-1.1	0.3	res.

The hardening was carried out in the vacuum thermal furnace BMI B63. The hardening temperature was 900 ± 5 °C, the heating was carried out in a vacuum medium with partial nitrogen pressure. The supply of partial pressure prevents the oxidation of the parts surface when heated. The hardening was carried out in the vacuum oil heated to 40 °C. The cooling rate is controlled by the oil temperature parameters, the pressure in the hardening chamber, and the intensity of the oil mixing. After hardening to confirm the quality of heat treatment, hardness measurement and metallographic analysis were carried out.

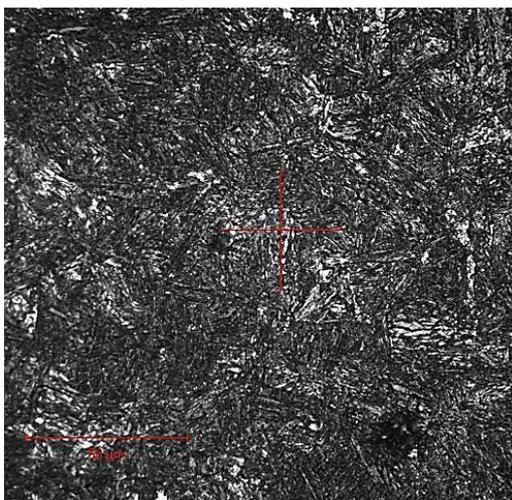
Measurement of hardness according to Vickers (GOST 2999-75) was carried out on the Tukon 2500 microhardness testing instrument. The Rockwell hardness test (GOST 9013-59) was performed on TK-2M hardness testing instrument. The results of hardness measurements are presented in table 2.

Table 2. Hardness of the samples after hardening 900 ± 5 °C

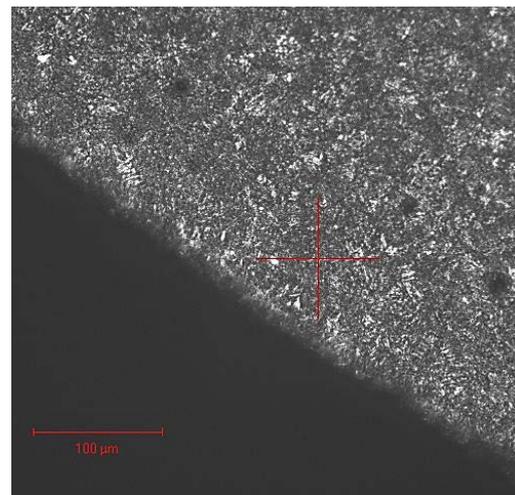
Batch No.	HV5 _{CENT.}	HRC _{SURF.}	HV5 _{SURF.}	HRC _{SURF.}
Batch 1 Ø 20 mm	490	48	500	48
Batch 1 Ø 25 mm	480	47	480	47
Batch 2 Ø 20 mm	490	48	500	48
Batch 2 Ø 25 mm	490	48	490	48

Analyzing the data of table 2, it can be concluded that samples from batch 1 and batch 2 with a diameter up to 25 mm have a uniform hardness throughout the section. The obtained hardness parameters satisfy the data described in the specialized literature [3].

Metallographic analysis after hardening showed a homogeneous martensite structure throughout the cross section of the samples. The microstructure of samples 25 mm in diameter from batch 1 is shown in figure 2.



Center x 200



Surface x 200

Figure 2. Microstructure of the sample with Ø25mm (batch 1) after hardening.

After hardening, high-temperature tempering was carried out in the B-53RNC+ vacuum furnace in an inert nitrogen atmosphere (99.999%) at a temperature of 510 ± 5 °C and a pressure of 300mbar. Steel grade 30KhGSA tends to temper brittleness of the second kind, so when it is tempered, it needs to be cooled quickly. In the furnace for uniformity of temperature during heat treatment (± 5 °C), as well as accelerated cooling, a turbine is installed. This turbine provides a high speed of cooling parts after tempering, which prevents the formation of temper brittleness.

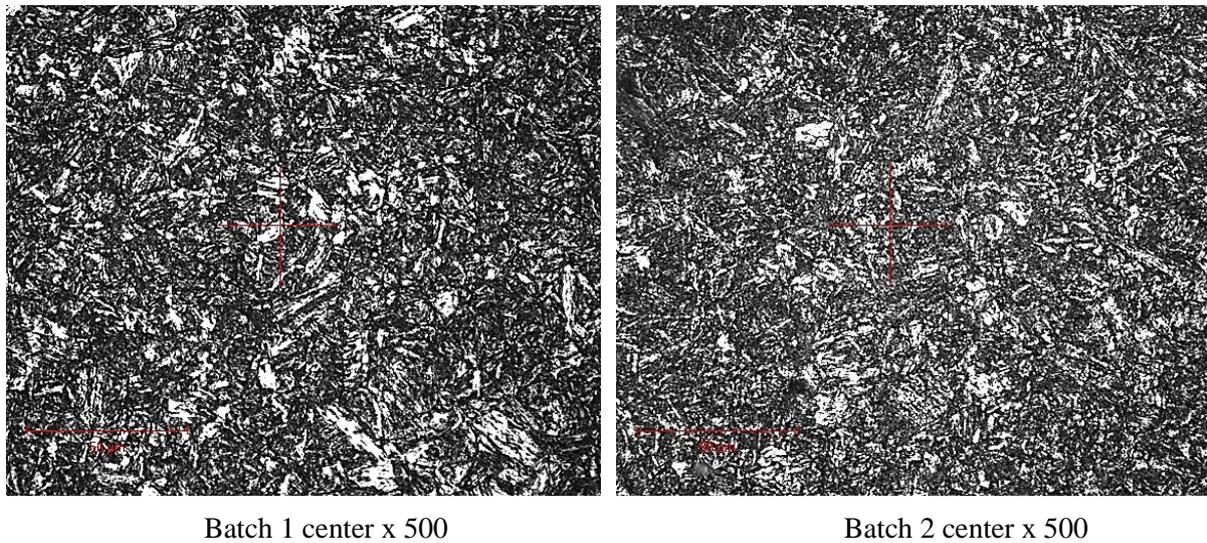
After carrying out the tempering operation, hardness testing and metallographic analysis were performed to confirm the quality of the heat treatment. The results of hardness measurements are presented in table 3.

Analyzing the data in table 3, it can be concluded that samples from batch 1 and batch 2 with a diameter up to 25 mm have a uniform hardness throughout the section. The obtained hardness indicators satisfy the data described in the specialized literature.

Table 3. Hardness of samples after high-temperature tempering 510 ± 5 °C.

Batch No.	HV5 _{CENT.}	HRC _{SURF.}	HV5 _{SURF.}	HRC _{SURF.}
Batch 1 Ø 20 mm	355	35	365	35
Batch 1 Ø 25 mm	360	35	370	35
Batch 2 Ø 20 mm	380	37	400	38
Batch 2 Ø 25 mm	380	37	390	37

The metallographic analysis after high-temperature tempering showed a uniform structure of sorbitol in the entire sample section. The microstructure of samples 25 mm in diameter from batch 1 and batch 2 is shown in figure 3.

**Figure 3.** Microstructure of samples with Ø25mm after high-temperature tempering.

In hardened and tempered samples from batch 1 and batch 2, which have uniform hardness over the entire section, a homogeneous structure of sorbitol is observed (figure 3).

For parts used in aircraft construction, it is required to obtain a temporary tensile strength 1200 ± 10 MPa. Tensile tests were carried out on INSTRON 300DX tensile testing machine. The test results are shown in tables 4 and 5.

Analyzing the data of tables 4 and 5, it can be concluded that the samples from batch 1 and batch 2, after carrying out final heat treatment on vacuum equipment, fully comply with the requirements for critical aviation components.

After working out the technology, vacuum heat treatment was applied to the “striker” part.

At the factory that produces these parts, the following problems were observed: the output of a good product on average was 60%. The current production technology of the “striker” component consisted of 22 operations. The thermal treatment was carried out in accordance with the production instructions. The main part of technological operations (17) was carried out after heat treatment, since atmospheric furnaces were used in the heat treatment process. In the process of heat treatment in atmospheric furnaces, the surface of the part reacts with the furnace gases inside the furnace, as a result of which the part is oxidized. Oxidation of the part reduces the number of alloying elements in the surface layer. This process adversely affects the mechanical properties of the part. As a result of oxidation of the surface after heat treatment, a large number of operations are required to smoothing the parts in size to remove the formed oxidized layer. These operations significantly lengthen the process of creating a part. Most of the defective products are detected after the heat treatment

operation, therefore, the technology of manufacturing the “striker” with the use of vacuum heat treatment was developed in cooperation with “TermoMet” JSC.

Table 4. Results of tensile tests of samples (Batch 1).

Sample No.	Conventional yield strength, MPa	Ultimate strength, MPa	Modulus of elongation, %	Reduction of area, %
1	1003	1115	16.3	47.1
2	1008	1107	17.5	48.7
3	1011	1112	15.1	48.5
4	1009	1115	15.2	47.1

Table 5. Results of tensile tests of samples (Batch 2).

Sample No.	Conventional yield strength, MPa	Ultimate strength, MPa	Modulus of elongation, %	Reduction of area, %
1	1043	1221	14.2	43.8
2	1001	1207	16.8	45.2
3	1058	1222	14.0	46.7
4	1042	1221	15.6	51.0

The entire technological process of creating a “striker” with the use of vacuum heat treatment includes 9 operations (4 operations before heat treatment + heat treatment + 4 operations after heat treatment).

To test the developed technology, a pilot batch of 40 pieces was produced. After passing through the whole technological process, the output of the good product was 100%, which is almost twice as much as for the parts manufactured using the old technology.

The main results of calculations of technical and economic indicators are given in table 6.

As a result of the work, the quality of the vacuum heat treatment of samples with a diameter up to 25 mm made of steel 30KhGSA was confirmed.

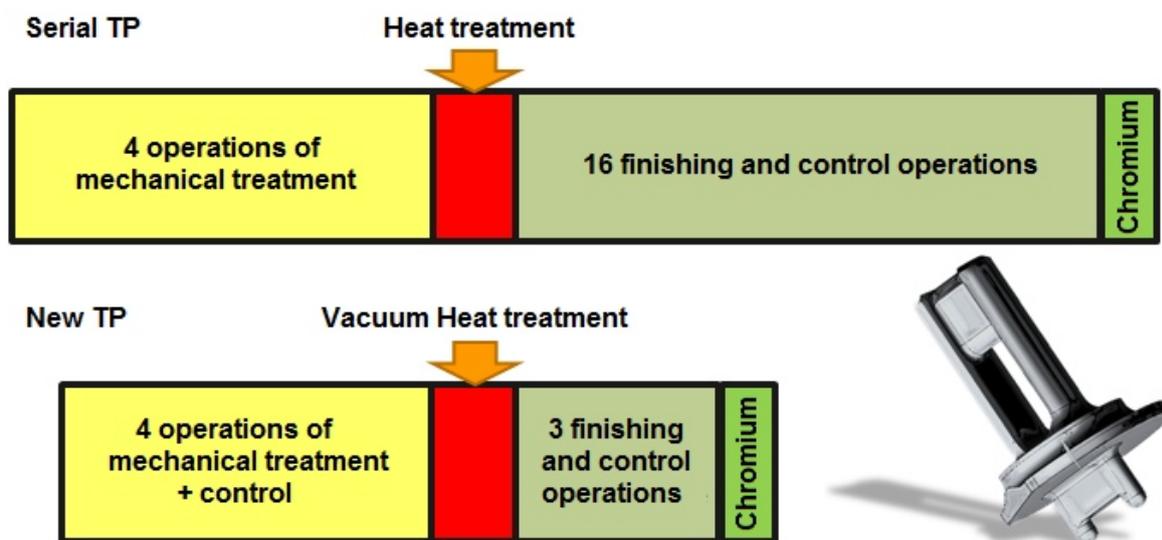


Figure 4. Technological scheme of manufacturing the “striker” part.

Table 6. Results of technical and economic indicators of the “striker” part.

Name	Old technology	New technology	Efficiency
Number of operations	21	8	2.6 times
Labour-output ratio, (standard hour)	6	4	33
Cost, rub.	5000	3500	30%

3. Conclusion

As a result of the work carried out, the technology of manufacturing the “striker” part, made of steel 30KhGSA, with the use of vacuum heat treatment, was developed. Using vacuum heat treatment for critical parts, it is possible to significantly increase the percentage of yield of good products, as well as to obtain high repeatability of the result, which is an important indicator in the production of serial products. The use of vacuum heat treatment has great prospects for implementation in modern manufacturing plants in Russia.

References

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