ISSN 2347 - 3983
Volume 8. No. 7, July 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter115872020.pdf
https://doi.org/10.30534/ijeter/2020/115872020

Investigation of the influence of heating temperature on the hardness of heat-treated tool steel

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ABSTRACT

The search for ways to improve the quality of pipe steel is caused by increased requirements for the mechanical and operational properties of casing pump-compressor pipes (tubing). To achieve the required level, the following tools were used: alloying, deformation modes, and heat treatment. Studies of the structure and mechanical properties and hardness of 32G2 steel used in the production of semi-finished products with planted ends for pumping and compressor pipes are given.
The influence of the quenching mode with hot deformation temperatures on the phase composition, grain size, structure, level of strength and plastic characteristics is shown.
Key words: heating temperature, heat-treated tool steel, cooling, pipes, hardness.

1. INTRODUCTION

The search for ways to improve the quality of pipe steel is caused by increased requirements for the mechanical and operational properties of casing pump-compressor pipes (tubing). To achieve the required level, the following tools were used: alloying, deformation modes, and heat treatment. «The search for optimal heat treatment modes is devoted to works that consider the possibility of using high-speed heating during quenching in a wide range of quenching temperatures, as well as the influence of the cooling speed on the formation of a complex of mechanical properties that ensure the reliability of pipes» [1] during operation.
«Pump and compressor pipes produced by domestic enterprises have several categories of quality class = (strength groups): "D", "K", "E", "L", " M "» [1].
«The strength group of the metal in the tubing increases from " D " to " M " depending on the terrain conditions (stony, freezing depth), the depth of the well, the composition of the transport agent and the increase in internal pressure. Pipes of group " E " are produced with the ends planted out (type of tubing-B, (figure 1)) must meet the requirements of GOST 32696-2014 (TU)» [1].

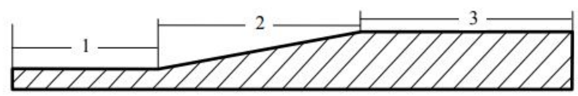

Figure 1: External pipe landing, precision group " D " and " E " (GOST 32696-2014) (according to V.B Dementiev)

Where the 1 area of the base metal pipe, 2 – transition zone (PZ), 3 – area planted pipe end (VZ).
Thermal hardening treatment of pipes includes quenching with «tempering depending on the chemical composition of the steel melting. To relieve stress after hot deformation, the pipes are annealed at a temperature of 660 °C on troostite» [1].
«Previously, it was believed that achieving the required level of properties is possible only through the use of hardening heat treatment» [1]. «However, currently popular methods of external influence on the structure in order to create special substructures» [1], due to which the improvement of the complex of physical and mechanical properties is mainly provided products. «It was of interest to investigate what effect on the structure and properties in the zones of the planted end of pipes (figure 1) will have quenching with forging heating with podstuzhivaniem at temperatures close to critical (AC1 and AC3), and whether podstuzhivaniem in a sprayer with cold water will be effective» [1].

2. THEORETICAL FRAMEWORK

According to the carbon content, tool steels are classified as follows: pre-eutectoid, eutectoid, over-eutectoid, ledeburite steels. Ledeburite steels have primary carbides in their structure [2]. In the cast state, excess carbides together with austenite form eutecticledeburite [3]. Tool steels are distinguished by their purpose as follows: for the manufacture of cutting, stamping and measuring tools. Accordingly, different types of steel are used [4]. Therefore, conditionally instrumental steels are divided into four categories:
- carbonaceous (low calcination, non-heat resistant) [5];
- alloyed (high calcinability, medium heat-resistant) [6];
- stamped (high hardenability: non-heat-resistant and heat-resistant) [7]];

- high-speed (high hardenability, increased heat resistance) [8].

Tool steels for cold forming dies must have high wear resistance, hardness, resistance to small plastic deformations (high yield strength-σ02 for compression) and other characteristics [9]. Depending on the working conditions of dies, tool steels must have one or another group of properties [10]. Thus, for cut-out (cut-through) dies, the service life is limited by wear resistance and resistance to brittle destruction (structural strength) [11]. For high-strength dies of complex shape, the defining properties are sanding and heat treatability (small deformation during heat treatment) [12]. The main types of cold deformation operations are classified into bending, cutting, drawing, forming, and volumetric stamping [13]. The most heavily loaded cold stamping operations include: volume stamping (pressing, reducing, and dropping) and cutting (cutting, punching) [14]. Working conditions are characterized by the amount of specific pressures arising during deformation [15], the nature of loading and the heating temperature of the working parts [16]. Specific pressures during cold forming reach up to 2200-2500 MPa, and in some cases even more [17].

For cutting tools that work in light conditions (files, hacksaws, taps, reamers), and for measuring tools, «carbon (u7–U12) and alloy steels (X, 8XF, X, 9XC, HVG) are used, containing from 0.7 to 1.5% C and alloying elements (chromium, tungsten, vanadium, manganese) in the amount of 1 to 5 %» [18]. «The structure of these steels before heat treatment is granular perlite. Heat treatment consists of quenching followed by low tempering at 150-170 °C» [18].

Carbon steels are usually quenched in water and alloyed in oil [26]. After tempering, the structure consists of martensite and a small amount of secondary carbides [19]. The hardness is HRC 60-64 [20]. When heated to 200 °C, the hardness begins to drop rapidly [21]. Therefore, during operation, it is not allowed to heat the tool made of these steels above 200 °C [22]. Having the same carbon content, they have almost the same cutting properties. Alloying elements in these steels increase the hardenability [24].Increased hardenability allows these steels to be hardened in oil, which reduces the risk of cracks, deformations, and warps [25].

Cutting tools that work at high cutting speeds are made of steels such as R9, R18, R18K10, R6M5, R18F2, R9K5, called high-speed cutting. In the designations of these steels, the percentage of tungsten (W) is indicated after the letter "P". The mass fraction of chromium for all grades of these steels is 3.8– 4.0 %. The mass fraction of vanadium in steels with 18% W is 1-1. 4 %, and in steels with 9 % W-2.0–2.6 %. The greater the carbon content, the more vanadium, and ranges from 0.7 to 1.55 % [26].

High-speed steels have increased heat resistance and redness, i.e. the ability to maintain the structure of martensite, and therefore, high hardness and cutting properties when heated to 625-655 °C.

3. RESULTS AND DISCUSSION

The purpose of this work is to study the influence of the heating temperature on the hardness of heat-treated tool steel. The following materials and tools were used to study the effect of heating temperature on the hardness of heat-treated tool steel:

- muffle furnaces;
- quenching tank with water and oil;
- pliers;
- Rockwell hardness tester;
- samples of tool carbon and alloy steel;
- Atlas of microstructures.

The study was conducted in several stages. For steel processing, three samples of tool steels were selected: carbon, medium-alloy and high-speed.

Further, the reference was used to determine the temperature for quenching and tempering for the tool steels under study.

The next stage was:

- steel quenching according to the corresponding modes. Determination of hardness (HRC) of steels after quenching. Release the steel according to the appropriate modes;
- determination of hardness (HRC) of steels after tempering;
- one sample of each steel grade was heated to a temperature of 200 °C, the next three samples - to 500 °C, the remaining three samples - to 700 °C. Excerpt was made taking into account the size and shape of the samples. Air cooling;
- determination of the hardness (NRC) of steels after cooling;
- the results of the study are entered in the Protocol in the form of a table;
- drawing of the graph of the dependence of the hardness of each steel grade on the heating temperature;
- conclusions about the heat resistance of each of the studied steels.
- execution of the research report.

Samples of 32G2 steel were used as the research material. The chemical composition of the steel is shown in table 1. Samples were cut from sections of the planted ends of pipes (figure 1) that were quenched with forging heating according to the modes shown in table 1.

Table 1: Chemical composition of steel 32G2%

Element	Fact	Class E requirements
C	0.33	0.30-0.35
Si	0 , 2 8	0.20-0.35
Mn	1.39	1.25-1.45
P	0.011	0,025
S	0.12	0,025
Cr	0.3	0.30
Ni	0.09	0.30
Cu	0.21	0.30
Al	0,031	0,020

Metallographic studies, «determination of hardness and testing of mechanical properties were carried out in accordance with the requirements of GOST 32696-2014. The phase composition was evaluated qualitatively using a D2 PHASER x-ray diffractometer with a Bregg-Brentano geometry and a lynxeye linear counter». Samples were taken in copper Ka radiation, diffractograms were analyzed using the diffrac.EVA software module, and phase identification was performed using the PDF – 2/Release 2010 RDB database of the international center for diffraction data ICDD.

«The steel under study is manganese with chromium, Nickel, and copper additives and belongs to the class of microalloyed steels» [1]. «In addition, the steel is deoxidized with aluminum, which is necessary for grinding grain due to fine nitrides» [1].

«The decomposition of austenite under supercooling occurs, as evidenced by thermokinetic diagrams, in the temperature range of 750 /400 °C» [1]. «When studying the phase composition, the presence of only iron with a lattice parameter of 2.8665 Å (0.0287 nm) was found (the unalloyed · α-Fe has a crystal lattice period of 2.86645 Å)» [1]. «X-ray images of cementite could not be obtained due to the small particle size of this phase (less than 50 nm)» [1]. «Since the x-ray diffractograms of all the samples studied are identical (the difference is only in the height of the main maximum peak from α-Fe), the phase composition is represented by a single peak of diffractograms, which shows how the amount of α-phase Fe varies depending on the quenching mode» [1]. «The highest intensity belongs to the phase of sample № 2» [1].

Results of investigation of microstructure: initial pipe № 1; planted pipe ends (№2-13); transition zone (№2.1-13.1) are shown in figure 2.

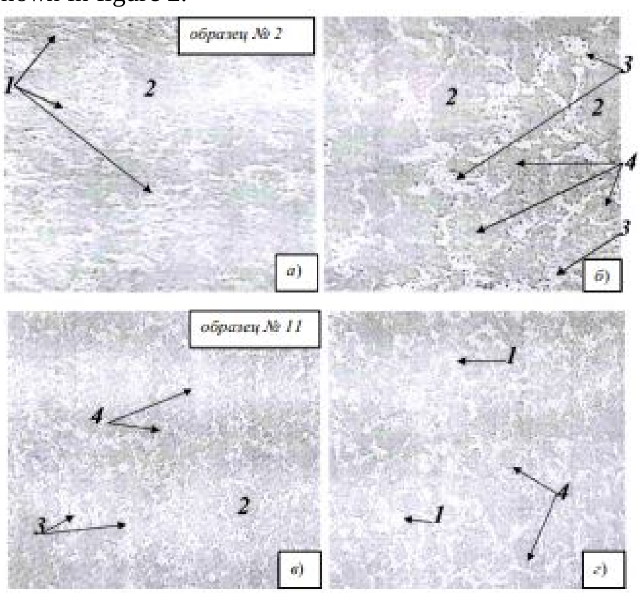

Figure 2: Microstructure of 32G steel after quenching with forging heating (1-discontinuous carbides, 2-perlite, 3 – continuous carbides, 4-austenite carbides); (a, C-the planted end, b, d-the transition zone) (according to V.B Dementiev)

As you can see, the ratio of structural components in the steel under study changes depending on both the conditions of forging (hot deformation) and the combined heat treatment mode with forging.

«At the same time, the amount of ferrite decreases, and the amount of perlite increases». «The ferrite mesh in medium-carbon steel becomes thinner, the cementite plates are shorter, and the structure of the perlite is crushed so much that it is impossible to resolve individual plates of perlite using an optical microscope» [1]. The microstructure obtained after quenching with continuous air cooling is represented by the following structural components: excess ferrite, perlite, carbides in ferrite of various morphologies and carbides by the boundaries of austenitic grains

4. CONCLUSION

In the process of work, we investigated the effect of heating temperature on the hardness of heat-treated tool steel. The study showed that with an increase in the forging temperature, the inhomogeneity of the structure is more pronounced. Also, indicators of structure homogeneity were identified, reflecting the stability of properties in the areas of GOST requirements. In the process of quenching at a temperature of forging heating at 1120 ° C and cooling to 900 ° C, a fine-grained structure was obtained. The study made it possible to reflect the effect of the hardening regime on the phase composition of the grain, to determine its size and structure, as well as the level of strength and plastic characteristics.

REFERENCES

1. V.B. Dementyev, T.M. Makhneva, F.Z. Sabrikov, V.I. Petrenko. **Influence of heat treatment on structure and mechanical properties of structural steel**. Chemical physics and mesoscopy, 21 (4), 579-588, 2019.
2. O.A. Andrienko. **On the need to apply gaming training technologies.** *Balkan Scientific Review*, 2 (4), 5-8, 2019.
3. G.T. Klinkov The specificity of manifestation of pedagogical communication as a special construct. *Scientific Vector of the Balkans*, 1, 51-52, 2018.
4. A. A. Sukhikh, T. M., Makhneva, V. B. Dement'ev **Austenite in nanostructured maraging steel,** *Inorganic Materials: Applied Research,* vol. 10, no. 4, pp. 966-973. , 2019. https://doi.org/10.1134/S2075113319040415
5. G.A. Vaskovskaya, **Features of implementation of pedagogical technologies of profile training.** *Balkan Scientific Review,* 1, 76-79, 2018.
6. O.P. Denisova, Z.V. Smirnova, O.I., Vaganova, M.N. Gladkova and J.M. Tsarapkina. **Development of partnerships in additional education.** *International Journal of Innovative Technology and Exploring Engineering*, 8 (8), 639-643. 2019.
7. K.Yu. Boyko, A.V. Skripkina and K.Yu. Smartly. **The use of syllabus funds in the technology of time**

management of self-educational activities of bachelors. *Multilevel system of continuous professional education in the socio-cultural sphere: problems of continuity and integration*, 73-78. 2019.

8. Z.V. Smirnova, O.I. Vaganova, D.A. Loshkareva, E.A. Konyaeva, M.N. Gladkova, **Practice-oriented approach implementation in vocational education.** *IOP Conference Series: Materials Science and Engineering*, 1, 483. 2019. https://doi.org/10.1088/1757-899X/483/1/012003
9. A.P. Cirdan, **Innovative technologies of professional training of future economists in the system of continuous education.** *Humanitarian Balkan Research,* 2(4), 27-30.2019.
10. I.F. Filchenkova**, Educational management of innovative activity of teachers as an object of pedagogical research.** *Vestnik Mininskogo universiteta* (*Vestnik of Minin University),* 2019. 7 (4), 3. (in Russ.). 2019. https://doi.org/10.26795/2307-1281-2019-7-4-3
11. E.V. Myalkina, **Diagnostics of the education quality in the higher educational institution.** *Vestnik Mininskogo universiteta (Vestnik of Minin University)*, 7, (3), 4. 2019. https://doi.org/10.26795/2307-1281-2019-7-3-4
12. I.I. Oros, **The role of international connections in the development of the adult education system.** *Humanitarian Balkan Research*, 1, 57-59.2018.
13. I.I. Osadchenko, **Key concepts of situational training technology in preparing future teachers.** *Scientific Vector of the Balkans,* 1 (3), 46-49. 2019.
14. G.A. Pichugina and A.I. Bondarchuk, **Structure of the training case in the organization of the educational process.** *Humanitarian Balkan Research,* 2(4), 5-7.2019.
15. G. A. Pichugina and D. A. Zhilyakova. **Structuring the organization of the process of creativity.** *Scientific Vector of the Balkans*, 3, 3 (5), 55-58. 2019.
16. V.M. Pliushch. **Independent work of students as a factor of improving education quality.** *Balkan Scientific Review,* 1, 69-71.2018.
17. L.V. Aleksieienko-Lemovska. **The activity approach as a basis for preschool teachers' methodological activities,** *Humanitarian Balkan Research,* 3, 4(6), 10-14. 2019.
18. I.G. Sizov, B.D. Lygdenov, D.M. Makharov, YU.P. **Aganaev, I.P. Obuneev. Metallurgy and heat treatment of metals: a manual for laboratory work** / Ulan-Ude: VSGTU, 2006, 238 P.
19. A.N. Chirva and O.G. Chirva. **Contents and method of professionally oriented training of informatic disciplines of future teachers of technologies.** *Scientific Vector of the Balkans*, 1, 27-31. 2018.
20. N.V. Kamenez, Zh. V. Smirnova, O. I. Vaganova, N.V. Bystrova and J.M., Tsarapkina. **Development of Instructing Techniques in Professional Training.** *International Journal of Mechanical Engineering and Technology*, 10(02), 899–907.2019.
21. P.N. Sharonin, E.V. Kozlova. **The role of instant messengers in the modern media space.** *Media economics of the 21st century*, 2, 12-15. 2017.
22. L. K. Ilyashenko, Zh. V. Smirnova, O. I. Vaganova, E. A. Chelnokova, and S.N. Kaznacheeva, **Methods of Conducting Practical Training on the Subject "Power Sources for Welding",** *International Journal of Mechanical Engineering and Technology*, 10 (02), 908–917. 2019.
23. T. K. Andriushchenko. **Personal aspects of pedagogue's innovative culture**. *Scientific Vector of the Balkans,* 1, 13-16. 2018.
24. N. P. Bakharev. **Creativity - a prerequisite for the formation of professional competences in specialists of technical direction of training.** *Scientific Vector of the Balkans,* 3, 4 (6), 17-21. 2019. https://doi.org/10.34671/SCH.SVB.2019.0304.0004
25. N.S. Abramova, O.I. Vaganova, L.I. Kutepova, **Development of educational and methodological support in the context of the implementation of content and communication technologies.** Baltiyskiy gumanitarnyy zhurnal. Baltic Humanitarian Journal, 7, no. 2 (23), 181-184. 2018.
26. M.N. Bulaeva, O.I. Vaganova, M.N. Gladkova. **Activity technologies in a professional educational institution.** Baltiyskiy gumanitarnyy zhurnal. Baltic Humanitarian Journal), 7, no. 3 (24), 167-170. 2018.