Study of the influence of carbide inhomogeneity on operational and technological properties of high-speed tool steels

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Abstract. The level of the current state in the field of information support (IS) of the activities of high-tech enterprises is considered in this paper. The main problems are shown on the way to achieving the required level of IS quality in high-tech enterprises of the country. The need for the formation of a number of standardized requirements for the IS quality of a high-tech enterprise to improve its level is determined. A typical list of requirements for the IS quality is determined and a model of a system for accounting for requirements for the IS quality is developed using the example of Scientific and technological center of unique instrumentation of the Russian Academy of Sciences.

Introduction

The destruction of the cutting tool made of high-speed steel during operation is a serious problem in modern production. Factors causing the destruction of any product during operation are:
- constructor errors;
- violations of technology and assembly;
- quality of the material;
- improper operation.

The state of the material structure as an element of quality that affects the operational and technological properties of tool steel is considered in the paper.

The structure of high-speed tool steel consists of martensite and carbides. A high level of operational and technological properties is ensured by very fine-needle martensite with finely dispersed, uniformly distributed carbides [1, 2].

It was found that carbides of two groups can form in steels [1]:

Group 1 – Fe3C; Mn3C; Cr23C6; Cr7C3; Fe3Mo3C; Fe3W3C;

Group 2 – Mo2C; W2C; WC; TiC; NbC; TaC; Ta2C; ZrC.

For some technological reasons, carbides in high-speed tool steel take both an uneven distribution over the volume of the product and take a different shape. This phenomenon is called carbide inhomogeneity [1, 3].

Level requirements and scales for determining the carbide inhomogeneity score are regulated by GOST 19265-73.

The following types of carbide inhomogeneity are distinguished [1, 3]:
- carbide lines;
- broad clusters of carbides;
- carbides deposited at the grain boundaries in the form of a grid;
- eutectic carbides arranged in a cellular structure.
- large angular carbides.

**Materials and methods**

In this regard, studies of the microstructure of the cutting tool after destruction during the operation were carried out (Table 1, Fig. 1-6).

Analysis of the results of the study of fractures, properties, and microstructure of the cutting tool are presented in Table 2.

Thus, studies of the microstructure of the cutting tool indicate that:
1) One of the main reasons for the destruction of the cutting tool is carbide in-homogeneity;
2) Carbide inhomogeneity reduces both operational properties and technological properties;
3) The causes of destruction of the cutting tool associated with carbide inhomogeneity are:
- inhomogeneity of the chemical composition due to the uneven distribution of carbides in the total volume and the micro volumes of the part, leading to inho-mogeneity of the microstructure and the appearance of additional internal stresses during quenching;
- stress concentrators on the cutting edge, formed by the output of carbide lines crushed during grinding [5];
- stress concentrators on the cutting edge, formed as a result of chipping large carbides, weakly associated with the matrix [6, 7];
- a steel strength decrease as a result of carbide precipitation along grain boundaries.

**Table 1. Study of fracture, mechanical properties, and microstructure of the cutting tool.**

| Tool          | Nature of destruction                                                                 | Standard requirement s | Research results                                                                                     |
|---------------|----------------------------------------------------------------------------------------|------------------------|-------------------------------------------------------------------------------------------------------|
| Countersink 1 | The first step of the countersink is destroyed in the longitudinal direction. The fracture is fine-grained, with an oxidized surface | P6M5 steel; hardness 62-65HRC | Hardness by GOST 8233-56; Microstructure by GOST 8233-56; In areas with accumulations of eutectic carbides - medium-needle martensite and troostite. The main structure is crypto-needle martensite with carbides (Fig. 1, b). In the microsection plane, the fracture surface is oxidized. |
| Countersink 2 | There collapsed in the transverse direction. The fracture is fine-grained without signs of oxidation. When checking on a magnetic flaw detector, deposits of magnetic powder in the form of thin longitudinal lines were found on the surface of the grooves for chip exit (Fig. 2, a, 2, b) | P6M5 steel; Hardness of the working part – 62-65HRC | Extremely fine-grained martensite 2 points of GOST 8233-56 scale with carbides. Non-uniform etchability (Fig. 2, c) | 10 points | Carbide inhomogeneity - 4A point scale No. 1. Coarse lines of large angular carbides are observed with chipping of carbide particles merging into long sections (Fig. 2d) |
| Tool  | Description                                                                 | Steel - P18  | Hardness | Martensite | Carbide inhomogeneity | Notes                                                                 |
|------|-------------------------------------------------------------------------------|--------------|----------|------------|------------------------|----------------------------------------------------------------------|
| Tap  | Destruction in the transverse direction of the working part of the countersink | P18 steel;   | 62-64HRC | 4 points of the GOST 8233-56 scale with carbides largely located along the grain boundaries (Fig. 3, a). The microstructure is not uniformly etched. | Not more than 3 points                                               |
| Broach | Destruction in the transverse direction along the working part. Some of the fractures adjacent to the surface have oxides (Fig. 4, a). When checking on a magnetic flaw detector, longitudinal deposits of magnetic powder were found on the surfaces of broaches (Fig. 4, c) | P6M5 steel;  | 63-64HRC | Extremely fine martensite with carbides. In the plane of a longitudinal microsection, longitudinal deposits of magnetic powder are clusters of angular carbides arranged in strips painted during machining. (Fig. 4, b). A crack was detected on the surface (Fig. 4, d) | 9-10 points |
| Drill | Mass breakdown. When checking with a magnetic flaw detector, deposits of magnetic powder in the form of thin longitudinal strips are observed on the surfaces for chip exit (Fig. 5, a) | P6M5 steel;  | 62-65HRC | Martensite with carbides. Carbides are large, form wide clusters, elongated in the direction of rolling. Martensite in the area of carbide accumulations - medium needle 5 points, in other places - hidden needle 1 point of the scale (Fig. 5, c, 5, d) | Carbide inhomogeneity corresponds to 4 points of scale No. 2 GOST 19256-73 |
| Gear cutter | Chipping of the working edge is observed on the gear cutter (Fig. 6, a)       | P18 steel;   | 62-64HRC | Very fine-needle martensite 2 points of the scale with eutectic carbides (Fig. 6, b; 6, d). Cracks passing through the accumulations of large carbides were found on the cutting edges (Fig. 6, c) | Carbide inhomogeneity has a slightly deformed cellular structure, consisting of clusters of unbroken eutectic (Fig. 6, d) |
### Table 2. Influence of types of carbide heterogeneity on the operational properties and production technology of cutting tools.

| Types of carbide inhomogeneity | The effect of carbide inhomogeneity of the cutting tool | Operational properties | Production technology |
|--------------------------------|--------------------------------------------------------|------------------------|-----------------------|
| Carbide lines                  | Coming to the surface, they are stress concentrators, which leads to the development of cracks |                        | A noticeable anisotropy of mechanical (strength and toughness) and physical properties appears in the longitudinal and transverse directions. Heat treatment of such steels is accompanied by increased deformation. |
|                                | A noticeable anisotropy of mechanical (strength and toughness) and physical properties appears in the longitudinal and transverse directions. Heat treatment of such steels is accompanied by increased deformation. |                        | 1) The concentration of stresses during hardening increases due to the inhomogeneity of the chemical composition of austenite. In this case, the steel has a grain of not the same size. In this regard, the sensitivity of steel to cracking during hardening of steels with an uneven distribution of carbides increases. 2) Chipping carbides hinder grinding and polishing tool |
| Broad clusters of carbides     | 1) the connection of large carbides with the matrix is reduced, which facilitates their chipping in the working edge; 2) going to the surface of areas with reduced microhardness reduces the fatigue strength of the cutting edge; 3) chipping carbides acting as abrasives | 1) The concentration of stresses during hardening increases due to the inhomogeneity of the chemical composition of austenite. In this case, the steel has a grain of not the same size. In this regard, the sensitivity of steel to cracking during hardening of steels with an uneven distribution of carbides increases. 2) Chipping carbides hinder grinding and polishing tool | |
|                                | Uneven structure. Around the accumulations of carbides, areas of medium-needle martensite with a large amount of residual austenite are observed, forming areas with reduced microhardness. Uneven grain sizes |                       | 1) The stress concentration increases during quenching due to heterogeneity of the austenite chemical composition 2) Chipping carbides hinder grinding and polishing tool |
| Carbides deposited at the grain boundaries in the form of a grid | Strength decreases | - | |
| Eutectic carbides arranged in a cellular structure | Large carbides crumble, reaching the surface of the working edge, forming stress concentrators. Cracks develop in large accumulations of carbides. | 1) The stress concentration increases during quenching due to heterogeneity of the austenite chemical composition 2) Chipping carbides hinder grinding and polishing tool | |

**Figure 1.** The microstructure of the countersink 1.  
a) medium-needle martensite and troostite in areas with accumulations of eutectic carbides; b) carbide inhomogeneity 6-7 points (scale No. 1) with eutectic carbides
Figure 2. The microstructure of the countersink 2.
a) deposits of magnetic powder in the form of thin longitudinal lines on the surface of the grooves for chip exit; b) deposits of magnetic powder in the form of thin longitudinal lines; c) uneven etching of the microstructure; d) coarse lines of large angular carbides with chipping carbide particles merging into long sections of length.

Figure 3. The microstructure of the tap.
a) Fine-needle martensite 4 points with carbides in a significant part located at the grain boundaries; b) cavities from spun out carbides x100; c) cavities from spun out carbides x500.
**Figure 4.** The microstructure of the broach.
a) oxides on the surface of fractures; b) accumulations of angular carbides lined up in strips; c) longitudinal deposits of magnetic powder on the surfaces of broaches; d) surface crack.

**Figure 5.** The microstructure of the drill.
a) deposits of magnetic powder in the form of thin longitudinal strips; b) cracks passing through longitudinal accumulations of carbides; c) a crack in longitudinal accumulations of carbides; d) austenitic grains 7-8 points in the area of accumulation of carbides.
Figure 6. The microstructure of the gear cutter.

a) chipping of the working edge; b) fine-needle martensite with eutectic carbides; c) cracks on the cutting edges passing through the accumulations of large carbides; d) the carbide inhomogeneity has a labially deformed cellular structure consisting of accumulations of unbroken eutectics.

References

[1] Artinger I 1982 Tool steels and their heat treatment Handbook: trans. with Hungarian. M.: Metallurgy 312 p
[2] Skrynchenko Yu M and Pozdnyak LA 1977 Serviceability and properties of tool steels Kiev "Naukova Dumka" 168 p
[3] Geller Yu A 1983 Instrumental Steel 5th ed., Rev. and add. M.: Metallurgy 527 p
[4] GOST 19265-73 2003 Bars and strips from high speed steel. Technical requirements (with Amendments 1-6) M.: Publishing house of standards 87 p
[5] Bondar OV and Smirnov AN 2015 Solutions for reducing carbide inhomogeneity and improving the properties of cold deformation stamped steel Collection of materials of the VII All-Russian scientific-practical conference of young scientists with international participation Kemerovo, Kuzbass State Technical University named after T.F. Gorbachev 649 p
[6] Antipov VI, Vinogradov LV, Lukina Yu A, Kolmakov AG, Doronin DI, Baranov E E and Mukhina Yu E 2017 Influence of carbide heterogeneity in the structure of high-speed steels R6M5 and 130R12M3F3K10-Sh on their physical and mechanical properties VII International Conference "Deformation and Fracture of Materials and Nanomaterials". Moscow. November 7-10, 2017 p 951
[7] Girshov VL, Korotkikh MT, Krupnova IV and Korobeinikov NV 2011 High-performance tool made of powder high-speed steels with dispersed structure Metalworking, publishing house "Polytechnica" (St. Petersburg, ISSN: 1684-6702, №4 (64) pp 44 - 48
[8] GOST 8233-56 2004 Steel. Microstructure standards (Moscow: IPK Publishing house of standards) p 5
[9] GOST 5639-82 2003 Steels and alloys. Methods for detecting and determining grain size (Moscow: IPK Publishing house of standards) 16 p
[10] GOST R ISO 9934-1-201.1 2013 Non-destructive testing. Magnetic particle method. Part 1. Basic requirements (Moscow: Standartinform) 16 p
[11] GOST 9013-59 2001 Metals. Rockwell hardness measurement method (with Amendments No. 1, 2, 3 with Amendment M.: IPK Publishing house of standards) 7 p