

Applications of HSS alloys for the production of planetary core cutting heads for tapping holes

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Abstract. This article provides for the possibility of manufacturing crown cutters from foreign-made high-speed steel HSS, which is not inferior to other similar alloys. The article presents the geometric parameters for the manufacture of a new crown cutter and its use in the field of mechanical engineering for cutting holes in the manufacture of machine parts and rolled products. An example is also given of connecting new pipeline lines to an existing pipeline, which is under pressure up to 2.5 MPa, in heat supply and water supply networks. Methods for eliminating vibration when cutting holes on pipes and rolled products using special lubricating coolants are considered. An example of an invented device design is given that cuts holes in pipeline networks used under pressure up to 25 MPa in hydrometallurgical plants for gold mining and in the chemical and oil industries. A practical example of replacing expensive (tungsten) carbide alloys with foreign high-speed alloys HSS is also presented.

1 Introduction

Since the advent of machine-building production, work to improve cutting (hole) tools has been carried out all over the world, in ever increasing volumes. This is evidenced by thousands of patents for new designs of cutting tools at annual international and national exhibitions. Teams of research institutes and laboratories, design bureaus of numerous companies and manufacturing enterprises are constantly working in this area. Work to improve cutting crown tools is closely interconnected with the development of machine tool industry, which poses the task of creating new designs of cutting tools. In turn, the emergence of new cutting materials and the design of new types of cutting tools leads to constant improvement and updating of the machine and metalworking areas. The main goals of this work are wear resistance, chip formation during the technological process, increasing processing productivity, meeting ever-increasing requirements for the accuracy and quality of surfaces of manufactured parts, and increasing economic efficiency when using new cutting tools.

Cutting tools used in machining form the external, internal, shaped and combined surfaces of parts. The performance of such a tool can be ensured only if its working part is made of

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instrumental material that has a set of certain physical and mechanical properties. High-speed steel must have high hardness, wear resistance, ensuring the preservation of the cutting edge of the tool, sufficient strength and toughness (for impact tools). The cutting edges of the tool can heat up to 500 - 900 °C. In these cases, the main property of high-speed materials is heat resistance, as well as the ability to maintain high hardness and cutting ability during prolonged heating. For example, HSS high-speed steels differ from carbon and low-alloy tool steels by their high degree of alloying with tungsten, molybdenum, chromium and vanadium. As a result of heat treatment of high-speed steels, alloying elements give them high red-hardness (up to 620°C), carbon - hardness (up to HRC 63 - 64), and alloying elements and carbon - bending strength (up to $\sigma_v = 3000 - 3500$ MPa).

Therefore, the cutting speed with tools made of high-speed steels is 4 - 6 times higher than the cutting speed with tools made of tool steels ($v = 25 - 50$ m/min, 600°C). Due to their high strength, high-speed steels are widely used, especially for the manufacture of complex-shaped tools (drills, cutters, thread-cutting and gear-cutting tools). HSS steel covers a wide range of materials and alloys. The abbreviation HSS (High Speed Steel) is used for foreign grades of high-speed steel, but under this marking there can be different types of high-carbon steels and alloys. The HSS group includes several grades of foreign steels, which are characterized by increased strength and hardness in cold and hot states. Let's try to figure out what exactly is called high-speed steels, consider the main characteristics, composition, mechanical properties and areas of application. HSS steel is used to produce tools intended for high-speed processing of metal workpieces.

High-speed steel HSS has excellent performance properties that distinguish the material from its carbon analogues and hard alloys. Under normal conditions, the hardness of carbon-containing steel is higher than that of high-speed steel. However, during the processing of a metal workpiece, significant heat transfer occurs, which triggers tempering processes and reduces the initial strength. Carbon steel has a temperature threshold of heat resistance of 200 degrees. HSS steel is capable of maintaining its properties at temperatures of 500-600 degrees.

2 Materials and methods

Features of the manufacture and heat treatment of HSS steels - in the manufacture of high-speed steels, several technologies are used, with special attention paid to forging. The quality of the material depends on the forging, and if forging is insufficient, carbide segregation processes occur. To improve the performance properties and characteristics of HSS steel, they undergo mandatory heat treatment using three basic techniques:

Annealing. Helps eliminate internal tensions of the material, improves the alloy's workability and subsequent hardening;

Hardening. Helps increase the red resistance of steel. The material is hardened at a temperature of +1300 degrees; exceeding this regime is not allowed in order to avoid the appearance of melting and graininess. Therefore, the hardening temperature is always maintained with maximum accuracy;

Vacation. This definition means cyclic cooling to a temperature of 550-560 degrees. The alloy is released at intervals of 60 minutes.

To increase the wear resistance of the HSS material, additional methods for chemical-thermal treatment are used. The essence of the process is that reinforcing components are added to the structure of the alloy, which penetrate the molecular crystal lattice. There are 3 methods to increase and improve the performance characteristics of modern high-speed steel HSS:

Nitriding. Exposure in a gas environment to saturate the material with nitrogen. Occurs at a temperature of 500-600 degrees, for 10-40 minutes. The process helps strengthen the surface layers;

Cyanidation. Saturation with zinc in a liquid or gaseous medium to improve wear resistance. The process can be high temperature or low temperature;

Sulfidation. Heating in sulfur-nitrogen salt, which promotes saturation with sulfur, increases the strength and wear resistance of cutting edges.

Figure (1,2,3) shows the main geometric parameters for obtaining an improved rod cutting tool from high-speed steel for cutting holes in metal structures and for installing pipeline parts with pressure up to 2.5 MPa.

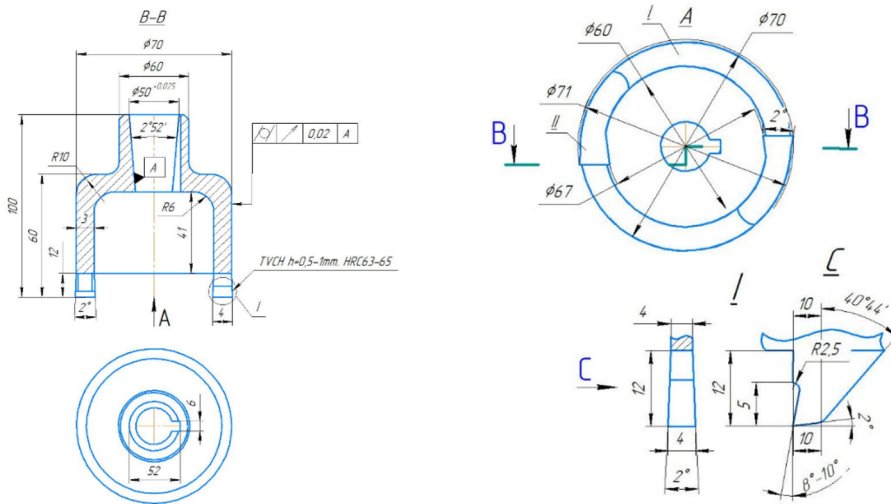


Fig. 1. The drawing shows an improved core cutting tool made from HSS material.



Fig. 2. Advanced core cutting tool made from HSS material.



Fig. 3. The process of cutting holes in metal structures.

3 Results and discussion

Experiments have shown that at ultra-high speeds the wear rate is reduced compared to conventional cutting. Already today, in the leading countries of the world, high-speed and ultra-high-speed processing is used at cutting speeds of 500 - 1500 m/min and more, which is only possible when creating new types of tool materials. and more advanced machines. Due to the high costs of coolant (up to 16% of the cost of processing parts), much attention is currently paid to the so-called “dry processing” of cutting, also without the use of coolant. In cases where complete elimination of them is impossible, for example, when drilling, it is recommended to process using a minimum amount of coolant, the so-called MMS technology (Minimalmengenschmierung), which consists of cooling the cutting zone with a small amount of coolant supplied under pressure to 0.6 MPa using air flow. The consumption of coolant, converted in this case into an aerosol, usually does not exceed 80 ml/h. This eliminates the costs of preparing and disposing of coolant, cleaning chips, etc. For example, according to the company “Gühring” (Germany), when deep drilling an aluminum alloy with gun drills for holes with a diameter of 10 mm and a depth of 200 mm, with this method of supplying oil coolant (through internal holes in the drill), it was possible to increase the tool life by 4 times, feed rate – 3 times, and cutting speed increased from 130 to 160 m/min [1,2].

Increasing the rigidity and vibration resistance of cutting tools makes it possible to increase their durability, increase feed, and, consequently, the productivity of the cutting process. For axial tools, this is achieved by increasing the cross-sectional area of the tool bodies and minimizing the length of the working part; when processing deep holes, this is achieved by using additional supports in the form of guides, rod stops, vibration dampers and other devices.

When designing multi-blade cutting heads, the issue of rational load distribution between the cutting teeth (edges) becomes of great importance, this development is optimal for cutting metals. For example, the design of the entire production (Figure 2) of a planetary cutting head uses modern high-speed steel HSS, this allows us to increase the reliability of the cutting operation of the cutting tool during the technological process, intensifies the cutting modes, and ensures quick replacement when they wear out, which is especially important for cutting holes on any metal structure and pipeline parts (Figure 3).

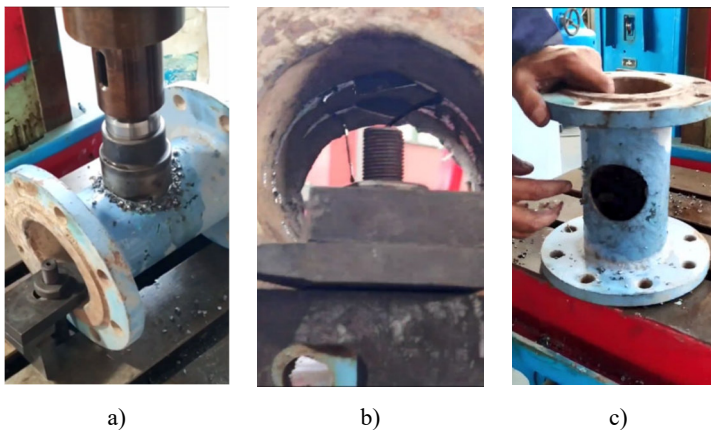


Fig. 4. The process of cutting a pipe $\text{Ø}109\text{X}4.5$ using crown cutters: a) external view of the cutting process; b) internal view of the pipe cutting process; c) after finishing cutting the hole.

This newly invented design (planetary cutting head) will allow us to create a wide range of products for the manufacture of crown planetary cutters and other types of tools of the latest designs. With the growth of technological progress, modern machines are becoming

more powerful and fast; in order to increase the reliability and durability of machine parts, ensure operation without vibrations and dynamic overloads, high demands are placed on the dimensional accuracy, shape and quality of the surfaces of their parts. In this regard, first of all, the requirements for the accuracy of cutting tools are being tightened.

Tools for production are characterized by even narrower tolerances on the final dimensions and runout of the cutting edges, the quality of the surfaces of the part and the yield of chips from the cut hole shown in Figure 3 [3,4].

HSS steels are considered high carbon, typically HSS steel tools have a hardness of 62-64 HRC. The main advantage in comparison with carbide tools is the durability and lower price of the tools. HSS steel performs well in interrupted cutting of carbon and alloy steels, the use of HSS material for the manufacture of cutting tools may have a low cutting speed compared to carbide, but is effective.

HSS steels are divided into three main groups:

- Tungsten (T);
- Molybdenum (M);
- High-alloy high-speed steels.

Tungsten steels are currently practically not used due to the high price of tungsten and its shortage. The most used are general purpose steels, such as T1, as well as steel with vanadium and cobalt, for example, T15. T15 steel is used for the manufacture of tools operating at high temperatures and subject to increased wear.

- M1: Used for the production of drills for various applications. M1 steel has less red resistance than M2 steel, but is less susceptible to impact and more flexible.
- M2: The most common material for making tools from HSS steels. M 2 retains its cutting edge for a long time and has good red resistance. Unlike other HSS steels with lower tungsten content, M2 is typically used for making tools in high-performance machine applications, such as drilling machines.

M7. Used for heavy construction drills when drilling hard sheet metal. This HSS steel is used where flexibility and increased service life are required.

M50. Used to make drills that are used for drilling on portable equipment. Does not have the same red resistance as other tungsten HSS steels.

M35. M35 steel has a higher red resistance compared to M2. At the same time, cobalt slightly reduces the resistance to impact loads.

M42. Steel M42 " Super Cobalt " has excellent wear resistance and high red-hardness. Used when working with viscous and difficult materials.

HSS-R (or simply HSS) is a designation on products that have undergone roller rolling and heat treatment. Such products have the lowest durability.

HSS-G - designation on products that are made of HSS steels, the cutting part is ground with CBN (cubic boron nitride). The products have increased durability and less radial runout. HSS-G tools are the most common and are used to solve standard problems.

HSS-E – in products made from HSS steel type M35, cobalt is added. Used when working with viscous and complex materials. There are also such markings as HSS Co 5 and HSS Co 8, which indicate cobalt content of 5 and 8%.

HSS-G TiN - this marking indicates the deposition of titanium nitride. This coating allows increasing surface hardness by approximately 2300 HV and heat resistance up to 600°C.

HSS-G TiAlN - surface of products coated with titanium-aluminum-nitride. This coating allows increasing surface hardness by approximately 3000 HV and heat resistance up to 900°C.

HSS-E VAP - VAP is used for processing stainless steels (V2A and V4A). It is obtained by “evaporating” the oxide non-metallic layer. This reduces the adhesion of workpiece chips

to the tool surface, which can lead to product failure. The result is improved surface quality and VAP improves adhesion of the coolant to the tool surface.

The designation of foreign manufacturers does not fully disclose the chemical composition of the HSS steel from which cutting tools are made. A particular tool is assigned a specific task, which is described in the catalog. Other details can be determined by determining the chemical composition. This can be done using a portable metal analyzer or by testing products experimentally [5,6].

Steels with high vanadium and carbon content are very resistant to abrasive wear. The type of steel from M42 is characterized by high hardness when working at high temperatures, or the term used is red resistance. Molybdenum steels are also used in the production of tools used in “cold” conditions - rolling dies, cutting dies. In such cases, HSS steels are hardened to lower temperatures to increase toughness. HSS steel is capable of maintaining cutting properties at high temperatures for 4 hours without loss of hardness. High-speed steel is characterized by its resistance to brittle fracture. It easily tolerates vibrations, shocks, high feeds and deep cuts.

To select the correct cutting tool (core cutter, countersink, core drill or step drill), check the “Short-term strength limit” value. The short-term strength limit is called the " Mechanical Properties" of the cutting tool. Tensile strength is the maximum mechanical stress above which destruction of the material subjected to deformation (in this case, blade processing using a cutting tool) occurs.

Tensile strength is indicated in (Table 1) of mechanical properties, with the letters σ in MPa, and is measured in megapascals (MPa). In regulatory documentation and standards this is referred to as “temporary resistance”.

Table 1. Mechanical properties of high-speed steel HSS.

Special steel appointments	Steel grade and application	Temporary resistance (Tensile strength) MPa/mm ²
Special high-alloy high-speed steel	HSS - designed for drilling and machining holes in steels of normal and high strength quality	up to 90 MPa

Additionally, the cutting tool is reinforced with a hardening coating, which effectively contributes to increased wear resistance of the metalworking tool. For drilling and/or cutting holes in durable and high-quality steels, it is recommended to use a cutting tool made entirely of special powder steel with the ability to process materials with a strength of up to 140 MPa/mm². The increase in hardness and deformation resistance depends on the content of the chemical compositions of high-speed steels [7,8,9] (Table 2).

Table 2. Of general chemical compositions of HSS steels and Russian analogues.

English Name	Russian analogue	Chemical composition, %								
		C	Mn	Si	Cr	V	W	Mo	Co	Ni
Tungsten HSS steels										
T1	P18	0.75	-	-	4.00	1.00	18.00	-	-	-
T2	R18F2	0.80	-	-	4.00	2.00	18.00	-	-	-
T4	R18K5F2	0.75	-	-	4.00	1.00	18.00	-	5.00	-
T5	-	0.80	-	-	4.00	2.00	18.00	-	8.00	-
T6	-	0.80	-	-	4.50	1.50	20.00	-	12.00	-
T8	-	0.75	-	-	4.00	2.00	14.00	-	5.00	-
T15	R12F5K5	1.50	-	-	4.00	5.00	12.00	-	5.00	-
Molybdenum HSS steels										
M1	-	0.80	-	-	4.00	1.00	1.50	8.00	-	-
M2	R6M5	0.85	-	-	4.00	2.00	6.00	5.00	-	-

M3	R6M5F3	1.20	-	-	4.00	3.00	6.00	5.00	-	-
M4	-	1.30	-	-	4.00	4.00	5.50	4.50	-	-
M6	-	0.80	-	-	4.00	2.00	4.00	5.00	-	-
M7	-	1.00	-	-	4.00	2.00	1.75	8.75	-	-
M10	-	0.85- 1.00	-	-	4.00	2.00	-	8.00	-	-
M30	-	0.80	-	-	4.00	1.25	2.00	8.00	-	-
M33	-	0.90	-	-	4.00	1.15	1.50	9.50	-	-
M34	-	0.90	-	-	4.00	2.00	2.00	8.00	-	-
M35	R6M5K5	0.82- 0.88	0.15- 0.40	0.20- 0.45	3.75- 4.50	1.75- 2.20	5.5- 6.75	5.00	4.5- 5.5	up to 0.30
M36	-	0.80	-	-	4.00	2.00	6.00	5.00	-	-
High alloy HSS steels										
M41	R6M3K5F2	1.10	-	-	4.25	2.00	6.75	3.75	5.00	-
M42	-	1.10	-	-	3.75	1.15	1.50	9.50	8.00	-
M43	-	1.20	-	-	3.75	1.60	2.75	8.00	8.25	-
M44	-	1.15	-	-	4.25	2.00	5.25	6.25	12.00	-
M46	-	1.25	-	-	4.00	3.20	2.00	8.25	8.25	-
M47	R2AM9K5	1.10	-	-	3.75	1.25	1.50	9.5	5.00	-
M48	-	1.42- 1.52	0.15- 0.40	0.15- 0.40	3.50- 4.00	2.75- 3.25	9.50- 10.5	0.15- 0.40	8.00- 10.0	up to 0.30
M50	-	0.78- 0.88	0.15- 0.45	0.20- 0.60	3.75- 4.50	0.80- 1.25	up to 0.10	3.90- 4.75	-	up to 0.30
M52	-	0.85- 0.95	0.15- 0.45	0.20- 0.60	3.50- 4.30	1.65- 2.25	0.75- 1.50	4.00- 4.90	-	up to 0.30
M62	-	1.25- 1.35	0.15- 0.40	0.15- 0.40	3.50- 4.00	1.80- 2.00	5.75- 6.50	10.0- 11.0	-	up to 0.30

4 Conclusion

In practice, it has been proven that a cutting head made of tungsten alloys becomes unusable when cutting metals due to vibration from the resulting friction between the metals and the cutting edges. The cutting tool (head) is not inferior in all respects to analogues in which the cutting edges are made of tungsten alloys. A cutting head made of HSS steel is lighter and convenient for cutting holes on metal structures and on pipelines in the drinking water line, this will make it possible to save time for installation work, as well as money for all industries of the Republic of Uzbekistan. High-speed alloys and its foreign analogues HSS are cheaper than tungsten alloys, since the manufacture of cutting heads from these alloys for any engineering enterprises will be cheaper than tungsten alloys. The implementation of the design of cutting tools (of various types) from these alloys for metal processing in piece production guarantees savings in foreign currency in the industry of the Republic of Uzbekistan.

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