

**Research Article**

## **Powder Sintering of High Speed Steel**

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### **ABSTRACT**

The article shows the important role of the use of powder materials in metallurgy, presents the investigations of high-speed steel R6M5 powders, obtained by electroerosion dispersion in kerosene environment. The results of studies on the particle size distribution, particles sintering, and the results of measurement of the microhardness and density of the sintered samples are shown. In particular, it was found that the average particle size is 26,72 microns, microhardness of sintered blank is 212 HV, the main elements are Fe, W, V, and Cr.

**Keywords:** powder high speed steel, electroerosion dispersion, size distribution, density, microhardness.

### **1. INTRODUCTION**

An important direction of mechanical engineering technology development is currently the improvement of existing and development of new waste-free, environmentally friendly, material-safe production processes, i.e. such processes, which provide producing of preforms with minimal allowances for subsequent machining or none at all, while reducing consumption of scarce materials. In solution of this problem a certain role belongs to a powder metallurgy.

Despite the fact that the production volume of the powder alloys is small and is only 0,1% of the total production volume of metals, they are very important in the national economy and their field of application is very wide. Thus manufacturing of many alloys is practically possible only from

powder, for example, the production of hard cermet alloys.

### **2. OBJECT DESCRIPTION OF RESEARCH**

Powders, that are used in powder metallurgy, consist of a particles size of 0,01 - 500 micrometers. By the method of electroerosion dispersion metal powder of high speed steel R6M5 brand was obtained. Instrumental speed steels, created in 1902, up to the present time are the main tool material from which up 60% of the instruments, used in industry, are made.

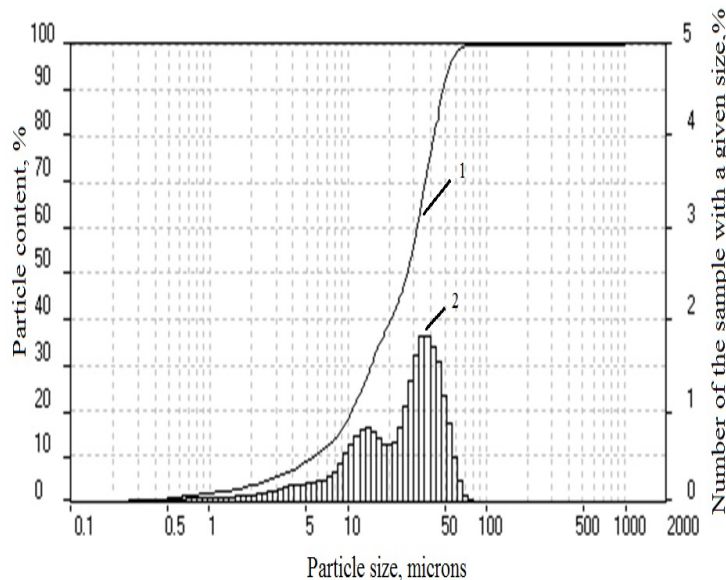
High-speed steels powders are used for the manufacture of cutting and forming tools by hot compaction. The most effective use of high-speed steels powder is for the manufacture of large sizes

tools, small tools, tool, working in aggregative machines and machining centers, bimetallic tool. The particles, obtained from waste of HSS R6M5 by electroerosion dispersion in kerosene, were analyzed, using a laser particle size analyzer «Analysette 22 NanoTec», for determining the distribution of the obtained powder particles in sizes. Laser diffraction has several important advantages, such as short analysis time, good reproducibility and precision, simple calibration, large measurement range (0,01 to 2000 microns) and high universality [1-7]. Powder size distribution of microparticles was determined by dispersing in a liquid with ultrasound. Dispersing was carried out by the

method of Fraunhofer according to the FR 1.27.2009.06762 in two stages. Initially we measured the background - in order to reduce the influence of the measuring liquid.

Further - measurement of particle size distribution: test sample of about 5,1 g was placed in the module for dispersion in a liquid (500 ml.). The measurement started automatically as soon as the absorbance value reached the specified value. Measuring range - 0.1 [micrometers.] - 1021.87 [micrometers.]; resolution - 102 channel (20/383 mm.); Absorption - 10.00%; measuring time - 90 (scans); regularization - average model.

The results of particle size measurement are presented in Table 1 and Figure 1.



**Fig. (1).** - The size distribution of the powder sample microparticles of high speed steel (kerosene working fluid): 1 - integral curve; 2 – histogram

It was found that the average particle size is 26,72 microns arithmetic value – 26,725 microns, surface area – 6725,95 cm<sup>2</sup> / cm<sup>3</sup>. Form is correct, spherical and elliptical. Next stage of work with resultant powder is its pressing. In this article we consider the method of isostatic pressing. Isostatic pressing is pressing in an elastic shell under hydrostatic compression. If the

compressive force is a liquid, so it is called a hydrostatic pressing, and if the gas - gasostatic [4]. In hydrostatic pressing powder is filled into a rubber shell, placed in a working humidistat chamber, in which the desired fluid pressure is created (Figure 2) with a high pressure pump.

**Table 1** - Results of the study of the microparticlessize distribution.

The particle diameter, microns	Name
	Powder from the HSS (drills (kerosene working fluid))
D10, 10% from total amount of particles	5,707
D50, 50% from total amount of particles	27,084
D90, 90% from total amount of particles	48,164
The volume mean diameter	26,72
The average diameter of the surface area	8,92
The average diameter in relation to volume	1,41
The average diameter relative to the area	0,56
The average diameter relative to the length	0,34

As liquid oil, water, glycerol may be used. In this type of pressing almost no friction of the powder particles about shell walls as the ones which are adjacent to the shell are moved together with it. Equality and uniform of compressive forces in all directions leads to lateral pressure that is equal to one. The density of the different sections of the resulting compact is almost identical.

The powder, which is in the shell, before the application of pressure thereto subjected to vibration for ensuring of uniform filling density and degassing, since the air existing in the pores of the filling, will prevent compaction.

Cylinders, tubes, balls and other items are obtained hydrostatic compression. The disadvantages of hydrostatic compression include difficulty of obtaining briquettes of sizes close to the target and the need for mechanical processing in manufacturing of products of precise shapes and sizes, as well as the low productivity of the process. Isostatic pressing is not widespread because of the complexity of the design of the press devices.

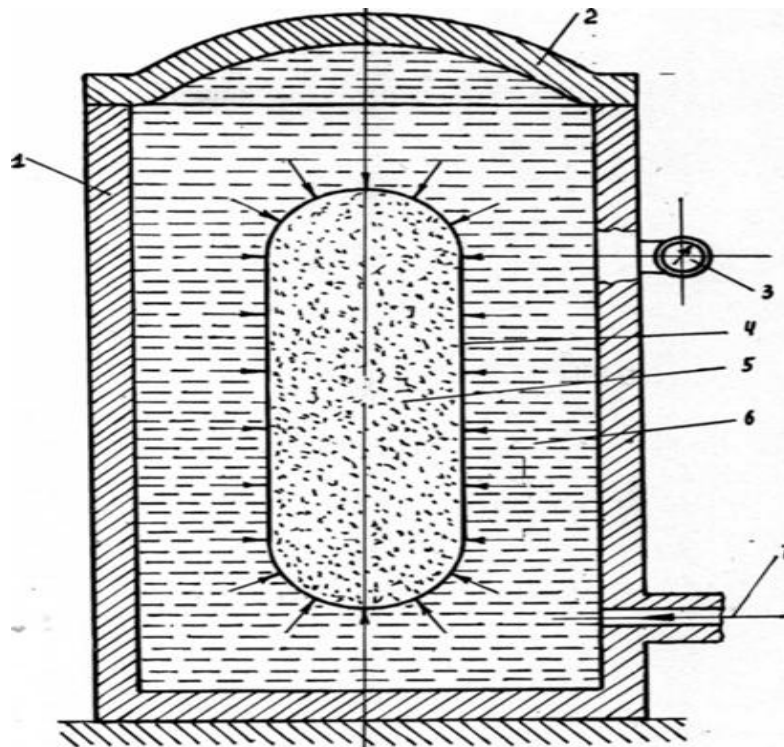
It can be carried out at room temperature or at elevated temperatures. Pressing at high temperatures, is combined with a sintering process and allows to obtain products of almost any material with a relative density close to the theoretical value.

As a result the pressed samples were obtained, which are ready for further sintering.

Powders of large size are better pressed, especially if among them there are small particles, and powders of small sizes are sintered better. Granularity of powders is determined by sieve analysis: powder is sieved through a series of sieves with increasingly small openings and weigh each sieve residue from. The shape of the grains is determined by considering them under a microscope with a grid eyepiece. Bulk weight of the powder is determined by the weight of 1 cm<sup>3</sup> freely poured powder. It depends on the size, shape and surface conditions of its particles and is a very important characteristic.

For the sintering of powder alloys electric furnaces with a metallic resistance, with carbon resistances as tubes and high frequency furnaces are used. During sintering of tungsten, molybdenum, hard alloys, magnetic and electrotechnical materials, hydrogen is used. The sintering temperature is about 2/3 of the melting point of the metal, for example for copper - 800-850 °C, for iron - 1050-1150 °C.

Sintering duration is about 2-3 hours. There are two basic types of sintering - a one-component system sintering, sintering of a multicomponent system with or without the formation of a liquid phase.



**Fig. (2).** - Scheme of hydrostatic pressing of powders. 1 - humidistat chamber housing; 2 - a cover; 3 - manometer; 4 - elastic shell; 5 - powder blend; 6 - a liquid; 7 - supply of liquid from the high-pressure pump/

During sintering the following sawing occur: an increase in temperature increases the mobility of the atoms, there is a change of the contact surface of the particles, which is largely increased; stress relief occurs in the contact areas, and recrystallization, accompanied by grain growth through the contact surfaces; oxides are restored and the adsorbed gases and liquides are removed and inthe result contact becomes metallic. Sintering was performed at  $t = 950\text{ }^{\circ}\text{C}$  ( $t_{\text{melt}} = 1450\text{ }^{\circ}\text{C}$ ) for 1 hour in vacuum at a pressure  $P = 300\text{ MPa}$ .

For comparison of quality characteristics of the material before and after sintering at a number of density measurements was conducted.

Device for the study of density AccuPyc 1340- is a fast, fully automatic device that provides high-

speed and high-precision measurement of the amount and calculation of the true density of powders, hard materials, pastes, concentrated suspensions and liquids with a low vapor pressure, with the volume of 0, 01 to 350  $\text{cm}^3$ . Analysis time is 2-3 minutes.

Without the intervention of the operator data is collected, calculations are performed, accurately and reliably the results are displayed. Operation principle consists in placing the sample in a calibrated chamber filled with helium. Gas molecules penetrate into the smallest pores of the sample. That is, the sample displaces a volume of gas equal to the volume of the only a truly solid phase. If the pre-weight of the sample was introduced, the device calculates its density [6].

**Table 2** - Summary information on the study of density before sintering.

Consolidated data	Average values	Standard error
Volume, $\text{cm}^3$	1,1441	0,0012 $\text{cm}^3$
Density, $\text{g/cm}^3$	5,6115	0,0057 $\text{g/cm}^3$

Total pore volume, cm <sup>3</sup> /g	0,8218	–
Temperature, °C	23,04	–

**Table 3** - Summary information on the study of density after sintering.

Consolidated data	Average values	Standard error
Volume, cm <sup>3</sup>	0,7634	0,0058 cm <sup>3</sup>
Density, g/cm <sup>3</sup>	5,6856	0,0440 g/cm <sup>3</sup>
Total pore volume, cm <sup>3</sup> /g	0,8241	–
Temperature, °C	23,38	–

It is mandatory to study the microstructure and elemental composition of the samples, carried out by scanning electron microscopy using a scanning electron microscope Quanta 200 3D; as well as hardness testing of coatings on microsections, conducted by an automatic system analysis of microhardness DM-8 by the method of micro-Vickers at a load on the indenter of 300 g in accordance with GOST 9450-76 (Measurement of microhardness by cave of diamond tips). Microhardness - resistance to plastic indentation (usually in a flat surface) of hard tip in the form of a cone or pyramid from diamond. Much rarer tests on the microhardness are carried out by scratching. The difference of tests on microhardness from the normal hardness measurements is very small quantities of the pinch loads and small depth and size of the print. Tests on the microhardness find important applications where other methods are not available:

1) Determination of the hardness of individual microstructural components; microhardness

allows, along with the qualitative microscopic study, to assess the properties of microparts;

2) determination of the hardness of thin surface layers; ordinary hardness tests evaluate the properties of relatively thick surface layers (on the order of a millimeter), while the measurement of microhardness allows to evaluate, for example, the effect of work hardening from polishing, from finishing cutting, from saturation of a very thin surface layer of gases.

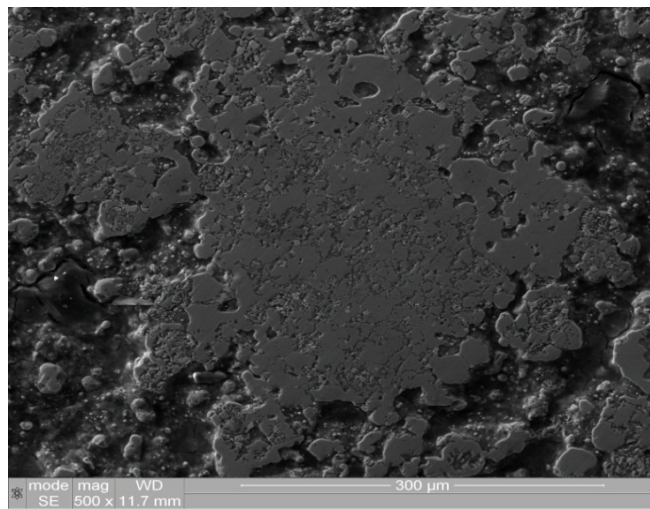
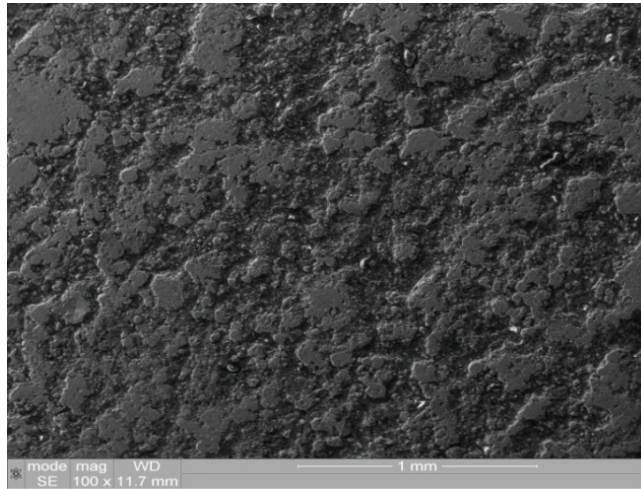
Figure 3 shows the results of a study of the microstructure of the sintered part from high speed steel powder, produced by electroerosion dispersion in kerosene. It is seen that the surface of the product is uniform and has a low porosity. Figure 4 shows the points, at which the elemental composition has been removed. The results of elemental analysis are shown in Figures 5-7.

The microhardness of the sample is presented in Table 4.

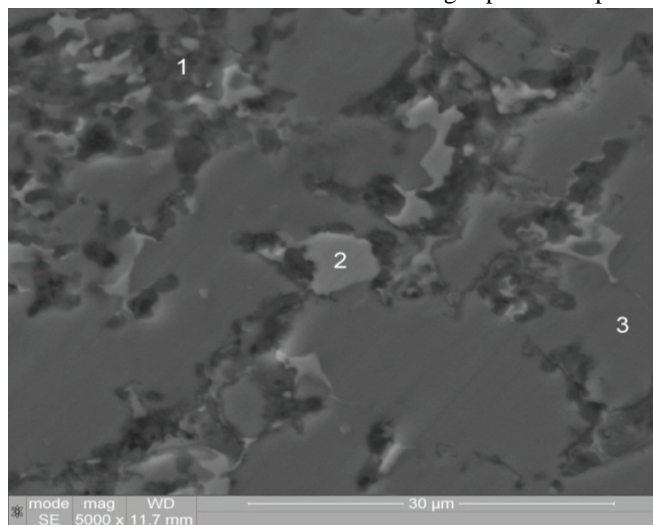
**Table 4** - Results of microhardness study of the sample, at a load of 300 g.

Measurement	Value
1	115
2	419
3	419
4	107
5	257
6	208
7	117
8	260
9	132
10	84,9
Average	212

It was found that the average microhardness is 212 HV; main elements are Fe, W, V, and Cr.



**Fig. (3).** - The microstructure of sintered detail from electroerosion high speed steel powder.



**Figure 4** - Points of elemental composition analysis (XRMA)

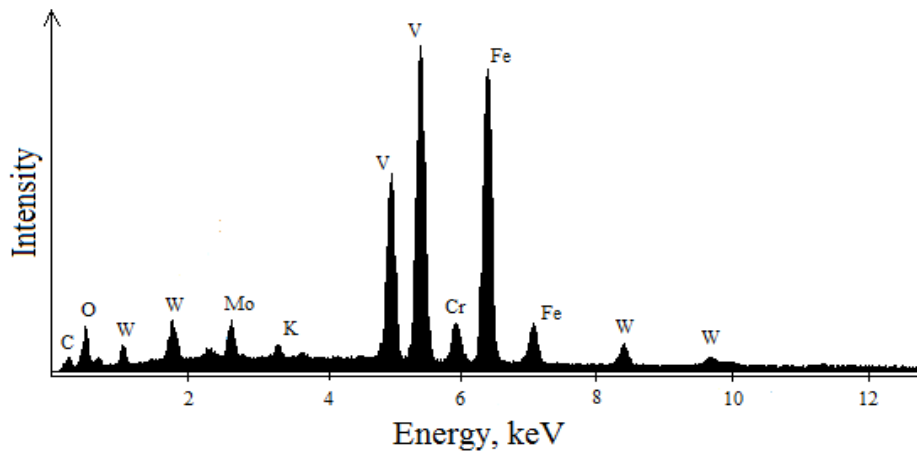


Figure 5 - The elemental composition in point 1

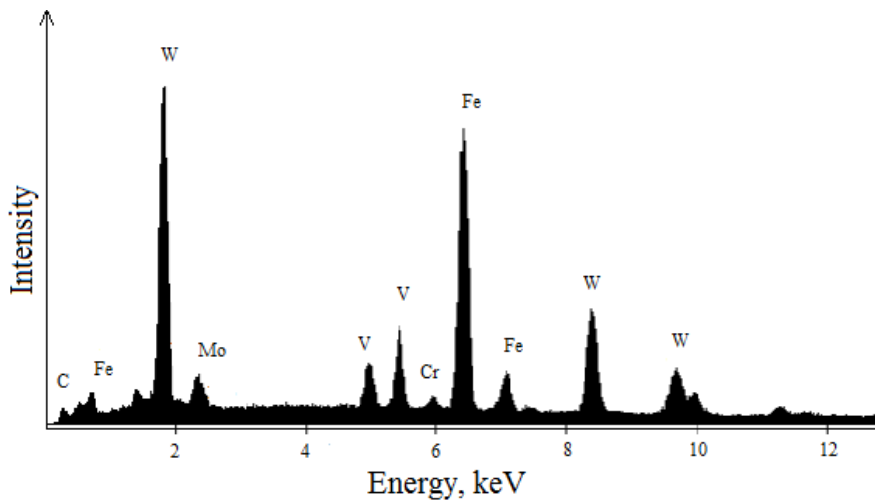


Figure 6 - The elemental composition in point 2

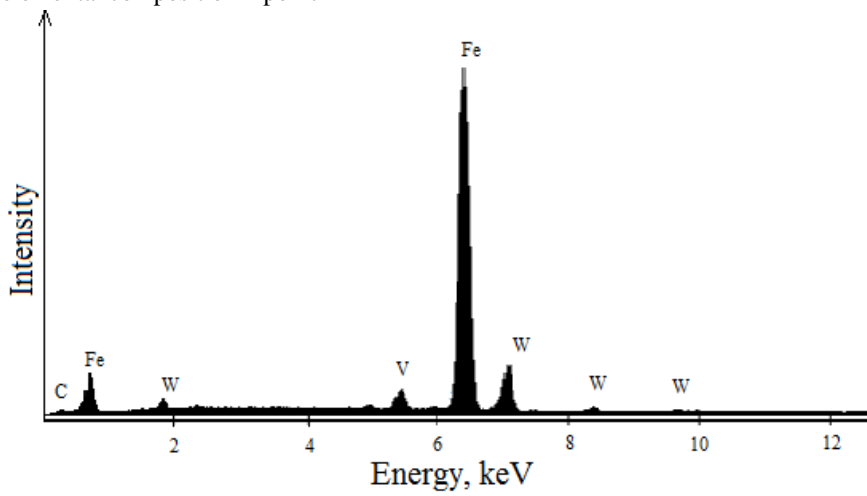


Figure 7 - The elemental composition in point 3

### 3. Findings

On the basis of conducted researches it was found:

- Average particle size is 26,72 microns, there are nanoscale fractions, particles form - spherical;
- The particles have a good compressibility due to a regular geometric shape and dimensions;
- microhardness after sintering is 212 HV (under a load of 300 g);
- Density after sintering increased by 2% and tends to increase with the improvement of technology;
- Main elements are Fe, W, V and Cr.

### 4. CONCLUSION

Thus, these data allow us to estimate potential opportunities of obtaining high-speed steel powder R6M5 by electroerosion dispersion and its further use in powder metallurgy. Based on the above we can conclude about the prospects of the method for producing a powder, and the possibility of its application in various fields of technology.

### Conflict of interests

The author confirms that the provided data do not contain any conflict of interests.

### Thanks

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