of the sprayed layer to the base. The cohesion strength of a coating sprayed with the air-
hydrocarbon plasma is more than three times greater than the cohesion strength of layers
sprayed by the electric arc method. A significant disadvantage of such a method of wire
metallization is the low life of hafnium and zirconium cathodes of standard production plasma-arc heads.

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FORMATION AND SOLID-PHASE SINTERING OF HIGH-SPEED STEEL POWDERS

L. A. Poznyak, K. A. Gogaev, 
V. A. Shtakun, and V. I. Ul'nish

It is known that in production of high-speed steels by powder metallurgy methods macro-
segregation of the materials is completely prevented and microsegregation is significantly 
reduced. As the result of the high cooling rate of the powder there is formed a material with 
a uniform structure and chemical composition, which in its properties exceeds high-speed steel 
produced by the traditional method [1].

At present the most common are production methods [2-4] in the use of which after vacuum 
annealing of the high-speed steel powder follow the processes of cold pressing, sintering, 
and hot plastic deformation, with sintering leading to the presence of the liquid phase. 
However, as the result of liquid-phase sintering there are formed coarse-grained carbides found, 
as a rule, at the grain boundaries, which reduces to a minimum the advantage of the powder 
method, obtaining of a uniform structure. Materials produced from high-speed steel powders 
using these methods have mechanical properties at the level of traditionally produced steels 
since liquid-phase sintering does not provide a high-quality microstructure.

Therefore sintering is one of the basic production operations, as the result of which a 
compact material is obtained from a freely poured powder or cold-pressed powder compacts in 
heating to high temperatures. In this case the structure is formed in the metal and the nec-
essary physicochemical properties are acquired.

This work presents data on the production by different pressing methods of compacts of 
R6M5K5 powders sprayed with inert gas and high-pressure water and also the results of solid-
phase sintering of cold-pressed compacts and sintering under pressure of freely poured powder. 
With spraying by nitrogen the powder particles had a 40-830 μm and with water spraying 40-250 
μm size. The microhardness after annealing was 280-320 HV. The powders were pressed in a 
die with a sectional die with a diam. of D = 30 mm. The H/D ratio after pressing was within 
limits of 1 < H/D < 2.

The differential thermal analysis method established that the temperature of the phase 
transformations, the temperature of appearance of the liquid phase in powder metallurgy

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article submitted June 24, 1988.
TABLE 1. Influence of Static Pressing Pressure on the Density of Powder Preforms

<table>
<thead>
<tr>
<th>Pressing pressure, MPa</th>
<th>Gas sprayed</th>
<th>Water sprayed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>density after pressing, %</td>
<td>density after sintering, %</td>
</tr>
<tr>
<td>0 (freely poured)</td>
<td>60</td>
<td>65.0/70*</td>
</tr>
<tr>
<td>400</td>
<td>72</td>
<td>74.0/76</td>
</tr>
<tr>
<td>600</td>
<td>75</td>
<td>76.5/77</td>
</tr>
<tr>
<td>900</td>
<td>80</td>
<td>81.5/82</td>
</tr>
<tr>
<td>1200</td>
<td>82</td>
<td>83.5/84</td>
</tr>
</tbody>
</table>

*Here and in Table 2 the first figure is for a sintering temperature of 1180°C and the second for 1200°C.

TABLE 2. Influence of the Parameters of Static and Dynamic Pressing on the Density of the Powder Preform

<table>
<thead>
<tr>
<th>Pressing pressure</th>
<th>Gas-sprayed powder</th>
<th>Water-sprayed powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>static, MPa</td>
<td>dynamic, kJ</td>
<td>density after pressing, %</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>4.5</td>
<td>82</td>
<td>83/84</td>
</tr>
<tr>
<td>6</td>
<td>83</td>
<td>84/85</td>
</tr>
<tr>
<td>600</td>
<td>3</td>
<td>83</td>
</tr>
<tr>
<td>4.5</td>
<td>85</td>
<td>86/87</td>
</tr>
<tr>
<td>900</td>
<td>3</td>
<td>87</td>
</tr>
<tr>
<td>4.5</td>
<td>90</td>
<td>90/91</td>
</tr>
<tr>
<td>1200</td>
<td>3</td>
<td>91</td>
</tr>
<tr>
<td>4.5</td>
<td>93</td>
<td>95/96</td>
</tr>
</tbody>
</table>

R6M5K5 steel, is 1225-1230°C. Metallographic investigations showed that at sintering temperatures above 1200°C the carbide phase increases sharply. On the basis of this sintering temperatures of 1180 and 1200°C with an isothermal hold of 0.5 h were selected. The density of the specimens was determined by hydrostatic weighing.

Static Pressing. Because of the undeveloped contact surface the gas-sprayed high-speed steel powders form poorly at forces used in production. It is not possible to obtain a strong compact after static pressing. Therefore such powders are placed in a metal can, sealed, and formed [1, 5] or the powder is cold pressed with a different type of plasticizer.

In static pressing on a DG-2432A hydraulic press with a force of 1600 kN of gas-sprayed powder polyvinyl alcohol in a quantity of 2% of the weight of the powder was used as the plasticizer. Data on static pressing and sintering of R6M5K5 high-speed steel powders sprayed with gas and water is shown in Table 1.

Combined Pressing. In addition to static pressing in closed dies the impact pressing method has obtained wide use in forming of metal powders. The use of the impact pressing method is the result of its advantages in comparison with other methods, the primary of which are [6] the obtaining of high-density parts, the capability of pressing low-plasticity and difficult-to-deform powders, and intensification of the sintering process. The advantages of the impact method increase with use of combined pressing including static and impact compaction of the powder [7].

The authors of this investigation used a combined pressing method which makes it possible to obtain strong compacts for production purposes from gas-sprayed R6M5K5 powder without the use of plasticizers. The prepressed compacts were impact loaded with a rate of application of the load of 15 m/sec and an impact energy of 3-6 kJ. The results of combined pressing and sintering are shown in Table 2.

Combined pressing makes it possible to increase the density of the powder compacts by an average of 10% with the same static pressing pressures. This increase in density was obtained as the result of impact pressing and with an increase in the force of static prepressing the effectiveness of combined pressing increases.