A WEAR-RESISTANT POWDER METALLURGICAL MATERIAL BASED ON TITANIUM CARBIDE

S. A. Tsukerman

To resist abrasive impact wear, a material must possess a combination of properties which are usually incompatible, namely, high strength, hardness, and toughness. Such materials can be produced by powder metallurgy techniques. The object of the present investigation was to develop a method for infiltrating skeletal structures with a tough constituent and study the conditions of preparation of wear-resistant materials for milling equipment.

Infiltration, with a metal or alloy, of porous solid bodies having a skeletal structure is becoming increasingly important as a powder metallurgy operation. Based on the principle of permeation of molten material under the action of capillary forces, this method has already found application in various branches of industry [1-4]. The mechanism of infiltration is determined by the reaction of a refractory solid phase with a liquid infiltrating phase. Infiltration ensures strong bonding between two phases; as a result, it becomes possible to formulate materials exhibiting unusual properties, for instance, simultaneously combining the hardness of a carbide skeleton with the toughness of a suitable infiltrating material, at adequate strength of the resulting composite.

The solid constituent chosen for study was titanium carbide containing 18.34% combined C and 0.22% free C. The tough constituent was an alloy of the following composition: 70-80% iron, 4-6% chromium, 14-18% tungsten, 1-2% vanadium, 0.6-0.9% carbon, and up to 0.5% molybdenum. Titanium carbide is a hard and strong material of low specific gravity. Moreover, it is relatively inexpensive and readily available.

The steel described above was chosen as the infiltrating material because it is relatively tough and contains constituents which dissolve, and are soluble in, TiC, so that the resulting material would be expected to possess high strength. Specimens, 6 x 15 x 30 mm in size, were produced by the following procedure: preparation of charge materials from various TiC fractions plasticized with a solution of synthetic rubber in benzine; compaction of specimens under pressures of 1 and 2 tons/cm²; drying and sintering in a vacuum furnace and in a hydrogen atmosphere in a furnace with a graphite heating element.

After sintering the specimens, of ~30% porosity, were subjected to infiltration by the contact technique, which facilitated accurate determination of the amount of infiltrating material and minimized finishing operations. The resulting specimens were used to study the effect of the particle size of the hard phase on wear resistance, examine the influence of technological factors (pressing, sintering, and infiltration parameters), and determine the optimum conditions leading to increased wear resistance.

Effect of Particle Size. Using titanium carbide powders of the particle agglomerate sizes listed below, specimens of ~30% porosity were prepared and infiltrated with the tough constituent:

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle agglomerate size, μ</td>
<td>3-5</td>
<td>+60</td>
<td>+160</td>
<td>+315</td>
<td>+400</td>
</tr>
<tr>
<td></td>
<td>-100</td>
<td>-250</td>
<td>-400</td>
<td>-500</td>
<td></td>
</tr>
</tbody>
</table>

In wear-resistance tests, the best results were obtained with mix No. 1. The wear resistance of specimens from the remaining mixes was very low. A fine-grained structure is favorable from both the strength and ductility viewpoints. It is essential that the carbide phase should be completely broken down, so that no particle agglomerates remain. It has been established that fracture upon impact is initiated in
Effect of Sintering Conditions on Structure and Properties of Material. The effect of sintering conditions was investigated on specimens prepared from a fine titanium carbide powder, sintered at various temperatures in the range 1200–2000°C. Metallographic examinations of specimens combined with grain size measurements on microsections by Spektorts secant method [6] revealed that, at 1200–1500°C, the grain size remains virtually unchanged and ranges from 2 to 4 μ. Beginning from 1600°C, the grain begins to grow vigorously, reaching 13–14 μ at 2000°C. Figure 1 illustrates the effect of sintering temperature on the grain size and volume shrinkage of titanium carbide.

Changing the sintering time from 30 to 60 min had no marked effect on the volume shrinkage and grain growth. To preserve a small grain size ensuring high wear resistance and attain a certain minimum strength of the carbide skeleton, the sintering temperature should lie, judging from the temperature dependence of grain growth, in the optimum range of 1300–1500°C. In actual tests on specimens, the best results were obtained with materials sintered at 1400°C.

Infiltration Conditions. The uniformity of distribution of the infiltrating material over the skeleton thickness is one of the factors influencing the quality of the resulting material. To obtain uniform infiltration, the infiltrating material was rolled into strip, which was cut to give plates of the same size as the specimens. The strip thickness was determined from the volume of material required for infiltration.

The decisive factors in infiltration by the contact technique are, apart from solubility, the process temperature and duration. A short period of contact between the liquid and solid phase may enable the geometry of the part to be preserved, whereas prolonged holding, particularly when the skeleton exhibits apparent mechanical strength, may lead to a weakening or even rupture of the part, together with loss of its initial configuration. Similarly, the process temperature must be higher than the melting temperature of the alloy in order to ensure that the infiltrating material is sufficiently fluid to penetrate rapidly into the pores of the carbide skeleton. The infiltrating alloy used in this study exhibits optimum fluidity at a temperature of 1600°C. On the basis of these considerations, treatment in a hydrogen atmosphere for 10 min at a temperature of 1600°C was employed to infiltrate titanium carbide skeletons with this particular alloy. Materials infiltrated with the same alloy in a vacuum proved to be less satisfactory in wear tests. Chemical analyses have shown that, during vacuum infiltration, the chromium in the alloy vaporizes, which appears to have an adverse effect on the properties of the resulting material.