THEORY AND TECHNOLOGY OF COMPONENT FORMATION PROCESSES

THE PROCESS OF COMPACTION OF MOLYBDENUM DISILICIDE

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Parts from the molybdenum disilicide MoSi₂ are widely used in various fields of engineering [1] because of the high resistance of this compound against oxidation and attack by various aggressive media, including molten metals, slags, and salts, as well as because of its catalytic properties.

While the processes of extrusion and sintering of molybdenum disilicide have already been investigated in detail [2, 3], little information is available in the literature on the conventional compaction of powders of refractory compounds [4-6], and nothing at all appears to have been published on the compaction of molybdenum disilicide powder. In view of this, the present investigation was undertaken with the object of studying the compaction of molybdenum disilicide powder. The influence of the time of holding of powder under pressure, repeated compaction, charge moisture content, and amount of plasticizer on the density of compacts was examined, and a study was made of force distribution during compaction, using Unckel's method [7], and the elastic recovery of compacts. Experiments were carried out on commercial molybdenum disilicide powder containing 63.5 Mo, 34 total Si, 0.35 free Si, 0.2 total C, and 0.35 wt.% Fe, having apparent and tap densities of 1.97 and 3.10 g/cm³, respectively. The particle size distribution of the powder, determined microscopically, is presented in Table 1.

To determine the influence of load application time, the molybdenum disilicide powder was plasticized with 4% bentonite [8] and compacted in a cylindrical steel die of 8-mm diameter at pressures of 20, 40, and 100 kN/cm² and a constant moisture content of 1.2%. At these pressures, a study was made of the effect of the time of holding the powder under load on the density of compacts. Compaction was performed either practically instantaneously (about 0 min) or at holding periods of 1 and 3 min.

The compact density was invariably found to be independent of holding time under pressure. For instance, the compact density after compaction at a pressure of 100 kN/cm² for 0, 1, and 3 min was 4.93, 4.93, and 4.92 g/cm³, respectively. This shows that molybdenum disilicide completely lacks ductility and remains in a severely stressed condition after compaction. A similar phenomenon was observed when titanium and chromium borides and the double boride (Ti, Cr)B₂ were compacted in [5].

In the study of the effect of repeated compaction operations on compact density, the molybdenum disilicide powder was compacted at pressures between 10 and 100 kN/cm² with or without a plasticizer. The plasticizer—bentonite or starch paste—was added to the charge before compaction in amounts of 4 and 2.5 wt.%, respectively. The results obtained are presented in Table 2. In the case of six consecutive compacting operations with or without intermediate rubbing through a sieve, the density of the compacts increased from compaction I to compaction V; at low pressures (10 and 20 kN/cm²), however, the density increased only slightly, and sometimes even remained unchanged. At high compaction pressures the density increased by 2-3%, particularly when intermediate rubbing through a sieve was employed. This phenomenon is probably due to the fact that, at high pressures, the particles fail in a brittle manner, and the fine fragments become distributed between the larger particles, which in turn increase the density of the compact. For this reason, it is desirable to employ double or treble compaction with intermediate rubbing through a sieve (to secure a more uniform distribution of the fine and coarse particles). The first compaction should be carried out at a pressure of 35-40 kN/cm², which is sufficient for the brittle rupture of particles, and the second at 15-20 kN/cm², as higher pressures give rise to stratification phenomena.

The compressibility of molybdenum disilicide powder is accurately described by a semilogarithmic dependence [9] of compaction pressure \( P \) (daN/cm²) on the relative volume \( \beta = d/\gamma \) \((d\) is the density of the material of...
TABLE 1. Particle Size Distribution of Starting Molybdenum Disilicide Powder

<table>
<thead>
<tr>
<th>MoSi₂</th>
<th>Mean particle size, μ</th>
<th>&lt;2</th>
<th>2</th>
<th>4</th>
<th>8</th>
<th>13</th>
<th>17-29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of fraction %</td>
<td>58.6</td>
<td>22.8</td>
<td>10.1</td>
<td>4.9</td>
<td>2.3</td>
<td>1.3</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 2. Effect of Pressure and Number of Consecutive Compacting Operations on Density of MoSi₂ Compacts

<table>
<thead>
<tr>
<th>Compaction pressure, kN/cm²</th>
<th>Density (g/cm³) and relative density (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without plasticizer</td>
</tr>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>10</td>
<td>4.03</td>
</tr>
<tr>
<td>20</td>
<td>64.0</td>
</tr>
<tr>
<td>66.2</td>
<td>66.1</td>
</tr>
<tr>
<td>4.25</td>
<td>4.29</td>
</tr>
<tr>
<td>70.7</td>
<td>70.8</td>
</tr>
<tr>
<td>69.4</td>
<td>69.7</td>
</tr>
<tr>
<td>4.43</td>
<td>4.48</td>
</tr>
<tr>
<td>70.5</td>
<td>71.1</td>
</tr>
<tr>
<td>4.48</td>
<td>4.47</td>
</tr>
<tr>
<td>71.1</td>
<td>-</td>
</tr>
<tr>
<td>4.52</td>
<td>-</td>
</tr>
<tr>
<td>71.8</td>
<td>-</td>
</tr>
<tr>
<td>4.55</td>
<td>-</td>
</tr>
<tr>
<td>72.2</td>
<td>-</td>
</tr>
<tr>
<td>4.61</td>
<td>-</td>
</tr>
<tr>
<td>90.0</td>
<td>-</td>
</tr>
<tr>
<td>4.86</td>
<td>-</td>
</tr>
</tbody>
</table>

the powder, g/cm³; γ is the apparent density of the compact, g/cm³ in the pressure range between 10 and 100 kN/cm² (Fig. 1). It follows from the semilogarithmic straight lines recorded that the process of compaction of molybdenum disilicide plasticized with 2.5% starch is described by the equations:

\[
\log P = -4.96 (β-1) + 3.28 \text{ (for single compaction)}
\]

and

\[
\log P = -4.86 (β-1) + 3.26 \text{ (for sixfold compaction)}.
\]

Densification during the compaction of molybdenum disilicide powder plasticized with 4% bentonite is described by the equation

\[
\log P = -2.7 (β-1) + 4.57,
\]

and the densification of molybdenum disilicide compacted without a plasticizer by the equation

\[
\log P = -5.88 (β-1) + 5.33.
\]