STRESSES SET UP IN THE WORKING PARTS OF DIE SETS DURING THE PRESSING OF METAL POWDERS

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The powder compaction process constitutes an important link in the full technological cycle employed in the production of parts by the powder metallurgy technique. Although powder compaction has already received much attention in the literature [1-9, etc.] and considerable progress has been made in investigations of this process, more investigational work is necessary if a clear understanding is to be obtained of the part played by some factors in the pressing of metal powders. In the present work, the strain measurement technique was employed for studying the stressed state of the die set in the pressing of iron, copper, and Stalinite* powders.

Figure 1 shows a diagram of the die set with longitudinal and transverse strain gauges bonded to its side wall. The die, which was made of U10 steel,† was quenched to a hardness of 52-54 Rockwell C, and its bore was ground and polished. The lower punch was built up of two parts. The central core and the outer ring of the lower punch and the ring placed under the die also carried strain gauges.

Since altogether 12 strain points had to be monitored simultaneously, in the experiments use was made of three TA-5 strain measurement units and an N-700 oscillograph. Analysis of oscillograms enabled the strains of the die side wall to be determined. Radial and longitudinal stresses were determined from the formulas [10]:

\[ \sigma_x = \sigma_l = \frac{E}{1 - \nu^2} (\varepsilon_l + \nu \varepsilon_\nu), \]
\[ \sigma_y = \frac{E}{1 - \nu^2} (\varepsilon_y + \nu \varepsilon_l), \]

where \( \sigma_x = \sigma_l \) are stresses set up along the circumference, \( \sigma_y \) are stresses set up along the compaction axis, \( \nu \) is Poisson's ratio, \( E \) is the modulus of longitudinal elasticity, \( \varepsilon_\nu \) are strains recorded by the longitudinal gauges. Pressing was performed in a 2PG-250 hydraulic press. The pressing load in all experiments was constant (4 tons/cm²).

The principal aim of the investigation was to determine the effect of the resistance to plastic deformation of powder particles being pressed and of the powder fill height on the stresses generated in the die wall and the pressures exerted on the lower punch and the sensor under the die.

Fig. 1. Diagrammatic arrangement of die set for determining stressed state of die and pressures exerted on lower punch.

*Nominal composition: 8-10 C, 13-17 Mn, 3 Si, 16-20% Cr, balance Fe – Translator's note.
†1% C grade – Translator's note.
The copper, iron, and Stalinite powders were pressed into 30-mm diameter compacts with diameter: fill height ratios, $D : H_f$, of 1 : 4, 1 : 2.6, and 1 : 1.3. The chemical and sieve analyses of the powders were already given in [11].

Data obtained by analyzing oscillograms were used for plotting diagrams of stress distribution ($\sigma_x/\sigma_y$) for the powders investigated (Fig. 2a, b, and c). Figure 2a shows diagrams of stress distribution on the outer die surface in the pressing of compacts with the ratio $D : H_f = 1 : 4$. The height of each compact is represented by a horizontal line extending up to the stress curve for the given compact material. The lower boundary of the compact is denoted by the horizontal line $a$. Analysis of the diagrams reveals a marked nonuniformity of stress distribution in the die wall; furthermore, the stresses do not, contrary to the generally held opinion, monotonically increase from bottom to top.

In the pressing of Stalinite powder, for example, stresses in the die wall decrease from a maximum in the zone of action of the upper punch, then increase at a distance of about two-thirds of the die height from the upper punch, and finally slightly diminish toward the lower part of the die. In the pressing of iron and copper powders, the character of stress distribution is similar, although less pronounced.

For compacts with the ratio $D : H_f = 1 : 2.6$, stress distribution in the pressing of the test powders has a different character (Fig. 2b). The stress curves do not rise monotonically from bottom to top, but have a convex character in the middle portion of the diagram. An exception is provided by the stress distribution curve for the pressing of the copper powder, which indicates a steady increase in stress from top to bottom. Another character of stress distribution is exhibited by compacts with the ratio $D : H_f = 1 : 1.3$, reflecting a monotonic rise in stress from top to bottom in all experiments (Fig. 2c).

The use of a composite lower punch has enabled one other new characteristic to be discovered. For tall compacts, with $D : H_f = 1 : 4$, even a slight increase in compaction pressure (0.1-0.2 ton/cm$^2$) resulted in stresses being recorded by the central core of the lower composite punch. At this pressure, the powder has not yet formed a true compact and disintegrates on being ejected from the die, so that one must conclude that pressure is transmitted by some mechanism from the upper to the lower punch even in the initial stage of compaction.

In Fig. 3 are shown diagrams of pressures on the lower composite punch in the pressing of the copper, iron, and Stalinite powders at various $D : H_f$ ratios. Analysis of the diagrams shows that, with decrease in the powder fill height in the die, the pressure on the lower punch increases, but the character of pressure distribution remains unchanged, i.e., the maximum pressure is exerted on the central core of the lower, composite punch. Losses due to friction between the powder and the die walls rise with increase in fill height (Fig. 4).