FORCES IN THE STATIC AND DYNAMIC PRESSING OF METAL POWDERS AND CHIPS

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Various methods for measuring the forces in static pressing have been described in the literature [1-8], but it has also been noted that some of the results obtained are contradictory [1, 2]. According to Unckel [3] and Samoilov [4], the proportion of the force expended on overcoming external friction, Kfr, decreases with rise in compaction pressure. Plotkin and Samsonov [5] found that, depending on the material of the powder and presence of a lubricant, Kfr can either decrease or increase. Other authors [6-8] claim that the proportion of external-friction losses is independent of compaction pressure.

Much less attention has been devoted to study of the forces in dynamic pressing [9-10]; the present work was therefore undertaken with the object of determining these forces and comparing them with the static-pressing forces.

For force measurement, use was made of a special device with differential inductive displacement pickups and wire resistance strain gauges. Signals were recorded on an ÉPP-09 electronic potentiometer, an S1-4 cathode-ray oscillograph with afterglow, and an N-102T loop oscillograph. Forces were measured in the pressing of PZh3M iron powder (fine, reduced grade) at 20 and 880°C, as well as of ShKh15 steel (1% C-1.5% Cr ball-bearing grade) and cast-iron chips up to 4 mm in size. Pressures up to 784.8 MN/m² (8000 kg/cm²) and energies up to 392 J (40 kg·m) were employed. The compact dimensions were d =20 mm, h_r/d =0.25, 0.50, 0.75, 1.00, and 1.25, where d is the diameter and h_r is the reduced height.

Let us introduce the following designations: Ppr is the pressing pressure, ΣPfr the external-friction pressure, Pb the pressure transmitted to the bottom punch, and Epr, ΣEfr, and Eb are the corresponding energies. Then, the fraction of the external-friction pressure losses in static (Kfr)st and dynamic (Kfr)dy n pressing can be determined from the appropriate values of pressure, using the following relationships:

\[ K_{fr} = \frac{\sum P_{fr}}{\sum P_{fr} + P_b}, \]  
\[ \sum P_{fr} = K_{fr} \cdot P_{pr}. \]

The results of the investigations, which are illustrated in Fig. 1, show that the relationship (2) is linear at h_r/d = const in the whole range of static-pressing pressures and dynamic-pressing energies employed and that, for this reason, (Kfr)st and (Kfr)dyn are independent of load. With increasing h_r/d (Fig. 1a-e), the magnitudes ΣPfr and ΣEfr increase, and Pb and ΣEb decrease, the following relationships being observed in all cases (allowing for experimental error):

\[ P_{pr} = \sum P_{fr} + P_b, \]  
\[ E_{pr} = \sum E_{fr} + E_b. \]

To obtain the data presented in Fig. 1, the gauges were statically calibrated and signals were recorded on film in the loop oscillograph. Static and dynamic-pressing signals were processed to determine
Fig. 1. External-friction losses (1 and 1'), compact density (2 and 2'), and magnitude $K_{fr}$ (3 and 3') plotted against static and dynamic ("prime" numbers) pressure in cold pressing of iron powder at $h_r/d$: a) 0.25; b) 0.50; c) 0.75; d) 1.00; e) 1.25.

Fig. 2. Dependence of external-friction losses $\Sigma P_{fr}$ on $h_r/d$ at $P_{pr}$ values (in MN/m²) of: 1) 98.1; 2) 196.2; 3) 392.4; 4) 588.6; 5) 784.8 (for static cold pressing of iron powder).

Another characteristic feature of compact-density variation in dynamic pressing is that the density increase markedly slows down at $h_r/d \geq 1$ owing to the fact that only the upper compact layers undergo densification and the mean recorded compact density is reduced by the unconsolidated lower layers. This...

In dynamic pressing, owing to the more rapid load application [11], the dimensionless fraction of the volume being deformed in material undergoing densification—a concept introduced for the first time by Bal'ashin [12]—decreases. This in turn increases the degree of deformation and the strengthening of this volume fraction, which explains, in the authors' opinion, why, under identical conditions, compacts of lower density are produced by dynamic pressing compared with static pressing. To attain the same compact density in dynamic pressing, forces 1.3-1.5 times higher are required (see curves 2', Fig. 1). Because of this, much higher stresses are generated on the contact surfaces, and, in the case of hot dynamic pressing, particle-welding conditions improve.

High internal stresses and smaller block sizes were also discovered by the authors in a study of the elements of fine intragranular structure in iron-powder compacts obtained by dynamic pressing compared with statically pressed compacts of the same porosity [13].