THE TRANSMISSION OF STRESS THROUGH A GRANULAR MASS UNDERGOING COMPACTION IN A DEEP DIE

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In compaction, the force applied by the punches to the material in the die is dissipated to the die wall, so that the further the material is from the punch face, the lower is the degree of compaction.

The same decay of pressure away from the punch face also occurs in the filling mechanism that operates in many high-speed capsule filling machines, notably the Zanasi and the Cam MG2, in which a vertical cylindrical tube is plunged into a bed of powder, and a piston imparts a pressure to the upper surface of the contained powder to produce a lightly-compacted plug that will reliably remain in the tube until it is ejected into the capsule body.

That the rate of decline of pressure in a column of powder is exponential was established long ago by Shaxby & Evans (1923), on the assumption that the force lost by friction to the die wall at any level was proportional to the pressure being exerted at that level. The pressures that they applied in testing their theory were low, and they had no means of directly monitoring the die-wall pressure as a function of depth.

We have used a deep Perspex die, 12 mm diameter and 8 cm deep, to compact sand, using a punch travelling in from one end only. The stress in the die wall was measured by observing the fringes produced when the die was viewed in polarised light, and by taking photographs so that the fringe order could be determined a graph of die-wall pressure against depth could be obtained. At the same time, force-displacement curves were produced during the compaction by measuring the punch displacement with an LVDT.

The materials compacted were sieved fractions of sand, shape-sorted according to the method previously reported (Ridgway & Rupp, 1969). The rate of fall of pressure with increasing depth was approximately exponential, and depended upon the particle size and shape. Deviations from the exponential form could be explained as being due to the crushing of individual sand grains, leading to a change in the mechanical properties of the material being compacted, the extent of the change being a function of the pressure to which the grains had been subjected.

By removing successive layers of the compacted (but generally non-adherent) material and sieving it, a measure of the amount of particle crushing as a function of depth within the bed was obtained, which could be correlated with the decay of pressure and also with the form of the force-displacement curve.

Ridgway, K. & Rupp, R. (1969). J. Pharm. Pharmac., 21, Suppl., 30S-39S.
Shaxby, J.H. & Evans, J.C. (1923). Trans. Faraday Soc., 19, 60.