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FLOW RATES OF GRANULAR MATERIALS THROUGH MOVING ORIFICES

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SUMMARY

An apparatus is described which will measure the flow of powder through a moving orifice (die). It is shown that this type of flow, denoted dynamic flow, differs in some respects from static flow, i.e. flow through a stationary orifice. In other respects, e.g. the relation of flow to orifice diameter, the relations found in dynamic flow are similar to the ones reported for static flow. The results are treated in such a fashion that extrapolations to speeds encountered in high speed tablet presses can be made.

INTRODUCTION

Scale-up of table formulae, especially to high speed tablet machines, is usually associated with a variety of problems. One of these is weight variation, and this is directly associated with flow rates of the granulations used. The critical flow rate may reside in the flow from the hopper to the feed frame, or it may be caused by inadequate flow from feed frame to tablet die (Carstensen, 1976, 1977).

In general most formulators test the flow of granulations in a static fashion (Carstensen et al., 1976; Carstensen and Chan, 1977), for instance through a funnel or a tube, and attempts are made to correlate this type of flow with the critical flow in the high speed machine. Such correlations are frequently not good, and the article to follow explains why, and suggests a method of dynamic measurement.

MATERIALS AND METHODS

Static flow, i.e. flow of powder through a static tube, may be fundamentally different from the flow into a moving orifice. To test this possibility, the apparatus shown in Figs. 1 and 2 was built.

A tablet die, A, shown in the center of Fig. 1, is positioned in a horizontally movable plate BC, driven by a motor, D, of high precision speed. A hopper (shown in position, in

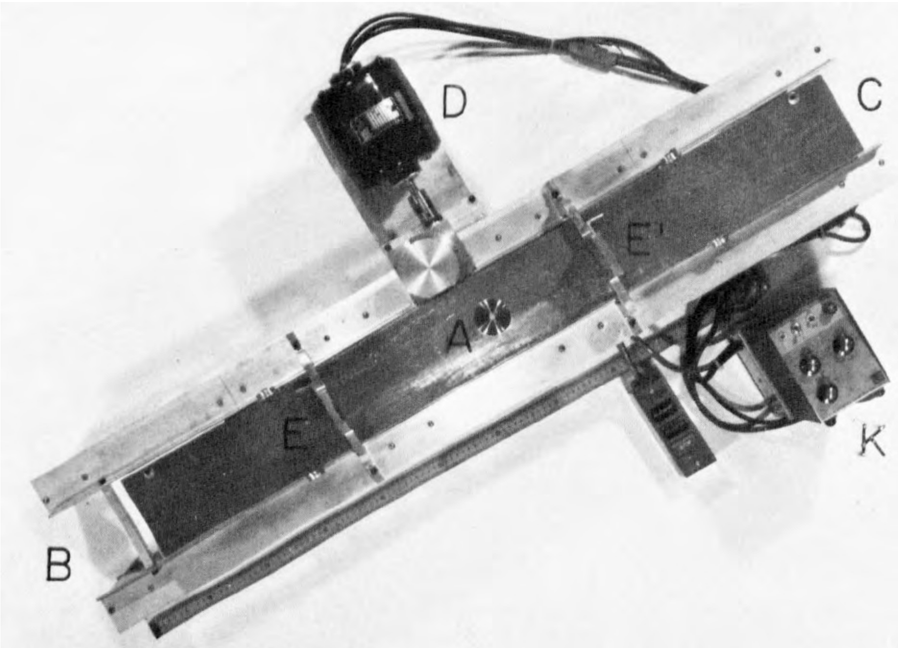

Fig. 1. Top view of the dynamic flow apparatus. Scale, 1 cm = 12 cm. A = die. BC = movable plate. E' and E = stationary plates holding hopper (F). D = drive motor of precision speed; K = speed control box.

Fig. 2) can be placed between the vertical, stationary plates E and E'. Powder is placed in the hopper and as the die traverses EE', powder will flow through the orifice of the die into the removable bin, G. The microswitches H and J allow braking of the plate movement after the die has passed the vertical retaining hopper plate (e.g. E). The hoppers can be partitioned into 4 parts by teflon plates as shown in Fig. 2.

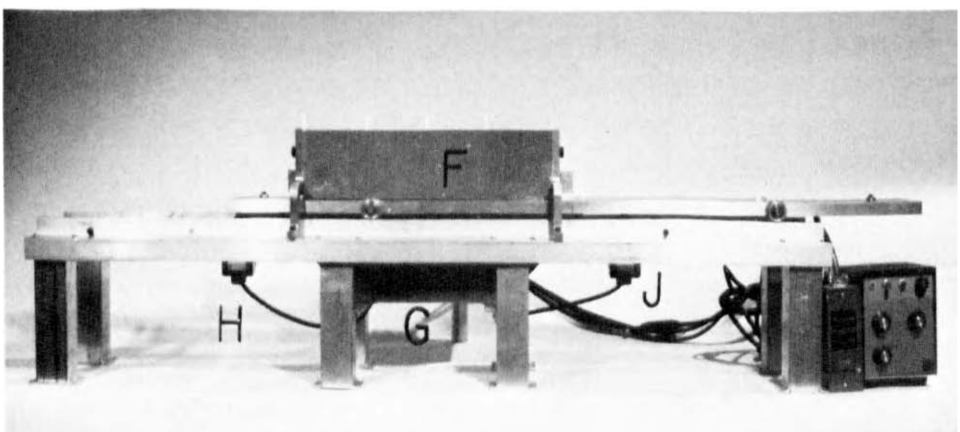

Fig. 2. Side view of apparatus, with hopper (F) and bin (G) in place, and showing the microswitches H and J.

A lactose starch granulation (Carstensen, 1977) containing 13% corn starch U.S.P. and 87% lactose U.S.P. was used. The moisture content was 4% and the flow experiments were carried out in an atmosphere at 25°C and 25% relative humidity.

A 20/40 U.S. mesh cut (i.e. of an average particle diameter of 0.063 cm) of the above granulation was placed in the hopper, and the plate, equipped with a tablet die, passed under it at a given speed (q cm/s) which was set (and controlled) by the setting at the control box (K). The amount of material captured in the bin was measured by weighing. The experiment was repeated three times in each direction. The 6 measurements were averaged and have a sample standard deviation of about 3%. Measurements were made with three die diameters: 1.25, 0.78 and 0.47 cm.

RESULTS AND DISCUSSION

If static flow principles apply to the dynamic apparatus, then the following sequence of arguments hold: if the width of the part of the hopper containing the granulation is ℓ, then the flow will occur during a time ℓ/q so that the flow rate is $W = M/(\ell/q)$, where M is the mass collected from the bin. This may be written logarithmically as follows:

$$\ln M = -\ln q + \ln(\ell W) \qquad (1)$$

The obtained data were plotted in this log–log fashion, and the plots are shown in Fig. 3. The plots are obviously linear, and the least squares parameters are shown in Table 1. It is noted that the linearity is manifested by correlation coefficients being close to minus one. However, the *slopes*, although close to minus one, differ slightly but significantly from this number, so that flow under dynamic conditions, in this repect, does not correspond to flow under static conditions. The data presented in Fig. 3 allow extrapolation to actual machine speed, so that the apparatus can be used to predict flow rates under actual operating speeds on a high speed press.

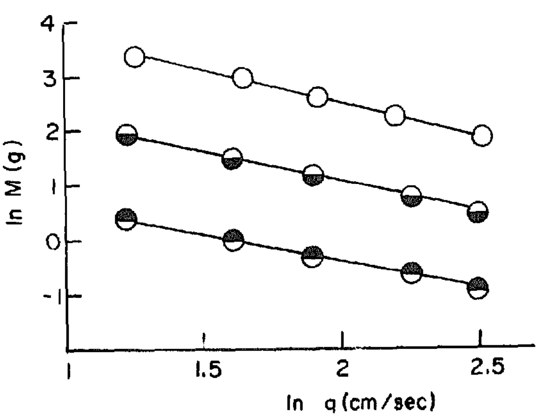

Fig. 3. ln M (g) plotted as a function of ln q (cm/sec), where M is the mass of granules that flowed through the orifice when the plate moved with a speed of q. Die openings: ○, 1.25 cm; ⊖, 0.781 cm; ⊖, 0.469 cm.

TABLE 1

LEAST SQUARES PARAMETERS FROM FIG. 3.

Orifice diameter, cm	1.25	0.781	0.469
Slope of line in Fig. 3	−1.200	−1.166	−1.014
Intercept (ln(Wℓ)), Fig. 3	4.925	3.402	1.645
Correlation coefficient	−0.9996	−0.9999	−0.9993
W (g/sec)	14.49	3.16	0.545

Jones and Pilpel (1966a, b) have shown that for many powders in static flow through orifices of diameter D_0 the following equation holds:

$$W = Q\,D_0^n \tag{2}$$

where the pre-exponential factor and the exponent, Q and n, are functions of the particular powder tested. The intercepts from Fig. 3 are shown in Table 1 and allow calculation of W for the various situations. These are shown in Table 1 also, and are plotted in Fig. 4 as a function of D_0, and according to the logarithmic form of Eqn. 2:

$$\ln W = n \ln D_0 + \ln Q \tag{3}$$

It is seen that this plot is linear, so that the Jones–Pilpel equation holds in dynamic flow also. Both Q and n may be functions of the particle dimensions, a point which is not part of this study. The intent here has been to describe the apparatus and its utility.

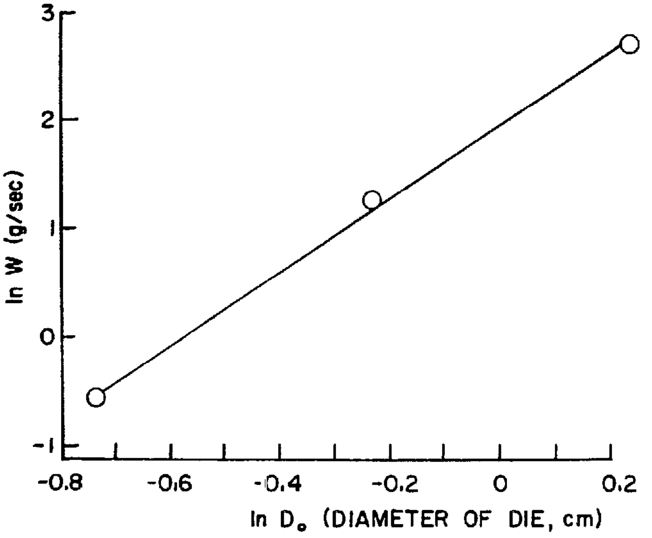

Fig. 4. ln W (g/sec) plotted as a function of ln D_0 (diameter of die, cm) where W is the flow rate calculated from the intercepts in Fig. 3.

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