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Capsule filling performance of powders with dosator nozzles of different wall texture

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Summary

The influence of the surface texture of wall of a dosator nozzle on the capsule filling performance has been assessed with a capsule filling simulator. The change in mean surface texture from the value 0.17 to 0.49 μm did not significantly affect the capsule weight variability when various size fractions of Starch 1500 and Avicel were used. This contrasts with previous findings with lactose and appears to be associated with the presence and absence of adhesion of the powder to the nozzle wall.

Introduction

Automatic capsule filling machines which employ the dosator nozzle system require the accurate dosing, retention and transfer of a powder plug within a cylindrical nozzle before its ejection into a receiving capsule body. Jolliffe et al. (1980) in their theoretical consideration of powder retention within a dosator nozzle stress the importance of both powder properties as well as powder and nozzle wall interaction in controlling the retention process. Correlations between powder retention ability and interaction with a wall surface have been observed by Jolliffe and Newton (1982) for lactose powders using a static rig. Further studies by the authors (Jolliffe and Newton, 1983a,b) using an mG2 simulator and a mG2 production machine have highlighted the importance of dosator nozzle wall texture to the filling performance of lactose powders. Their work indicates that capsule filling performance is generally improved by using resurfaced nozzles and an optimum surface texture exists for capsule filling. This supports their concept of an optimum angle of wall friction for powder retention with minimum compression stress.

Using a modified annular shear cell, Tan and Newton (1990b) studied the influence of two dosator nozzle wall materials of different textures on the angle of wall friction of various size fractions of five pharmaceutical excipients. Their findings indicate that the angle of wall friction (ϕ) and powder wall adhesion are functions of the powder material, its particle size and the dosator wall texture. Smaller values of ϕ are generally obtained for coarser powders and a smoother wall surface.

The capsule filling performance of the powders filled on an instrumented mG2 simulator fitted with a size 1 dosator nozzle of defined wall rough-

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ness (nozzle M, Ra = 0.49 μm) has been reported by Tan and Newton (1990a,c).

This paper assesses the capsule filling performance of size fractions of Starch 1500 and Avicel PH101 powders when a smoother textured dosator nozzle, S (Ra = 0.17 μm) is used. Results are compared to those obtained with nozzle M.

Materials and Methods

Materials

Size fractions of Starch 1500 and Avicel PH101, fractionated and characterised as described elsewhere (Tan and Newton, 1990a) were used for the present study.

Surface texture measurement

A Surfcom 550A surface finish measuring instrument (Advanced Metrology Systems Ltd, Leicester, U.K.) was used to assess the surface roughness of the internal wall of two different dosator nozzles. Surface roughness measurements expressed as Ra (BS1134: 1972) were made axially along the nozzle wall. Each value of Ra is a mean of three measurements.

Capsule filling

Using the smooth textured dosator nozzle (S), capsule filling studies on the Starch 1500 and Avicel powders were carried out with both clean and coated nozzles as described previously for nozzle M (Tan and Newton, 1990a).

Results and Discussion

Surface roughness of nozzle wall

The Ra values of nozzles S and M are presented in Table 1 and their surface profile traces are shown in Fig. 1a and b. It can be seen that the Ra value of nozzle M is almost 3 times that of nozzle S. Examination of Fig. 1a and b also shows the more pronounced and variable peak heights and troughs of the surface profile of nozzle M.

TABLE 1

Arithmetical mean deviation (Ra) values of dosator nozzles M and S

Ra (μm)	Nozzle M	Nozzle S
$\bar{x}$	0.49	0.17
(±S.D.)	0.04	0.03

Cut off = 0.80 mm; traversing length = 8.00 mm; vertical trace magnification = × 5000; horizontal trace magnification = × 20; $\bar{x}$ = mean value (of 3 measurements); S.D. = standard deviation.

Fill weight, weight variation and powder coating studies with nozzle S

For Starch 1500 powders there is no significant difference between results obtained from a clean or a coated nozzle for the fill weight variability (Fig. 2) and the weight of coating per unit length (Fig. 3). Hence only results with a clean nozzle are presented.

Comparison of these graphs with those previously obtained with a medium-textured (M) nozzle, (Tan and Newton, 1990c) also shows similarities among the profiles. It is thus apparent that the use of a smoother-textured wall has little influence on the fill weight parameters and powder coating on the wall.

When the graphs for Avicel powders are considered, comparable profiles are again seen for both clean and coated nozzles, hence only graphs for the latter are presented (Figs 4 and 5). Fig. 4 shows the capsule weight variability while Fig. 5 presents the coating per unit length of nozzle. The trends shown by these graphs are also essentially similar to those obtained with nozzle M (Tan and Newton, 1990c). Slight differences observed may be attributed to the varying affinities of the powders for the different wall surfaces or be due to the inherent variability in the nature of the experimental work.

Compression and ejection stresses

For Starch 1500 and Avicel powders, similar trends in the compression and ejection stress results are generally obtained with both clean and coated nozzles as in the case of nozzle M (Tan 1987). Graphs for the clean nozzles are presented in Fig. 6a and b.

The main influence exerted by a smooth wall is

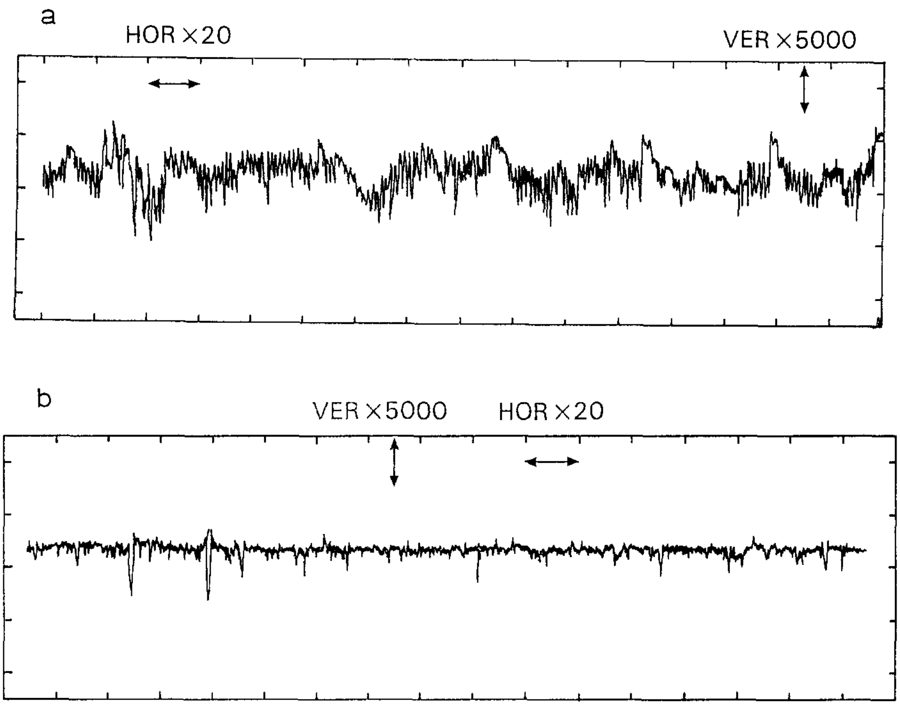


Fig. 1. (a) Surface profile trace of dosator nozzle M, axially along the nozzle wall. (b) Surface profile trace of dosator nozzle S, axially along the nozzle wall.

to decrease the angle of wall friction for a particular powder (Tan and Newton, 1990b). For a very free-flowing powder, this may cause powder retention problems at low applied compression stress as frictional support at the wall is reduced. For Starch 1500 powders, however, no retention problems have been encountered even for the coarsest size fraction S3 (most free flowing) at low applied compression stress. This implies that the smooth-textured wall (S) could still provide sufficient frictional support for the powder in spite of the small angle of powder wall friction, and this satisfactorily explains the general similarities in the graphs obtained with nozzle S and nozzle M. Results obtained for Avicel powders may be similarly explained but there may be a slightly reduced tendency for the coarse size fraction A2 to be firmly retained by the smooth nozzle S, at low compression (Cr) setting.

Studies by Jolliffe and Newton (1983a) have shown that wall texture has a pronounced effect on the capsule-filling properties of lactose pow-

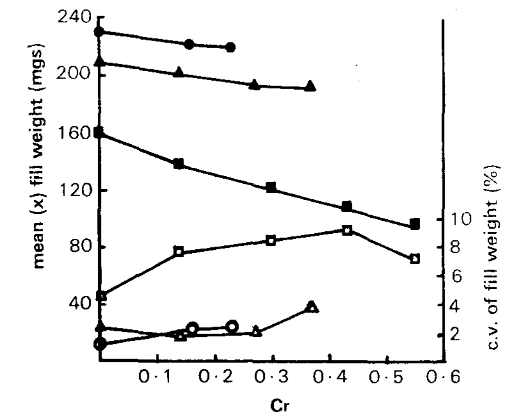


Fig. 2. Capsule fill weight as a function of compression ratio (Cr) for Starch 1500 ('clean' nozzle S).

	S3	S2	S1
x	●	▲	■
c.v.	○	△	□

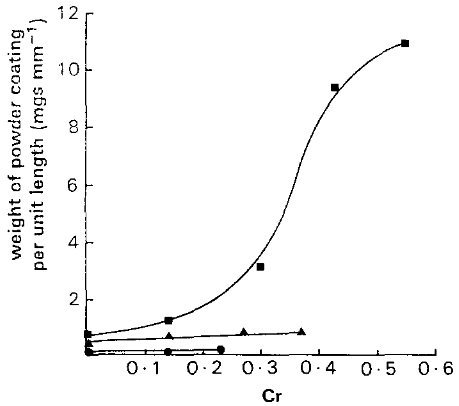


Fig. 3. Weight of powder coating per unit length of nozzle as a function of Cr for Starch 1500 ('clean' nozzle S). S3 (●), S2 (▲), S1 (■).

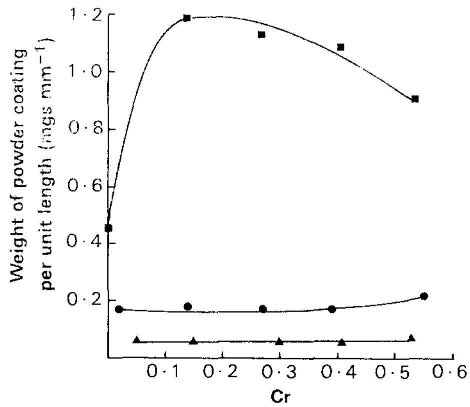


Fig. 5. Weight of powder coating per unit length of nozzle as a function of Cr for Avicel PH 101 ('clean' nozzle S). A3 (●), A2 (▲), A1 (■).

ders. They used four nozzle surfaces (of different Ra values) to fill three size fractions of lactose (15.6 to 155.2 μm) and observed that capsule filling with resurfaced nozzles showed an increase in fill weights and uniformity with reduced stresses compared with the original nozzle (having the highest Ra value). They also found that a nozzle

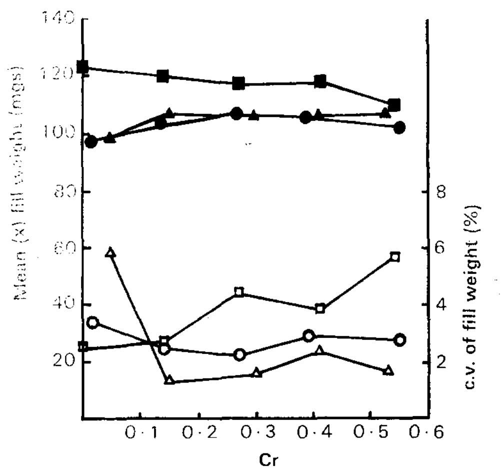


Fig. 4. Capsule fill weight as a function of compression ratio (C_r for Avicel PH 101 ('clean' nozzle S).

	A3	A2	A1
x	●	▲	■
c.v.	○	△	□

with intermediate Ra value gave the best filling performance,thus supporting their concept of an optimum angle of wall friction for powder retention with minimum stress.

From the results of the present studies and those of Jolliffe and Newton (1983a) it is evident that the effect of nozzle wall texture on capsule filling involves an intimate interaction between the powder and the wall surface. For powders which tend to bind onto the wall (e.g. lactose) the influence of surface texture is an important consideration. In contrast, for powders which have little affinity to bind or coat on the wall (e.g. Starch 1500, Avicel PH101) the effect of wall texture on capsule-filling performance becomes less critical.

Conclusions

When a smooth-textured (S) nozzle is used to fill powders of Starch 1500 and Avicel PH101, the results are comparable to those obtained using a medium-texture (M) nozzle. It is thus apparent that for powders which have little affinity to bind or coat on the nozzle wall, wall texture exerts only a minor influence on the capsule-filling performance.

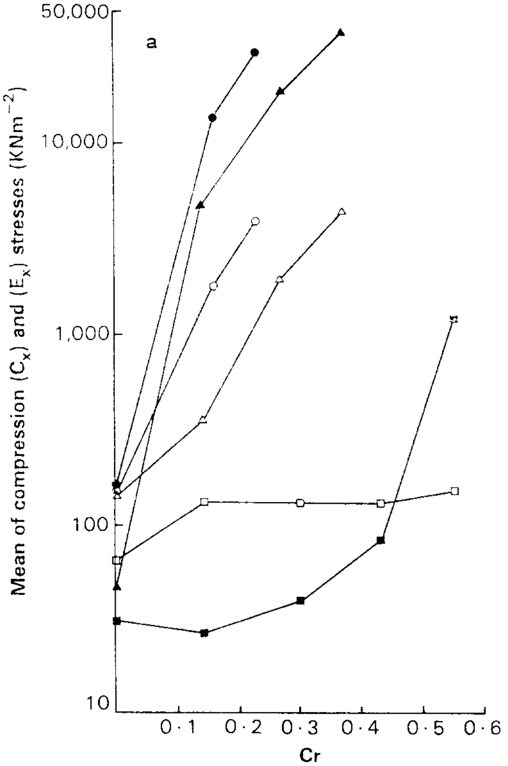
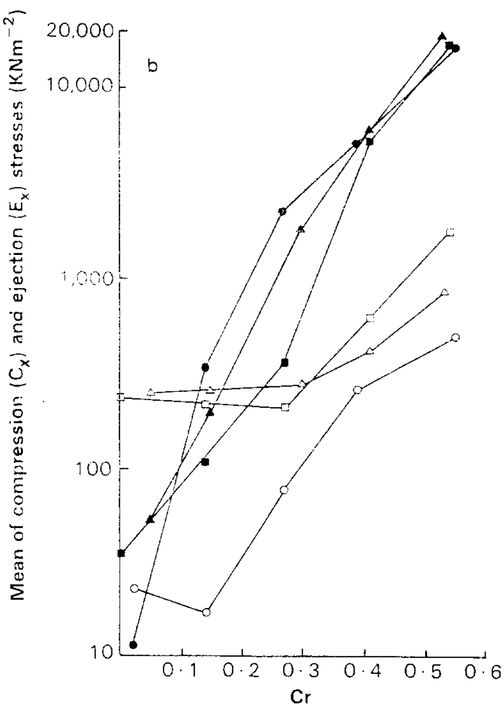


Fig. 6. (a) Log of mean compression (C_x) and ejection (E_x) stresses as a function of Cr for Starch 1500 ('clean' nozzle S).

	Powder code		
	S3	S2	S1
C_x	●	▲	■
E_x	○	△	□



(b) Log of mean compression (C_x) and ejection (E_x) stresses as a function of Cr for Avicel PH 101 ('clean' nozzle S).

	Powder code		
	A3	A2	A1
C_x	●	▲	■
E_x	○	△	□

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