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A photometric analysis of tablet movement in a side-vented perforated drum (Accela-Cota)

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A novel particle tracing technique has been used to study the effect of the normal process variables i.e. drum speed, drum loading and the presence/absence of mixing elements (baffles) on the movement of tablets in a side-vented perforated drum (24 in diameter Accela-Cota). The technique involves measuring the duration of light emission from a single luminous tablet using a photomultiplier mounted to scan the same area as a spray gun, and has enabled the quantification of both the time that the tablet spends on the surface per pass (surface time) and the time that the tablet spends within the bulk of the tablet bed (circulation time) over run lengths equating to the normal tablet coating cycle. The technique also allows the study of the uniformity of tablet appearances by means of circulation profiles. It was found that, while both the surface and circulation times decreased with increasing drum speed and loading, there was irregularity of tablet appearance especially at low drum speeds and in the absence of baffles.

It is well recognized that poor tablet movement in the bed of a tablet coater can lead to differences in coating thickness from tablet to tablet within the coated batch. This variation can result in detectable colour variation beween tablets, bridging of the intagliations on the film coated tablet (Rowe & Forse 1980) and, where the film is used as a diffusion barrier, variability in the drug release rate. Effective optimization of process parameters to obtain the best possible conditions of tablet movement cannot be satisfactorily undertaken without an understanding of the behaviour of tablets within the moving beds and a knowledge of the frequency and duration of tablet appearance on the bed surface. Previous work on the measurement of tablet appearance times has involved photographic and manual counting techniques to obtain a limited amount of data from a bed of tablets containing a number of differently coloured tracer tablets (Prater et al 1980). However, the need for specialized photographic equipment and the time needed to abstract data from replayed film makes this technique unsuitable for more than a cursory assessment of tablet movement, although it can provide some useful information on the direction and orientation of tablets as they move through the spray region. The simple method reported in this work, when applied to the Accela-Cota (Manesty Machines plc, Liverpool), enables the rapid collection and processing of tablet appearance data over run lengths equating to normal coating run times, making it ideally suitable for use in evaluating the dependence of tablet movement on related process parameters.

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EXPERIMENTAL TECHNIQUE AND EQUIPMENT

The technique employed was developed by Sibbett & Oliver (1984) originally for studying particle movement in fluidized beds. By measuring the duration of light emission from a single luminous tablet it is possible to quantify (a) the time that the tablet spends on the surface per pass (surface time); (b) the total time that the tablet spends on the surface during a normal coating run (total surface time); (c) the time that the tablet spends within the bulk of the tablet bed (circulation time); and to obtain profiles of the tablet appearances with time under varying operating conditions.

The equipment used is shown diagramatically in Fig. 1. The 24 inch diameter Accela-Cota was of standard design fitted with standard plough baffles. A photomultiplier (EMI Tubes Ltd, type 9789B) was mounted on the spray bar in approximately the same position as the spray gun would normally be fitted and adjusted to scan an area approximating to the normal spray zone during coating. The signal generated by the photomultiplier was then passed to a comparator, the purpose of which was to convert the normal pulses into digital on/off signals for reception by the microcomputer, and to remove signals below a certain light intensity level (i.e. noise or intensities outside the scan zone). An unprocessed signal was recorded on a flat bed chart recorder, while the

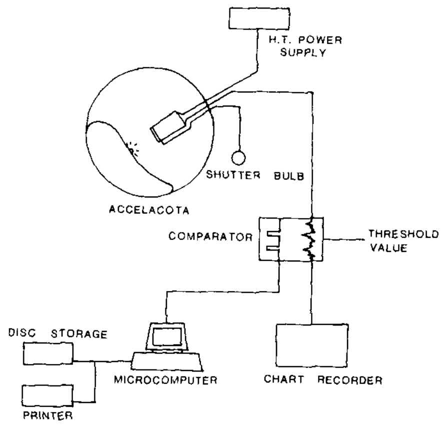

FIG. 1. Equipment used for tablet movement studies.

processed signal was logged by the computer running a real-time machine code data logging program. The computer was equipped with discs and printer.

In order to minimize signal noise the coater windows and joints were masked and complete darkness was maintained in the laboratory. Spurious light emissions caused by reflection through the tablet bed were eliminated by coating the tablets in the coater with a black iron oxide film. The drum was enclosed in a sealed stainless steel cabinet and operated with both air inlet and outlet fans running in order to simulate the conditions existing during normal operation as closely as possible. It is realized that due to the constraints of the technique, only dry beds could be used and any further effects that might occur as a result of spraying could not be assessed.

The luminous tracer tablet itself was prepared by painting a thin film of a mixture of luminous zinc sulphide and clear varnish onto the tablet surface, followed by exposure to a uv light source. For each experiment the tracer tablet was of the same size and density as the bulk, and was initially positioned in the centre of the scan zone and 2 cm beneath the bed surface. Up to 200 tablet appearances were recorded per experiment, representing run times of 15–20 min.

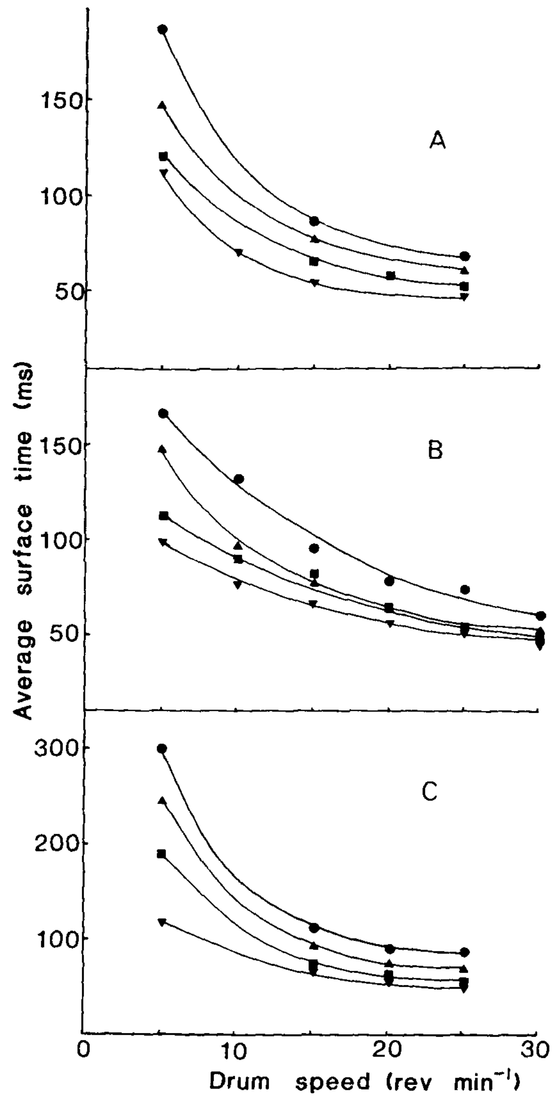

FIG. 2. The effect of drum speed on the average surface time for different tablet sizes. A, 7·5 mm diameter; B, 9·0 mm diameter; C, 11·0 mm diameter. ● 6 kg drum loading, ▲ 8 kg drum loading, ■ 10 kg drum loading, ▼ 12 kg drum loading.

RESULTS AND DISCUSSION

Surface time

Fig. 2 shows the effect of drum speed and drum loading on the average time the tablet spends under the spray for each appearance. Predictably, surface time decreased as drum speed, and hence the rotational speed of the bed, increased. However, an increase in tablet bed weight also resulted in a decrease in surface time. This was due to the steeper angle formed at the bed surface—a result of increased friction between tablet bed and drum wall at higher drum loadings—causing the tablets to fall through the scan area at greater velocity.

For a given running condition, the effect of increased tablet size was to increase surface time. This could be attributed to the change in force balance acting on the individual tablets, resulting in the smaller tablets being lifted further, forming a steeper bed surface angle.

The standard deviation of the surface time (Fig. 3) generally followed the surface time/drum speed relationships and indicates a similar variation from the mean at all drum speeds and bed loads. A high standard deviation reflects the different line the tracer tablet will take through the scan area at each pass: a tablet travelling across the centre will register a maximum surface time whereas one at the edge of the scan will show a minimum. The similar variation occurring at all conditions suggests similar movement within the scan area for all cases.

Using photographic techniques, Prater et al (1980) reported surface times of 120 ms (s.d. 3·5 ms). This, while in agreement with the present data, clearly does not reflect the dependence of surface times on process variables, nor does the standard deviation describe the wide difference in surface times experienced by tablets across the spray region.

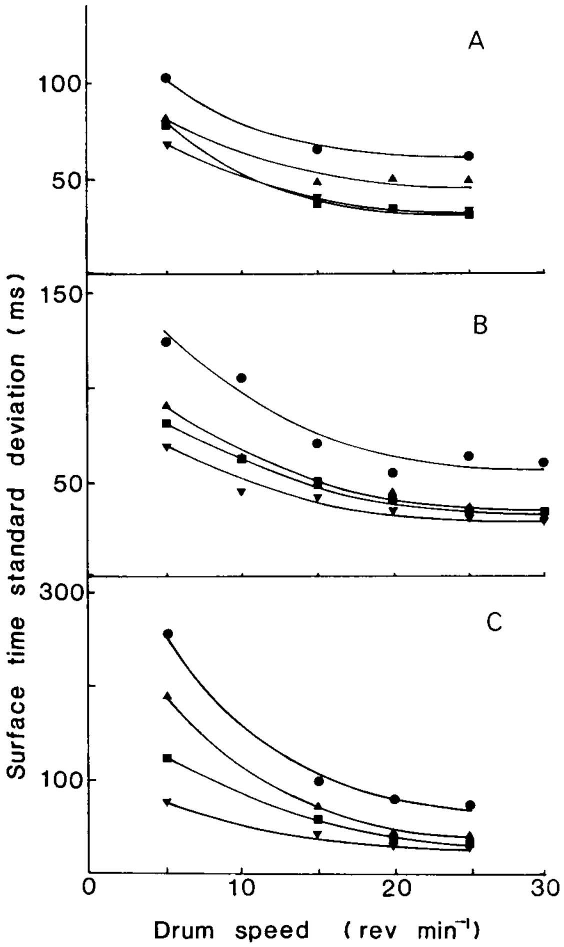

FIG. 3. The effect of drum speed on the standard deviation of the surface time for different tablet sizes (symbols as for Fig. 2).

Circulation time

Typical tablet appearance/circulation profiles as recorded by the chart recorder are shown in Fig. 4, each peak above the threshold representing a tablet appearance in the spray zone. These clearly demonstrate the irregularity of tablet movement in the bed, with disappearances of up to 2 min (e.g. point 'X') and multiple appearances on the bed surface as the tablet follows the revolution of the tablet bed (e.g. point 'Y').

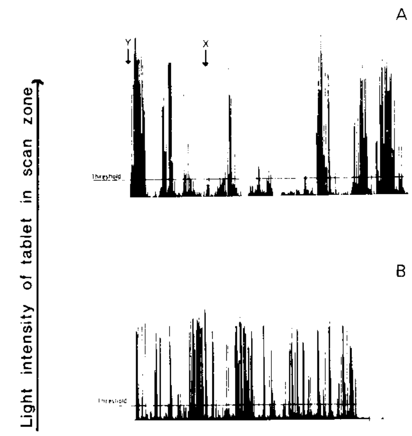

FIG. 4. Typical tablet appearance/circulation profiles for 9·0 mm diameter tablets at a 10 kg drum loading: A, 5 rev min^{-1} drum speed; B, 25 rev min^{-1} drum speed.

Fig. 5 shows a general decrease in circulation time as drum speed increases and, in part, this was attributable to greater baffle-induced turbulence within the tablet bed. However, it was principally a time base effect since when expressed in terms of tablet bed revolutions, the decrease in circulation period was not as clearly marked. Bed weight will predictably affect the circulation time in relation to tablet population.

The average circulation times (Fig. 5) were significantly lower than those reported by Prater et al (1980) who found, in a spread of 2–243 s, an average circulation time of 25 s. The high average figure is probably due to two factors—firstly the technique used may not have captured a sufficient number of data points for derivation of a time average value, and secondly the coating drum used may not have been as well equipped with mixing elements as the machine used for the present study.

It can be seen from Fig. 4 that it is the uneven circulation time distribution that can primarily be

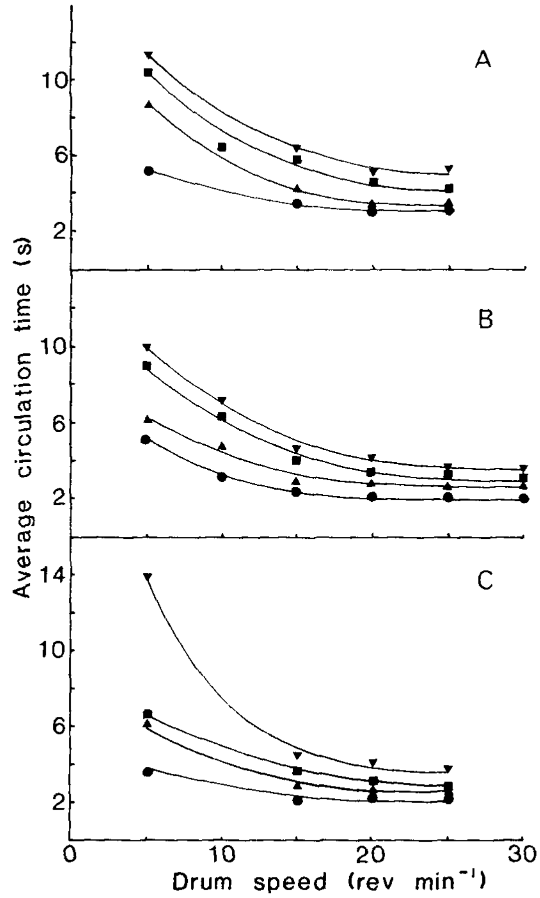

FIG. 5. The effect of drum speed on the average circulation time for different tablet sizes (symbols as for Fig. 2).

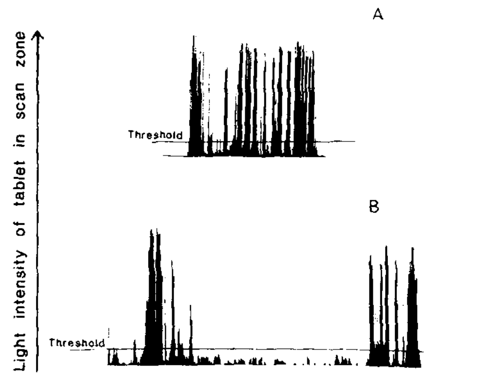

FIG. 6. The effect of baffles on tablet appearance/circulation profile for 9·00 mm diameter tablets at a 10 kg drum loading and 15 rev min^{-1} drum speed: A, baffled system; B, unbaffled system.

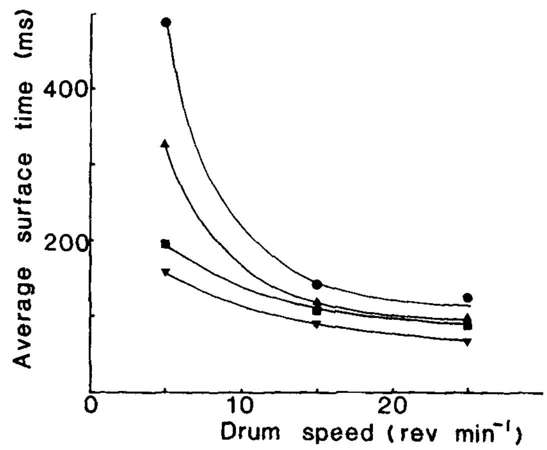

FIG. 7. The effect of drum speed on the average surface time for 9·0 mm diameter tablets in an unbaffled coating drum (symbols as for Fig. 2).

held responsible for the uneven exposure which leads to coat thickness variation from tablet to tablet. Fig. 6 illustrates the extent to which the situation is made worse on removal of baffles with circulation times increasing to values up to 14 min. Under these conditions the rotating tablet bed is thought to be behaving in the manner described by Schneider & Speiser (1968) and illustrated by Bauer (1977) for unbaffled vessels, with dead zones forming in the centre region of the bed.

Baffles also have an effect on the surface time of the tablet with considerably higher surface times being recorded in the unbaffled system due to the absence of induced turbulence within the bed (Fig. 7).

Total surface time

The total time that a tablet spends on the bed surface determines the share of coating solution that tablet received during the coating run. For the perfect situation of zero colour or coat thickness variation, each tablet in the bed would have the same total surface time equal to the theoretical exposure calculated from the number of tablets in the bed. By examining the total surface time of a single tablet in the bed over a number of experiments, it is possible to illustrate, by consideration of the variation of total surface times from the calculated theoretical value line, how closely the findings are to the perfect situation. The shaded portion of Fig. 8 represents the spread of results around the theoretical value. This suggests that, for a baffled 24 inch diameter drum coating, agreement with the theoretical exposure time over run times of approximately 15 min is reasonable and is consistent with the low colour variation that would be expected in practice (Rowe 1984).

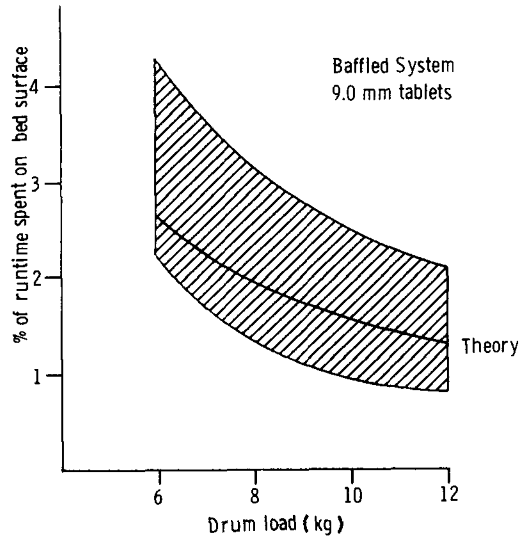

FIG. 8. The variation of total surface time for 9·0 mm diameter tablets—baffled system.

As total run time increases, the deviation from theory would be expected to reduce as the longer circulation times (Fig. 4 point 'X') become less significant in relation to total run time.

For an unbaffled system the situation is markedly different with considerable deviation from ideal, suggesting high potential for colour variation (Fig. 9). The skewed distribution of results about the theoretical line clearly demonstrates the inability of the unbaffled system to dislodge the tablet from its starting position on the outer layer of the bed during the 15–20 min run time: longer run times would be expected to reflect a more even distribution about the theoretical values as slow circulation out of the scan area and the dead zone proceeds.

Conclusions

The experimental technique is simple to apply and is capable of capturing a large amount of data in a short period of time. The technique is recommended for use in the evaluation of any mixing system in which a light-tight environment can be maintained.

In the 24 inch diameter Accela-Cota it has been shown that surface time is directly related to drum speed and tablet bed weight. Thus the spray picked up by a tablet per pass through the spray can be controlled to achieve the optimum tablet covering rate for minimum coat thickness variation.

The pattern of tablet appearance, i.e. the circulation time distribution, cannot be controlled by regulation of operating parameters but is a function

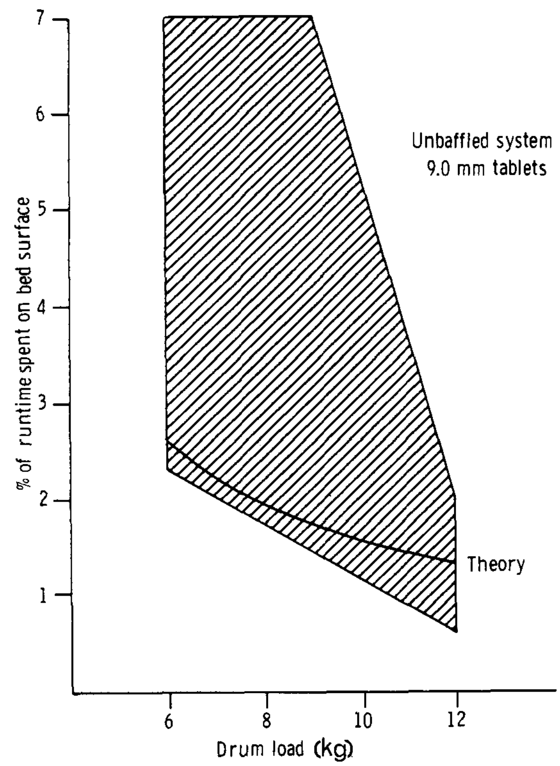

FIG. 9. The variation of total surface time for 9·0 mm diameter tablets—unbaffled system.

of the design of the rotating drum. The frequency of appearance can be accelerated by increasing drum speed and although this would be expected to reduce coating thickness variation to some degree, improved regularity of tablet appearance to approach absolute coating uniformity will only be achieved by mixing system design improvements.

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