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THE EFFECT OF PROCESS AND EQUIPMENT PARAMETERS ON THE DRUM GRANULATION KINETICS

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Results of studies on agglomeration of powder material in drum granulators at drop-wise wetting of a bed with constant flow rate of supplied liquid are presented. The effect of process and equipment parameters, including drum diameter D, drum filling φ, rotational speed of the drum n, on granulation kinetics was determined. The effect of these parameters on mean diameter of granulated material d, and variability defined as the ratio of standard deviation of particle size distribution to the mean diameter (s/d) was discussed.

Keywords: drum granulation, granulation kinetics

INTRODUCTION

The process of agglomeration covers processing of dust and powder materials into a granulated form. One of the basic properties of a product obtained in such a process is its particle size distribution. Of importance is not only the mean particle size of granulated bed but also homogeneity of the product obtained. One of frequently applied methods of granulation is drum agglomeration which consists of forming and agglomeration of particles in a moving (tumbling) bed of fine-grained material. In this

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process, the final product quality is affected by the following factors: granulation time, geometry of the drum, its operating parameters and bed wetting conditions.

The effect of operating parameters on granulation kinetics was studied by Newitt and Conway-Jones (1958) among the others. Kapur and Fuerstenau (1966) tried to find a relationship between particle size and process parameters (the absolute number of drum rotations n). They found that the process depended on water content in the agglomerate and particle size distribution of the raw material. That was confirmed by studies carried out by Linkson et al. (1973). Due to the range of studies, these investigations did not result in general solutions related, for instance, to the effect of several parameters on particle size of the product.

AIM OF THE STUDY

The aim of the present study was to determine the effect of some equipment and process parameters (drum diameter, its filling with raw material and rotational speed) on the granulation kinetics.

MEASURING EQUIPMENT AND METHODS

Investigations were carried out in a laboratory drum granulator. The drum was driven by motoreducer by means of a belt transmission and a gear. A smooth change of the drum rotational speed was achieved by means of inverter. The granular bed in the drum was wetted drop-wise by sprinkler, inserted axially to the equipment.

The wetting liquid was supplied from tank and its flow rate was controlled by rotameter. A constant level of liquid in the tank was maintained during the testing which ensured constant pressure of the supplied liquid. The wetting liquid was distilled water which was fed over the tumbling bed by means of a sprinkler which ensured a uniform supply along the entire drum length. The granular bed was wetted at a constant liquid flow rate ($Q = 10^{-6}$ m^3/s), until overwetting of material which caused sticking of the bed to the inner wall of the granulator. The process of granulation was carried out batch-wise, each time at a determined filling of the drum, rotational speed of the granulator and drum diameter.

For comparison, in the investigations the values of relative velocity n_w expressing the ratio of rotational speed n to critical speed of the drum n_{kr} were used. The relative velocity n_w was changed in the range which ensured a sudden motion of the bed tumbling in the drum. In time intervals equal to 60 s samples were taken from the drum to determine on this basis the particle size distribution in the bed. Owing to a constant rate and continuous feed of the wetting liquid, changes of the tested values during granulation (wetting) were identical with the changes referring to the bed moisture content in the drum.

Tests were carried out in a batch drum granulator for the following range of parameters:

- drum diameter of the granulator D = 250-400 mm
- drum filling with granular bed φ = 5–20%
- the ratio of drum rotational speed to critical (relative) velocity $n_w = n/n_{kr}$ = 0.15–0.375.

A testing material was casting bentonite of grain size ranging from 0 to 0.16 mm (mean diameter d_m= 0.056 mm) and batch density ρ_n = 0.865 kg/m^3.

RESULTS AND DISCUSSION

The effect of equipment and process parameters on the particle size of the final product obtained for different wetting times (moisture content of the granulated bed) was analysed. On the basis of the studies, the relationships of the effect of the tested parameters on mean particle size of the granulated material and on its size distribution were developed.

On the basis of results obtained during screen analysis some parameters of grain size distribution of the granulated material were calculated according to Kafarov (1979) and Achnazarova and Kafarov (1982):

ordinary moments of the first order (mean diameter)

$$d = m_1 = \sum_{i=1}^{n} x_{si} \cdot d_{mi} \tag{1}$$

– central moments of the second order (variances)

$$M_2 = s^2 = \sum_{i=1}^{n} x_{si} \cdot \left(d_{mi} - d\right)^2 \tag{2}$$

The variability coefficient defined as the ratio of standard deviation of particle size distribution to the mean diameter s/d (PN-90/N-01051) determining the spread of particle size of the obtained product in relation to mean diameter d, was proposed.

The dependence of mean particle diameter of the granulated product on wetting time is described by the equation:

$$d = C \cdot t + 0.056 \tag{3}$$

An example of the dependence of the increase of mean particle diameter of the granulated material during the process on different drum diameters is shown in Fig. 1.

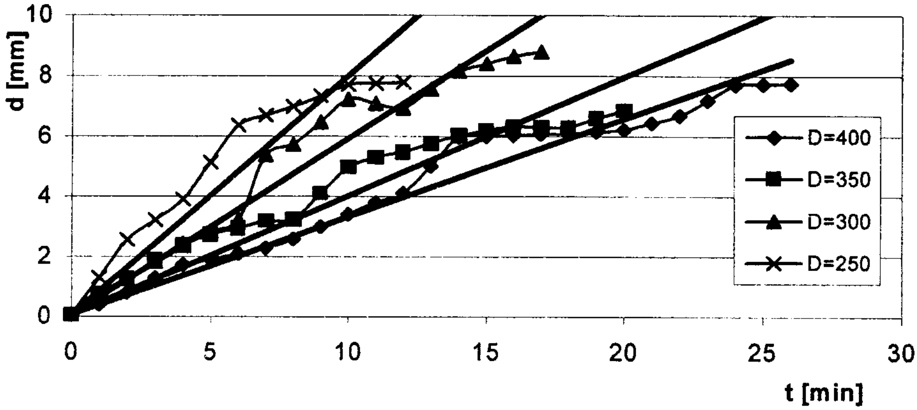

Fig. 1. The effect of wetting (granulation) time on the mean particle diameter of the product for different drum diameters at $n_W = 0.2$ and $\varphi = 15\%$

For other tested parameters of the granulator operation (drum filling φ and relative rotational speed n_W) similar relationships were obtained. They are presented in Figs. 2 and 3.

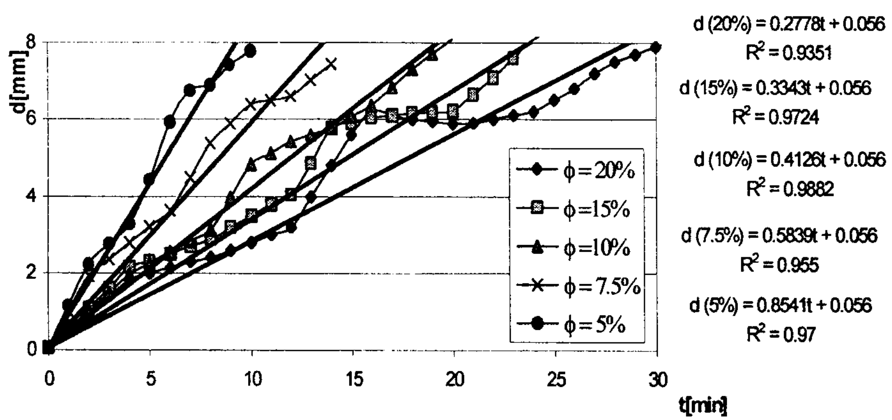

Fig. 2. The effect of wetting time on mean particle diameter of the product for different drum filling ($D = 400$ mm, $n_W = 0.15$)

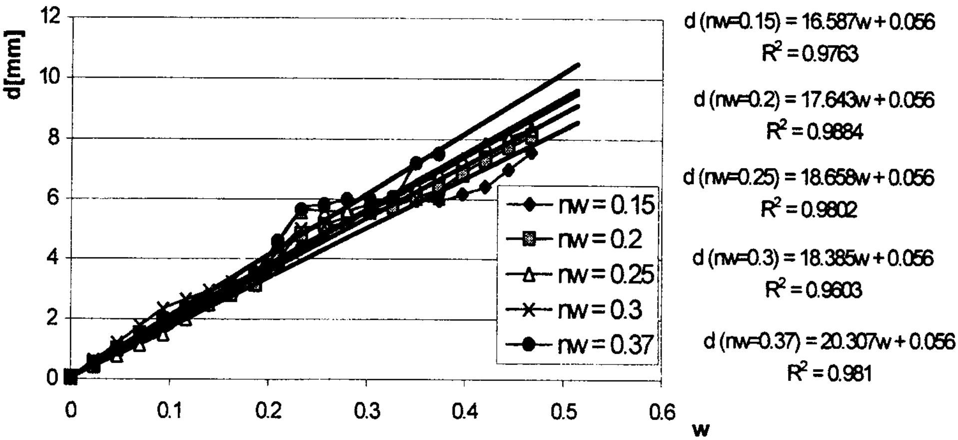

Fig. 3. The effect of moisture content (wetting time) on mean particle diameter of the product for different relative rotational speeds of the drum (D = 400 mm; φ = 20%)

These relationships allowed us to propose a general relation for the growth rate of granulated material in the form of the following correlation:

$$C = \frac{\partial d_{śr}}{\partial t} = 10^{-2} \cdot n_w^{\,0.144} \cdot D^{-2.06} \cdot \varphi^{-0.9} \tag{4}$$

The correlation coefficient in the above equation was R = 0.98.

The variability coefficient s/d was made dependent on the tested equipment and process parameters. The dependence of coefficient s/d on the wetting (granulation) time for all tested parameters is described by the equation:

$$\frac{s}{d} = A \cdot t^B \tag{5}$$

Examples of changes in the variability coefficient s/d during granulation for varying equipment and process parameters (drum diameter D, filling of the drum with material φ, relative rotational speed n_W) are presented in Figs. 4 - 6.

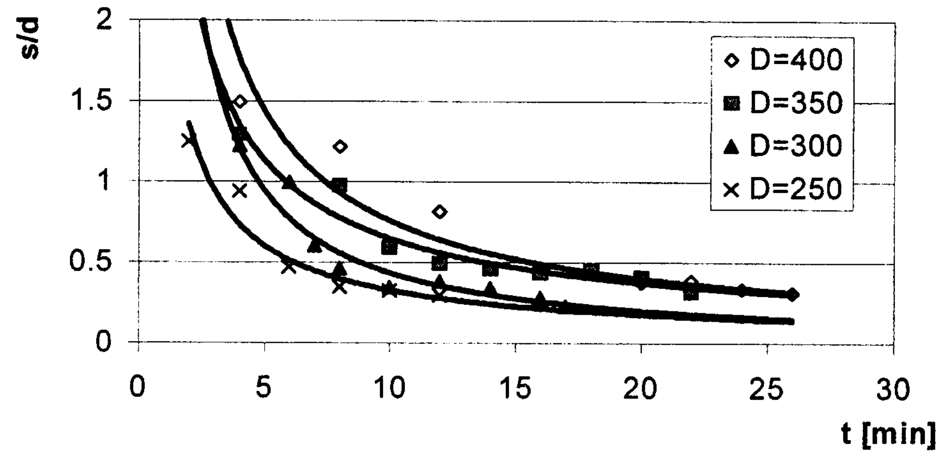

Fig. 4. The effect of wetting time on variability coefficient s/d for granulated material obtained at different drum diameters D (n_W = 0.15; φ = 0.15)

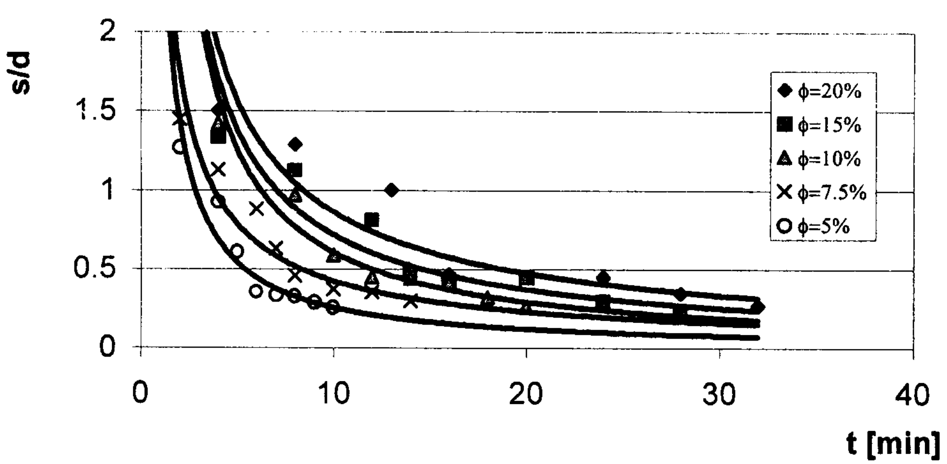

Fig. 5. The effect of wetting (granulation) time on variability coefficient s/d, for different values of drum filling φ (D = 400 mm; n_W = 0.2)

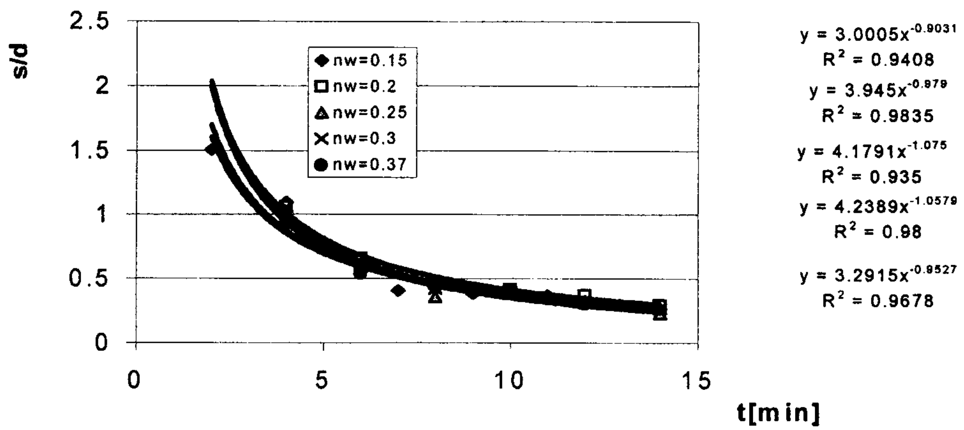

Fig. 6. The effect of wetting time on variability coefficient s/d of the product for different relative rotational speeds n_W of the granulator drum (D = 350 mm, φ = 10%)

For all tests the value of coefficient B in eq. (5) was close to -1, therefore the equation was simplified to the form:

$$\frac{s}{d} = A \cdot \frac{1}{t} \qquad (6)$$

For all tests the coefficient A in eq. (6) was related to the parameters: drum diameter D, its filling φ and relative rotational speed n_w, obtaining the following equation:

$$A = 10^{-3.5} \cdot D^2 \cdot \varphi \qquad (7)$$

The effect of relative speed n_W appeared to be insignificant and as such was omitted in the final form of the equation. Equation (7) was obtained at correlation coefficient R = 0.94.

CONCLUSIONS

1. The mean particle diameter of granulated product depends linearly on wetting time (moisture content of the granulated bed).
2. The rate of changes in the mean particle diameter of the granulated product can be related to the equipment and process parameters.
3. Variability coefficient s/d determining the scatter of grain size of the granulated product depends on the drum diameter and its filling. It is inversely proportional to the granulation (wetting) time.

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NOMENCLATURE

A, B, C	– coefficients
D	– drum diameter, m (in figures in mm)
d	– mean particle diameter of the granulated material, mm
m_1	– ordinary moment of the first order
M_2	– central moment of the second order
d_{mi}	– mean diameter of class i, mm
x_{s_i}	– mass fraction of class i
n_w	– relative rotational speed
φ	– drum filling with material
t	– granulation (wetting) time, s
s^2	– variance

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Jedną z podstawowych własności uzyskanego w procesie aglomeracji produktu jest jego skład granulometryczny. Istotny jest tu nie tylko średni wymiar charakterystyczny dla zgranulowanego złoża,

ale także jednorodność otrzymanego produktu. Jedną z częściej stosowanych metod wytwarzania granulatu jest bębnowa granulacja aglomeracyjna polegająca na formowaniu i narastaniu cząstek w ruchomym złożu materiału drobnoziarnistego (przesypowym). W procesie tym na jakość produktu końcowego wpływ ma wiele czynników takich jak czas granulacji, parametry geometryczne aparatu, parametry jego pracy oraz warunki nawilżania złoża. Celem pracy było określenie wpływu niektórych parametrów aparaturowo-procesowych na kinetykę procesu granulacji. Badania prowadzono w granulatorze bębnowym o działaniu okresowym dla następującego zakresu zmian parametrów:

-średnica bębna granulatora D=0.25–0.40m

-wypełnienie aparatu złożem ziarnistym φ=5%–20%

-stosunek prędkości obrotowej bębna do prędkości krytycznej: $n_w = n/n_{kr}$=0.15–0.375

Do badań zastosowano bentonit odlewniczy o średniej wielkości ziarna d_m=0.056mm, a jako ciecz zwilżającą wodę destylowaną, którą podawano na przesypujące się złoże równomiernie na całej długości granulatora, przy stałym natężeniu wypływu cieczy $Q=10^{-6}$ m^3/s. W odstępach czasu równych 60s pobierano z bębna próbki, na podstawie których określano skład granulometryczny złoża. Na podstawie uzyskanych wyników opracowano zależności dotyczące wpływu badanych parametrów aparaturowo-procesowych na średnią wielkość uzyskanego granulatu oraz współczynnik zmienności s/d określający rozrzut wielkości uzyskanego produktu względem średnicy średniej d. Zależność średniej wielkości ziarna granulatu od czasu nawilżania opisano równaniem, a jej przykładowe wzrosty w czasie procesu dla różnych parametrów aparaturowo-procesowych przedstawiono na rysunkach. Charakter uzyskanych zależności pozwolił na zaproponowanie ogólnego równania na szybkość wzrostu ziaren granulatu. Zależność współczynnika s/d od czasu nawilżania (granulacji) dla wszystkich badanych parametrów opisano równaniami.