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CHANGE IN THE PROPERTIES OF BEDS GRANULATED IN DISC GRANULATORS

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During tumbling of a powder bed wetted with liquid, material particles are agglomerated. Both the formation of granules and increase of the bed moisture content cause changes in bulk density and the coefficient of material friction against the granulator surface. They in turn determine energy transfer to the granulated material.

In the present study, a change of the above mentioned parameters during batch granulation was investigated by comparing results obtained with a change in granulation degree and torque on the granulator shaft. Experiments were made in three disc granulators of diameters 0.5, 0.7 and 1 m, with rotational speeds equal to 0.2 of critical velocity. Variable parameters were the degree of disc filling and the angle of inclination of the disc axis to the level. The experimental material was bentonite with particles from 0 to 0.16 mm in diameter (d_m = 0.056 mm), specific density 2420 kg/m^3 and bulk density 790 kg/m^3. The material was wetted drop-wise with water during the granulation at constant liquid flow rate Q = 0.7 ml/s.

The angle of disc axis inclination in the applied range of its changes had no effect on the process and layer properties.

In all cases, bulk density of the bed during granulation decreased. When observing change of the coefficient of friction between the bed and disc surface during granulation, three ranges of this parameter change were found. In the first, the coefficient was growing. In the second, short period, the coefficient decreased slightly. In the third, it increased again.

Changing the in torque on the granulator shaft was also analysed. Three ranges could be distinguished here as well. In the first, unit moment increased to up to 50%. In the second, it dropped. In the third, it remained constant.

key words: agglomeration, bulk density, friction coefficient, energy of granulation

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INTRODUCTION

In drum or disk batch granulators, agglomeration of particles and formation of granules are induced by material layers mutually dislocating in the bed. The bed is elevated to a certain level due to the friction between it and moving surface of the apparatus. It then goes downward due to gravity force. At the beginning of the process, the primary material layer slides down the free bed surface and it is wetted with liquid. Granules formed after a certain time do not slide down but roll down, and relevant mechanisms cause an increase in mean diameter and strength (Rumpf, 1977). The intensity of granulated bed tumbling is determined among the others by the coefficient of bed friction against the granulator surface. At higher values the material is elevated to a higher level. It slides or rolls down a more inclined surface and tumbling is more intense. This is related to a higher torque value on the granulator shaft. A change of the inner bed structure during wetting and agglomeration (an increase of moisture content and granulation degree) causes a change in its bulk density and coefficients of inner friction and material friction against the apparatus surface. These, in turn, determine energy transfer onto the granulated material and its tumbling intensity (Gluba, 2000; Chadwick, 1997).

The aim of the present study was to investigate how the above parameters change over time during granulation, and how they are related to moisture content of the bed and particle size distribution. Another parameter which was measured for comparison during the granulation was changing torque on the granulator shaft over time.

EXPERIMENTAL

Granulation was carried out on a properly equipped experimental rig with an exchangeable disc whose angle of inclination to the level α could range from 45° to 53°. Tests were made for three disc diameters: 0.5, 0.7 and 1 m. In all cases, rotations frequency of the disc was $n = 0.2\ n_{cr}$, where n_{cr} represents the critical value of rotations frequency at which the bed started swirling with the disc. This enabled proper bed dynamics and prevented the feed from getting outside the disc. On the other hand, this made it possible for the results of all disc diameters to be compared. Tests were made for five different degrees of disc filling: 3%, 4%, 5%, 6% and 7%. The granulated material was bentonite with particle size ranging from 0 do 0.16 mm. The mean particle diameter was 0.056 mm. Specific density of dry bentonite was 2420 kg/m^3, its bulk density was 790 kg/m^3, and tangent of the angle of natural repose was 1.15.

The material was wetted drop-wise with distilled water during granulation at constant liquid flow rate of 0.7 ml/s. At time intervals, samples were taken to determine the particle size composition of granulated material, the bulk density, and the coefficient of material friction against the disc surface. Instantaneous values of the torque on the disc shaft were also measured. The values were used to calculate the unit moment varying in time using the following formula:

$$M^*(t) = \frac{M(t) - M_0}{m_s + Q \cdot \rho_l \cdot t} \tag{1}$$

where:

$M(t)$ – instantaneous value of measured moment,
M_0 – moment at the empty disc rotation,
m_s – mass of loose material (feed) on the disc,
Q – wetting water flow rate,
ρ_l – wetting water density,
t – time of water dosing (granulation time).

RESULTS

There have been many stadies on the change of material particle size distribution over time (Kapur, 1972) (Sastry, 1973) (Kapur, 1981) (Pataki, 1987). Most of these studies were conducted on a small scale in the laboratory. The present study was conducted on a large scale. Basing on particle size analysis of the agglomerated material, mean particle diameter d_m for subsequent granulation times, was calculated from the formula:

$$d_m = \sum_{i=1}^{n} x_i \, d_{mi} \tag{2}$$

where: x_i–mass fraction i,
d_{mi}–mean particle diameter in fraction i.

The change in particle diameter over in time at different filling degrees and disc diameters is shown in Fig. 1 and 2, respectively. Significant differences result mainly from the fact that, in subsequent trials, the mass of raw material to be granulated was different, while wetting intensity was constant.
The mean moisture content of the bed in particular trials for the same wetting time was different.

If we compare the change of mean diameter *d* with the change of bed moisture content, this relationship will be similar for all trials, regardless of the disc diameter, the filling, and the angle of inclination of the disc axis. Fig. 3 shows this for random points taken from the whole data set.

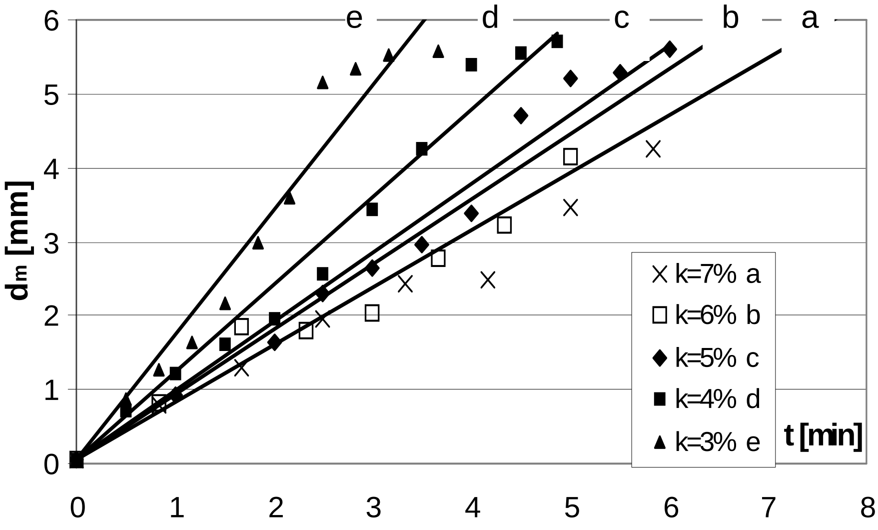


Fig. 1. The effect of wetting time (process duration) on mean particle diameter of the granulated material, for different disc filling degrees
(D = 0.5 m, α = 45°)

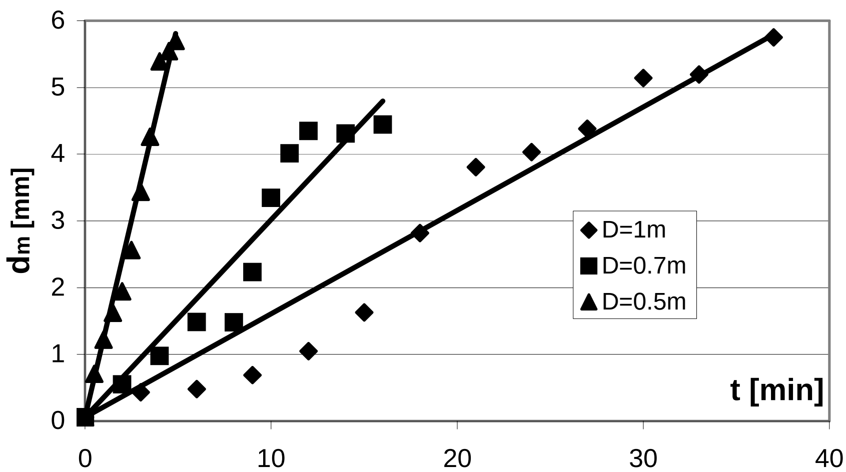


Fig. 2. The effect of granulation time on mean particle diameter of granulated material at different disc diameters D (α = 45° and k = 4%)

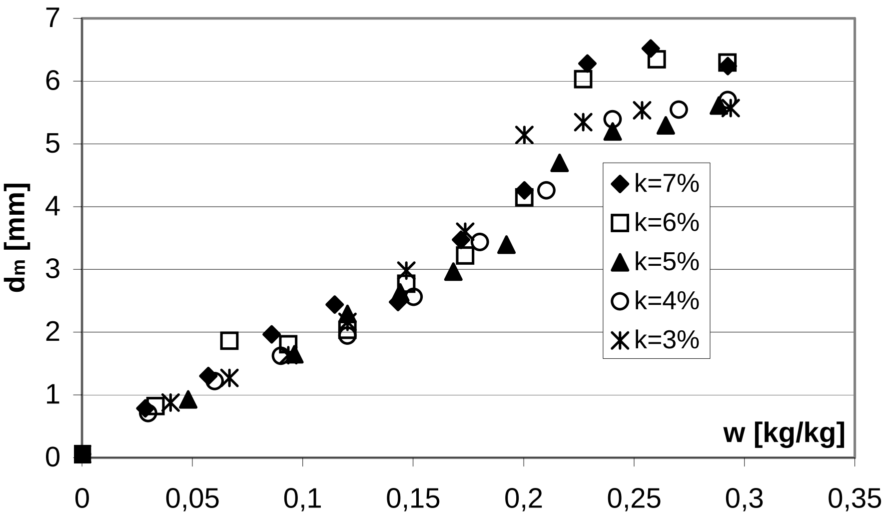
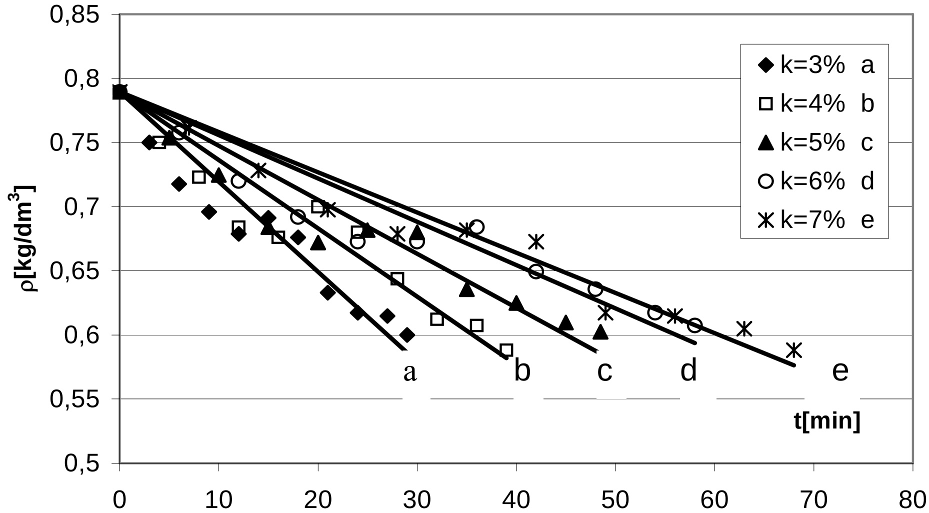


Fig. 3. The effect of mean moisture content of the bed on mean particle diameter of the granulated



material

Fig. 4. Change in bulk density of granulated material for different degrees of disc filling
(D = 1 m, $\alpha = 47°$)

Similar conclusions follow from the analysis of data which describe a change of bulk density of the material during granulation. Opposite relationship are obtained for subsequent disc filling degrees and diameters when this density change is observed over time (Fig. 4 and 5).

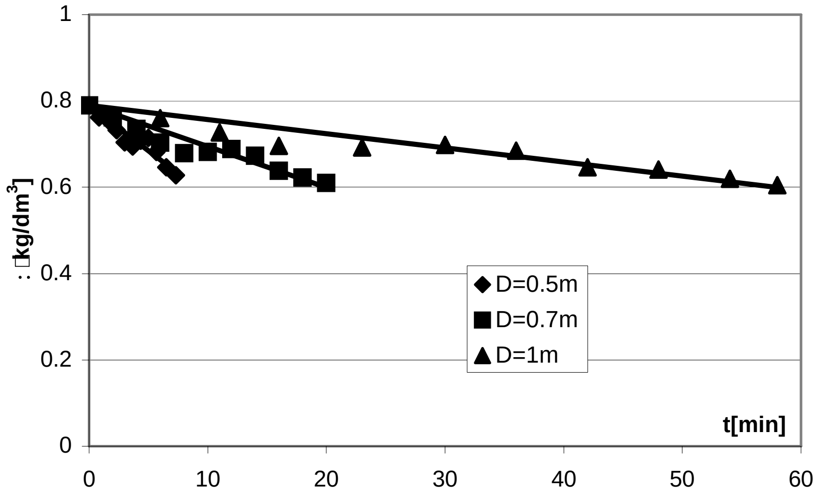


Fig. 5. The effect of wetting time (granulation time) on bulk density for different disc diameters ($k = 6\%$, $\alpha = 49°$)

When bed moisture content is the independent variable, then the measuring points are located on a single straight line (Fig. 6 and 7).

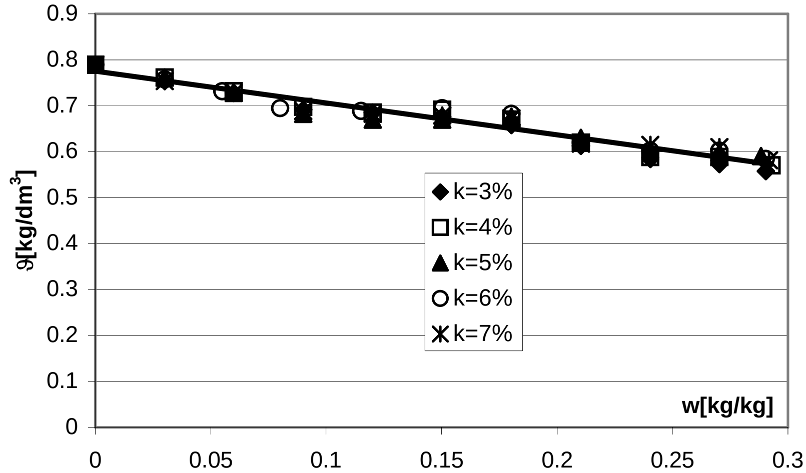


Fig. 6. Change of bulk density as a function of bed moisture content for different disc filling degrees ($D = 1$ m, $\alpha = 51°$)

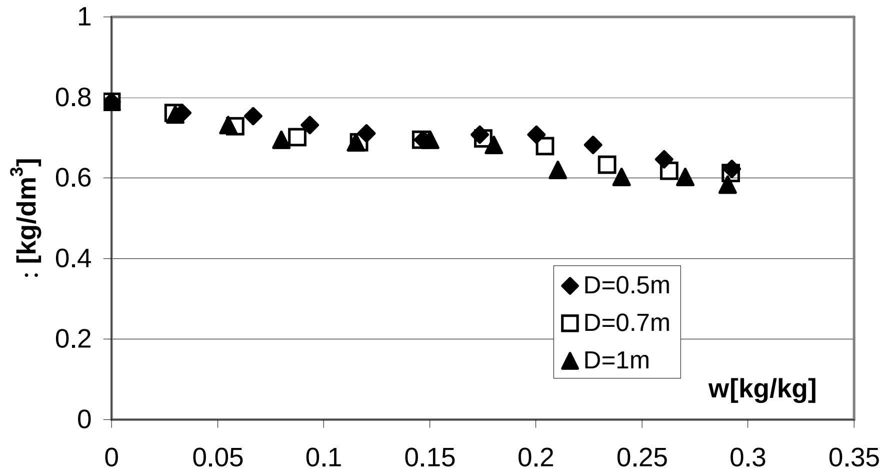


Fig.7. Change of bulk density with an increase of bed moisture content for different disc diameters ($k = 6\%$, $\alpha = 51°$)

Analogously, disc inclination angle had no effect on this relationship. In the tested range of disc filling, diameter and inclination angle, these parameters have no effect on the relationships between bulk density and granulated material moisture content.

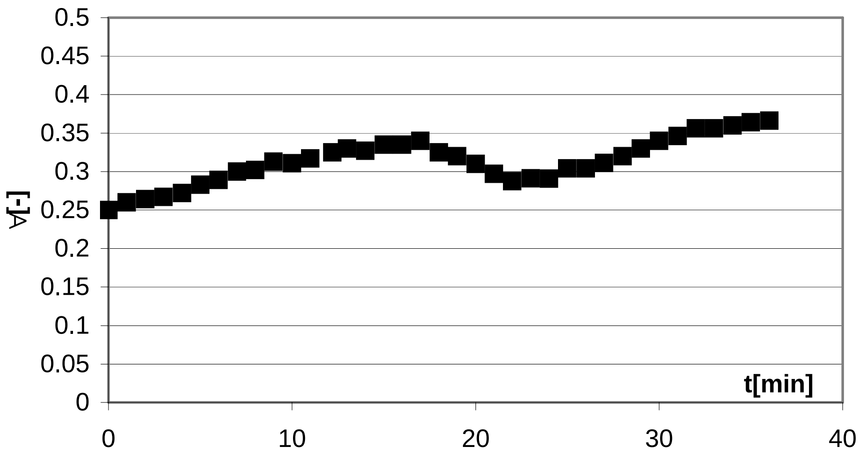


Fig. 8. An example of change in the coefficient of friction between granulated material and disc surface during the process

Energy input for granulation is related to the coefficient of friction between the bed and disc surface, because the energy is transmitted from the disc to the bed because of the friction. The coefficient change during granulation is therefore important. For all granulation tests, this relationship was the same (Fig. 8).

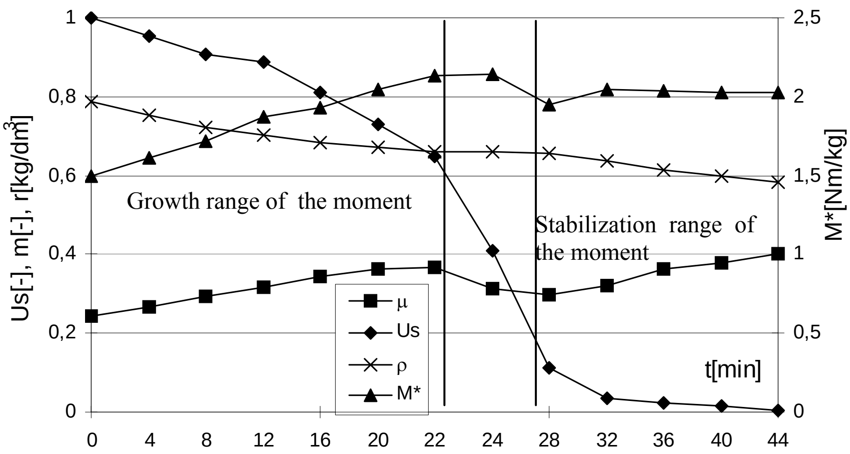


Fig. 9. A comparison of friction coefficient μ, bulk density ρ, non-granulated material U_s and unit moment M* during granulation (D = 1 m, k = 5%, α = 53°)

Three periods can be observed when changes in friction coefficient in the granulation process proceed differently. At the beginning, there is an increase caused by the growth of bed moisture content and partial sticking of material to the disc surface. As a result, the bed is elevated to a higher level and tumbling is more intense. At a certain point, the friction coefficient decreases. In the second stage, the amount of non-granulated material decreases quickly. This is illustrated in Fig. 9, where U_s is the amount of non-granulated material calculated on the basis of sieve analysis as a mass fraction smaller than 1 mm.

The second stage ends when practically the whole feed is transformed into granulated product with a relatively low moisture content mainly inside the granules. Further granulation and wetting causes an increase in the moisture content of the granules, which are additionally consolidated. Liquid from inside is pressed to their surface. This surface moisture causes that granules stick locally to the disc surface, and the coefficient of averaged friction on the whole bed-disc contact surface increases.

Figure 9 also shows the change over time of bulk density and unit moment calculated from equation (1) for the same granulation trial. The change over time of all measured values can be divided into three stages in the same time intervals. In the first stage non-granulated material appears and the fraction of granules increases. Bulk density of the bed decreases, the coefficient of material friction against the disc bottom grows and the unit turning moment on the disc shaft also increases significantly. In the second, transient period, an abrupt decrease of non-granulated material is observed, granules are probably dry on the surface, friction coefficient decreases and the granules reveal a decreasing tendency to stick to the walls. In this time bulk density remains constant and the torque also decreases. In the third stage, there is no non-granulated material. A mean granule diameter continues to increase owing to the mechanisms of crushing weaker granules and combining them into more resistant granules (Fig. 2). Bulk density of the material decreases and friction coefficient grows due to an increase of surface moisture content of the granules. This moment on the granulator shaft is constant during this stage.

CONCLUSIONS

There are changes in the properties of the bed granulated in the disc granulator at continuous wetting. In the tested range of changes of the angle of disc inclination, filling, disc dimensions, the change of bulk density of the bed and the coefficient of bed friction against the granulator can be described only as a function of bed moisture content. There was a correlation between the change of bulk density and friction coefficient and the unit torque on the granulator shaft with the granulation degree (mass fraction of non-granulated material).

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REFERENCES

CHADWICK P.C., BRIDGNATER I., (1997), *Solids Flow in Disc Granulators*, Chem. Eng. Sci. 54, 15, 2497-2509.

GLUBA T., HEIM A., OBRANIAK A., (2000), *Driving Torque in the Process of Drum Granulation*, CHISA 2000, Praha.

KAPUR P.C., SASTRY K.V.S., FUERSTENAU D.W., (1981) *Mathematical Models of Open-Circuit Balling or Granulating Devices.*, Chem. Process. Des. Dev., 20, 519-524.

KAPUR P.C., (1972)Kinetics of Granulation by Non-random Coalescence Mechanism, Chem. Eng. Sci., 27, 1863.

PATAKI K., HORVATH E., ORMOS Z., (1987) *The Effect of Rolling Time on the Physical Properties of Granules*, Hung. J. Ind. Chem., 15, 133-140.

RUMPF H., (1997) *Particle Adhesion, Some Fundamental Aspects of the Selective Agglomeration of Fine Coal*, Agglomeration 77 (K.V.S. Sastry ed.), AIME, New York 1977 pp. 97-129.

SASTRY K.V.S., FUERSTENAU D.W., (1973) *Mechanisms of Agglomerate Growth in Green Pelletization.*, Powder Tech., 7, 97-105.

Heim A., Obraniak A., Gluba T., *Zmiany właściwości złoża granulowanego w granulatorze talerzowym***,** Physicochemical Problems of Mineral Processing, 44 (2010), 53-62, (w jęz. ang), http://www.minproc.pwr.wroc.pl/journal

Granulacja talerzowa to uniwersalna metoda aglomeracji pozwalająca prowadzić proces w sposób okresowy lub ciągły oraz sterować poprzez dobór parametrów procesowych rozmiarem i właściwościami uzyskanego produktu.

Celem pracy było zbadanie wpływu parametrach aparaturowo-procesowych (średnicy talerza, stopnia jego wypełnienia oraz kąta pochylenia) na zmiany wartości średniego rozmiaru granul, gęstości nasypowej granulatu, oraz kąta tarcia złoża podczas procesu granulacji talerzowej. Proces prowadzono w sposób okresowy dla następujących zakresów zmian parametrów:

- kąt pochylenia osi talerza w stosunku do poziomu α=45-53% co 2 stopnie
- stopień wypełnienia aparatu materiałem k=3-7% co 1%
- średnica talerza granulatora D=0.5, 0.7, 1m

Do badań jako materiał modelowy użyto drobnoziarnistego bentonitu odlewniczego o składzie granulometrycznym z zakresu 0-0.16mm. Badania granulacji przeprowadzono przy stałym natężeniu dopływu cieczy zwilżającej (woda) Q=0.7 g/s i ustalonej końcowej wilgotności granulowanego wsadu w=0.29. Uzyskane podczas trwania eksperymentów wartości badanych parametrów uzależniono od zmian wilgotności granulowanego złoża ziarnistego oraz czasu granulacji. Dokonano porównania szybkości zmian rozmiaru średniego oraz gęstości nasypowej dla szeregu granulatorów talerzowych różniących się średnicą talerza i kątem jego pochylenia, przy zmiennym stopniu wypełnienia surowcem.

słowa kluczowe: aglomeracja, gęstość, współczynnik poślizgu, energia, granulacja