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DISK GRANULATOR. IMPROVEMENT OF CONSTRUCTION AND SELECTION OF PROCESS PARAMETERS

Summary

Granulation is a process of agglomeration of small particles of shredded materials into larger units and is carried out in the presence of liquid. As far as the energy used in agglomeration is concerned, the process can be divided into pressure pelletizing: pressing, tableting, briquetting, and extrusion, and low pressure granulation, commonly known as non-pressure granulation, which primarily consists of the following processes: sintering, accompanied by high temperatures – below the melting point of the ingredients; granulation in a fluidized bed, i.e. powder grains aggregating as a result of collisions in a humidified fluidized bed; and agglomeration granulation, which consists in turning and moving of layers of granular deposits. Improvement of the quality of granules can be achieved by improving granulators, a careful selection of process parameters, and using various additives to the granulated mixture of raw materials. In comparison with pressure granulation devices, granulators for non-pressure granulation have many advantages, including simplicity of equipment, a significantly lower purchase cost, and a longer life. Another advantage consists in the energy efficiency of the method, which translates into economic benefits. The resulting non-pressure granulation products should frequently be subject to drying or partial drying, which is regarded as a disadvantage. Moreover, granules obtained in this manner are characterized by a diversity of grain classes. The paper presents the equipment and process parameters that have an impact on the process of non-pressure disk granulation with the use of a raking blade.
***Key words**: granulation, disk granulator, granulation blade, granulation parameters*

GRANULATOR TALERZOWY. DOSKONALENIE KONSTRUCJI I DOBÓR PARAMETRÓW PROCESU

Streszczenie

Granulacja jest procesem aglomeracji małych cząstek materiałów rozdrobnionych w większe zespoły i prowadzona jest w obecności cieczy. Biorąc pod uwagę energię wydatkowaną w procesie aglomeracji, proces ten można podzielić na: granulację ciśnieniową: prasowanie, tabletkowanie, brykietowanie oraz wytłaczanie. Granulacja niskociśnieniowa, potocznie zwana bezciśnieniową, to przede wszystkim procesy: spiekania, któremu towarzyszy działanie wysokiej temperatury, niższej od temperatury topnienia składników; granulacja w złożu fluidalnym, czyli łączenie się ziaren proszku w wyniku zderzeń w złożu fluidalnym nawilżanym cieczą; granulacja aglomeracyjna, polegająca na przesypywaniu się i przemieszczaniu warstw złoża ziarnistego. Poprawę jakości granulatów można uzyskać doskonaląc urządzenia do granulacji, dobierając starannie parametry procesowe, a także stosując różne dodatki do granulowanej mieszaniny surowców. W porównaniu z urządzeniami granulacji ciśnieniowej granulatory metody bezciśnieniowej mają wiele zalet m.in.: prostota stosowanych urządzeń, zdecydowanie niższy koszt ich zakupu oraz dłuższy czas eksploatacji. Dodatkowym atutem jest energooszczędność metody, co przekłada się na korzyści ekonomiczne. Powstałe produkty podczas granulacji bezciśnieniowej powinny być najczęściej poddawane suszeniu lub podsuszaniu. Cecha ta traktowana jest jako jedna z wad. Otrzymane w ten sposób granulki charakteryzują się różnorodnością klas ziarnowych. W pracy przedstawiono parametry aparaturo-procesowe, mające wpływ na przebieg procesu bezciśnieniowej granulacji talerzowej z wykorzystaniem łopatki zgarniającej.
***Słowa kluczowe:** granulacja, granulator talerzowy, łopatka granulacyjna, parametry granulacyjne*

1. Introduction

Granulation is a process of agglomeration of small particles of shredded materials into larger units and it is carried out in the presence of liquid. As far as the energy used in agglomeration is concerned, the process can be divided into pressure pelletizing (pressing, tableting, briquetting, and extrusion) and low pressure granulation, commonly known as non-pressure granulation (sintering, accompanied by high temperatures – below the melting point of the ingredients; in a fluidized bed – powder grains aggregating as a result of collisions in a humidified fluidized bed; and agglomeration – consisting in turning and moving of layers of granular deposits) [8].

Raw materials used in the fertilizer and chemical industries are those most often subject to low-pressure granulation. these include: urea superphosphate, dusty simple super phosphate, chlorinated sylvinite, magnesium in the form of dolomite, magnesite, kiresite [1], activated alumina [11], molten slags, molten metals, urea, ammonium nitrate, nitrate of lime, nitrophoska, perborates, petroleum ingredients: paraffin, wax, tar, sulphur [12], magnesium sludge, phosphate slime, by-products from the production of nitrate of lime and nitromagnesite, spent acid [15], dolomite meal [6], sediment from municipal waste, fine coal, hydrated lime, Portland cement, calcium aluminate cement, fly ash from bituminous coal [14], fine coal mixed with tobacco or cotton waste, wood dust, and waste produced during the production of meat-and-bone meal [9], zinciferrous, furnace waste, mixtures containing converter slimes, foundry bentonite, or washing powder [3].

According to Korpal [8], other materials subject to granulation are: beetroot seeds, radish seeds, quartz meal, a mixture of cellulose and maize starch, quartz dust, fine-grained bentonite, peat pulp, powdered milk, cocoa, brewery yeast cake, rye and wheat middlings, fodder mixtures consisting of cereal products and bone meals, fish and shrimp meals, powdered sugar, pellet shells of dried apples, dried vegetables: cucumbers, lettuce, carrots, parsley, leek, celery, onion; salt dust.

The process of granulation during low pressure agglomeration is usually carried out wet in granulating devices such as a granulation drum, bowl, or disk [1]. Among granulation liquids used in the granulation process there are water and its mixtures with sugar or honey; distilled water [6]; silicone oil, paraffin oil [12]; aqueous solution of sodium silicate [4], sulphuric acid [15]; purified water, aqueous solution of nitric acid and ammonium hydroxide [11]; aqueous solution of yellow dextrin [4].

In comparison with other production techniques, granulation in the environment of a liquid medium allows to obtain granulated products of a higher quality [12]. In addition, a process that occurs on a granulation disk is classification of materials. As the increasing size of granules depends on the place where water or glue is dosed on the disk, appropriate dosing makes it possible to obtain granules with a minimum distribution of grain sizes [5]. Another advantage of the granulation disk consists in a full visual control over the course of the process, which is crucial considering the constantly changing seed material. General trends in the development of techniques of granulation of chemical and food products result from the necessity to increase production efficiency and products quality. Basically, the known granulation methods ensure that a finished product with the required quality parameters is obtained. In the case when the range of these parameters is narrowed, there is a need to look for means and methods of improvement of the known granulation processes and to design new, more effective methods. For this reason, the development of granulation techniques is usually closely connected with general developments in technology of production of the product in question and determining the impact of individual parameters on its course, and hence on the quality of granules [7].

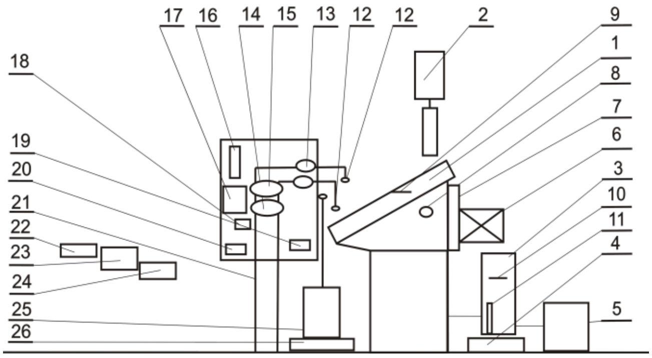
2. Test stand

The scheme of the test stand is shown in fig. 1. The test stand allows to carry out tests in a periodical manner.

Raw materials in coarse loose form were used for the tests. In order to achieve susceptibility sufficient to form granules with the use of the non-pressure method, they have to be shredded into fine-grained form (below 0.1 mm). Flail crusher 24 is used for this purpose.

A mixture of shredded raw material is fed to the hopper placed above vibrating dispenser 2, which allows to dose shredded ingredients into the appropriate place on the granulation disk.

The liquid is prepared in a container. It is then conveyed from the container to pressure tank 3, made from stainless steel. The tank allows to retain an appropriate temperature of the liquid inside for longer periods of time. A heating element – electric spiral heater 11 – is placed at the bottom of the liquid tank. Its operation is controlled by means of thermostat 18, which allows to adjust the temperature of the liquid in the range from 15°C to 90°C. At the bottom of the tank a ball drain valve is placed, which enables emptying.



Source: own work / Źródło: opracowanie własne

Fig. 1. Scheme of a test stand for non-pressure disk granulation: 1 - replaceable granulation disk, 2 - vibrating dispenser of shredded raw material, 3 - heated granulation water tank, 4 - large scales, 5 - compressor, 6 - electric motor, 7 - belt, 8 - screw mechanism, 9 - scrapers, 10 - liquid level sensor, 11 - heating element, 12 - spray nozzles, 13 - ball valve, 14 - reducing valve, 15 - manometer, 16 - rotameter, 17 - inverter, 18 - thermostat, 19 - clock, 20 - tachometer with an inductive sensor, 21 - rubber hoses, 22 - vibrating screen, 23 - weighing dryer, 24 - flail crusher, 25 - unheated granulation water tank, 26 - scales

Rys. 1. Schemat stanowiska badawczego do bezciśnieniowej granulacji talerzowej: 1 - wymienny talerz granulacyjny, 2 - dozownik wibracyjny rozdrobnionego surowca, 3 - zbiornik podgrzewanej cieczy granulacyjnej, 4 - waga duża, 5 - sprężarka, 6 - silnik elektryczny, 7 - przekładnia pasowa, 8 - mechanizm śrubowy, 9 - zgarniaki, 10 - czujnik poziomu cieczy, 11 - element grzewczy, 12 - dysze rozpyłowe, 13 - zawór kulowy, 14 - zawór redukcyjny, 15 - manometr, 16 - rotametr, 17 - falownik, 18 - termostat, 19 - zegar, 20 - obrotomierz z czujnikiem indukcyjnym, 21 - przewody gumowe, 22 - przesiewacz wibracyjny, 23 - wagosuszarka, 24 - rozdrabniacz bijakowy, 25 - zbiornik niepodgrzewanej cieczy granulacyjnej, 26 - waga mała

The liquid is fed to spray nozzles 12 as a result of overpressure above the liquid surface in the heated liquid tank. The overpressure is created by means of compressor 5 placed next to the lubricating liquid tank. Pressure is controlled by means of reduction valve 14, whereas its value is read out by means of a manometer. The stream of liquid is controlled by the performance of the two spray nozzles and ball valves 13, which dampen their flow. It is fed to the granulator at one or two points. The range of liquid flow rate is from 0.025 $l \cdot min^{-1}$ to 0.3 $l \cdot min^{-1}$.

The stream of raw material dosed from the dispenser and the stream of the sprayed granulation liquid meet on rotating disk 1. Depending on its intended use, the disk is characterized by the following parameters: diameter, flange height, and rotational speed. The rotational speed in question is achieved through control of operation of single-phase electric motor 6, to which inverter 17, whereas a drive is transferred through belt 7. This mechanism allows to change the frequency of rotation in the range from 0.1 s^{-1} to 1.7 s^{-1}.

During contact between the shredded raw material and the lubricating liquid as well as through the pouring motion of the material, a characteristically round granule is created.

At a set disk inclination angle, adjusted by means of screw mechanism 8, granules with an expected diameter leave the granulation disk. Values of granulation disk inclination may fall within the range of 0º to 90º.

Through a set of sieves comprising vibrating screen 2, the granules are subject to sieving into the fundamental fraction, the by-product, and contaminations.

Scrapers are used to clear the material remaining on the disk walls. For sealing, the device can be equipped with a protective anti-dusting cover. The level of heated liquid in the water tank is controlled through electrically-controlled sensor 11. The amount of the granulation liquid drawn during the experiment is read out from the display of scales 4, on which a heated lubricating liquid tank is fixed. The flow rate of the lubricating liquid is read out from the scale of rotameter 16 placed on the control panel. Rotation of the granulation disk is measured by means of an induction sensor and read out on the display of tachometer 20. Compressed air and the lubricating liquid are conveyed in the rubber hoses.

Granulation liquid in small tank 25 can also be used in the tests. For construction reasons, the tank is not equipped with a heating element. The amount of liquid used during granulation is shown on the display of scales 26, on which the tank is placed.

3. Parameters of the granulation process

Devices for disk granulation of fine-grained materials belong to the group of technological machines and devices. Tests of technological machines and devices require an interdisciplinary approach that would cover issues related to their construction and operation, process engineering, and the quality of the obtained product. The course of the granulation process, its efficiency, and the quality of the obtained product are closely connected with the instrumental and process parameters presented in fig. 2.

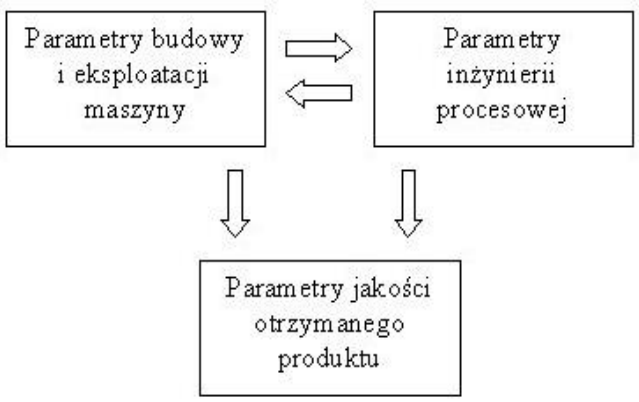


Fig. 2. Scheme of interdisciplinary relationship of instrumental and process parameters [13]
Rys. 2. Schemat interdyscyplinarnej zależności parametrów aparaturowo-procesowych [13]

When planning tests, especially when determining the ranges of variability of individual parameters, preliminary experiments should be performed. Literature analysis [1, 2; 3, 6, 8, 11] leads to the conclusion that the parameters listed in tables 1 and 2 are crucial for the non-pressure granulation process.

Table 1. Main factors of the non-pressure granulation process (physico-chemical properties of material and parameters of construction and operation of machines)
Tab. 1. Główne czynniki procesu granulacji bezciśnieniowej (własności fizykochemiczne materiału oraz parametry budowy i eksploatacji maszyn)

Physico-chemical properties of material	Parameters of construction and operation of machines
• granulometric composition • structure of material • grain surface • porosity of particles • moisture content • wettability • hygroscopicity • bulk density • grain consistency • grain temperature • natural angle of repose • internal friction coefficient • plasticity of material • shape factors: shape coefficient, sphericity of particles, etc.	• type of disk material • diameter of granulation disk • disk flange height • angle of inclination of the disk in relation to the horizontal • place of dosing of the granulation liquid • method of dosing of the granulation liquid • spray angle of pressure nozzles • method of dosing of loose raw materials and type of dispenser • place of dosing of loose materials • number of granulation blades • setting of granulation blades in the disk (angle of inclination of granulation blades in the disk (angle of inclination in relation to the vertical and the horizontal) • area of the working surface of the granulation blade

Source: own work / Źródło: opracowanie własne

Table 2. Main factors of the granulation process (parameters of process engineering)
Tab. 2. Główne czynniki procesu granulacji bezciśnieniowej (parametry inżynierii procesowej)

Parameters of process engineering
• frequency of disk rotation • rotational speed of the disk • degree of covering of the disk surface (disk filling) • overpressure above the free surface of the granulation liquid • working pressure of spray nozzles • type of granulation liquid • flow rate of the granulation liquid • temperature of the granulation liquid • performance of pressure (spray) nozzles • drop size of the granulation liquid • mass of granulation liquid added to the disk during the granulation process • time of the material staying in the granulator • self-cleaning of the disk surface

Source: own work / Źródło: opracowanie własne

Example values of individual parameters are listed in table 3. An experiment carried out for selected parameters was presented in the doctoral thesis devoted to disk granulation, during which agricultural fertilizer was produced [10].

Table 3. Main parameters of a granulator for non-pressure (disk) granulation

Tab. 3. Główne parametry granulatora do granulacji bezciśnieniowej (talerzowej)

Parameter	Value
overpressure the free surface	5-12 (bar)
flow rate of the granulation liquid	0.025-0.3 (l/min)
temperature of the granulation liquid	15-90 (°C)
working pressure of spray nozzles	max 6 (bar)
spray angle of pressure nozzles	60, 90, 110 (°)
performance of pressure (spray) nozzles:	3.72-7.44 (kg/h)
number of rotations of the granulation disk	7.2-21.6 (rpm)
angle of inclination of the granulation plate	0-90 (°)
degree of disk filling	3-15 (%)
time of the material staying in the granulator	8-14 (min)
mass of granulation liquid added to the disk during the granulation process	0.252-0.324 (kg)

Source: own work / Źródło: opracowanie własne

4. Conclusions

The usefulness of a disk granulator for granulation of loose materials with diverse properties was the reason for undertaking work aimed at improving the design. An improvement in the quality of granulators can be achieved by improving granulation devices, carefully selecting the process parameters, as well as using various additives to the granulated mixture of raw materials. The paper proposes a range of construction and process parameters that in the future may have an impact on the quality of the obtained granules. In comparison with devices for pressure granulation, non-pressure granulators have numerous advantages, including: simplicity of the used devices, a significantly lower cost of purchase, and longer life. An additional advantage consists in energy efficiency of the method, which translates into economic benefits. Instrumental and process parameters adjusted during the disk granulation tests (with the use of a granulation blade) have an impact on the quality of the obtained granules [10]. The most important ones are:

- increasing the amount of granulation liquid added to the disk results in an increased average diameter of granules,
- decreasing the angle of inclination of the granulation disk results in an increased average diameter of granules,
- the average size of granules increases together with the time when the material stays in the granulator,
- increasing the rotational speed results in an increased average size of granules.

Work on the development of the design of a disk granulator are being continued. Their aim is to form assumptions and then design a granulation blade (with an extended working surface), which would allow to reduce granulation time and obtain granules with appropriate quality properties.

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