

RESEARCH ARTICLE

TESTING AND ANALYSING THE GRINDING UNIFORMITY OF POLYMER PRODUCTS

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ARTICLE DETAILS

ABSTRACT

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This work aims to improve the uniformity of the grinding polymer materials (recycling of thermoplastic polymers) and reduce the power consumption of the grinding process for the polymer recycling process. The uniformity of grinding polymer materials is considered in many ranges: technical, material and control (steering). The influence of the method and grinding agent, the susceptibility properties and homogeneity of the grinded material was illustrated in this search. Irregularity of the operation of the dosage (feeder) of the granular material (δ) depends on the diameter (D) and the screw pitch (S). The uniformity of grinding polymer materials increases when the S/D is 0.25 or 1.67. The uniformity of grinding polymer materials for the S/D of 1.67 is better than for S/D of 0.25.

KEYWORDS

Grinding Uniformity, Polymers Recycling, Polymers Grinding

1. INTRODUCTION

AT Energy efficiency represents utilizing lower energy to do the same work leading to reduce energy waste. Energy efficiency gives many advantages including reduction in the request for energy imports, cost and gas emissions. Energy efficiency is affected by uniformity, energy consumption, working resistance to obtain an increase in the specific surface area and temperature increase. Power consumption and efficiency of the grinding process depend on the movement of the elements, on the properties of the grinding materials and on the design of the machine used. Power consumption during the grinding process for polymer recycling process reduces with the increasing the uniformity of grinding of polymer materials. This research aims to improve the uniformity of grinding of polymer products during recycling process.

2.1 MATERIALS AND METHODS

2.1 Model of Research Object

For needs of a detailed analysis of uniformity, a general dependence was used, however, it covered the essence of machine processing for heterogeneous materials (polymer thermoplastic materials from the waste) [1-5]. After taking into account the variability of: individual resistance to grinding, operational characteristics of the engine and gearbox driving (transmission) of the grinder, time constant of the drive control system, grinding and servicing, performance characteristics of operating devices (selectors, feeders, separators and others). Depending on irregularity of the grinding materials and time, it can find the relationship and correlation between the general irregularity of grinding (δ_R) and: irregularity operation of the grinding machine (δ_{MR}), irregularity operation of the drive system (δ_N), irregularity operation of the control system (δ_S), irregularity operation of service and supply devices (δ_O), irregularity and heterogeneity of material properties of the feed (stock)

(δ_M) and during the observation or system duration (t), as shown in Equation (1).

$$\delta_R = f(\delta_{MR}, \delta_N, \delta_S, \delta_O, \delta_M, t) \quad (1)$$

2.2 Model of Feed Uniformity

For long feed (stock), a feed chute (Figure 1) that is attached to the structure or foundation plate is used to feed polymer materials into quasi-shearing. As such, the disk hole (Figure 2) is used to cut polymer materials into pieces by action of the edges, and the grinding product can be thrown out away with blades. Where, the edges of the holes in the rotating discs are cutting the pieces with specified thickness during the movement of the material in the gutter.

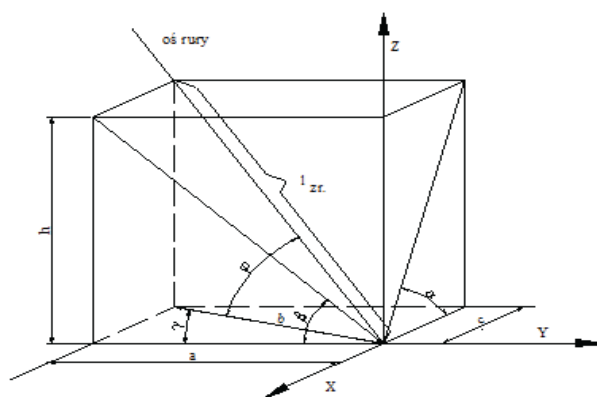


Figure 1: Geometrical relations when feeding the polymer materials to the grinder

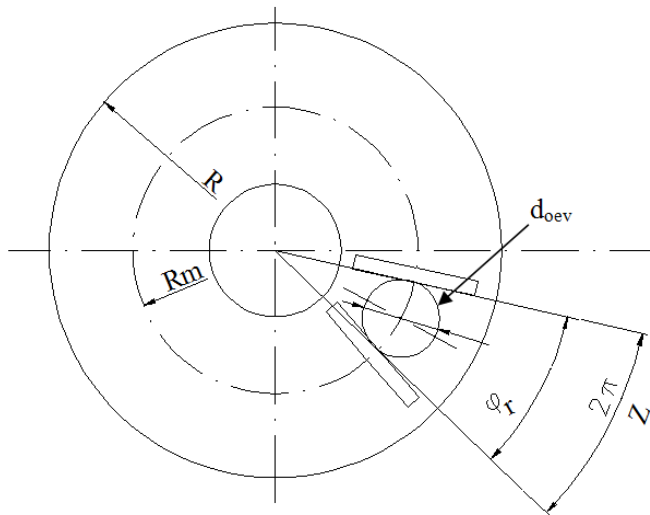


Figure 2: Scheme of the location of the feed (stock) in relation to the edge of the knives

Figure 1 shows the length of granulate (l_{zr}) and angles of the inclination of the supply gutter. The plane x-z represents the frontal surface of the discs, and the y-axis is parallel to the axis of the shaft. Angle β can be calculated in Equation (2):

$$\tan \beta = \frac{h}{a} \quad (2)$$

Equation (2) can be rewritten as below:

$$\beta = \arctan \frac{h}{a} \quad (3)$$

Depending on the Equations (2) and (3), it can select the proper position of feed (stock) that reduces the cutting resistance and feed (stock) movement, leading to reduce power supply irregularity. Movement of the edge beyond the plane of the discs is determined by geometrical relationships in Figure 1. Equations (4) and (5) can be written below [2,6]:

$$\frac{b}{l_{zr}} = \cos \varphi \quad (4)$$

$$\frac{a}{b} = \cos \gamma \quad (5)$$

Equation (6) can be rewritten by incorporating Equation (4) into Equation (5) below:

$$\frac{a}{\cos \gamma \cdot l_{zr}} = \cos \varphi \quad (6)$$

Equation (6) can be rewritten as below:

$$a = l_{zr} \cdot \cos \varphi \cdot \cos \gamma \quad (7)$$

Because of the feed (stock) rises somewhat during the cutting, it can be accepted that a (mm) is smaller than the size obtained from the formula. To determine the angle β , which is necessary to determine the position of the supply gutter, the value of h has to be calculated. So that, based on Figure 3, the value of h (mm) can be calculated in Equation (8):

$$\frac{h}{b} = \tan \varphi \quad (8)$$

By combining Equation (5) into Equation (8), it can be rewritten as Equation (9):

$$\frac{h \cdot \cos \gamma}{a} = \tan \varphi \quad (9)$$

Equation (9) can be rewritten as below:

$$h = \frac{a \cdot \tan \varphi}{\cos \gamma} \quad (10)$$

The condition of uniform quasi-shear continuity can be determined by Equation (11):

$$\frac{2 \pi R_m}{z} \leq \frac{d_o}{\cos \varphi} \quad (11)$$

Equation (11) can be rewritten as below:

$$2 \pi R_m \cdot \cos \varphi \leq z \cdot d_o \quad (12)$$

Where, d_o is the average diameter of the feed (stock), while $\frac{2 \pi R_m}{z}$ represents the distance between individual knives (hole edges) that is measured around the circumference on a mean radius as seen in Figure 2. The mean radius of the quasi-shear can be calculated as shown below:

$$R_m = \frac{60 \cdot v_{ev}}{2 \pi \cdot n} \quad (13)$$

Where, v_{ev} is peripheral speed (m/s), while n is rotational speed (s^{-1}).

If the distance between the edges of the holes - knives is greater than the diameter of the d_{oev} , between the work of two successive knives, there is a certain period of break (defined by the angle φ_r in Figure 2), during which the loose run takes place - then the cutting continuity condition does not occur, as justified above. The quasi-shearing process takes place on an angular path:

$$\varphi_r = \frac{d_{oev}}{R_m} \quad (14)$$

In contrast, the loose travel takes place on an angular path:

$$\varphi_p = \frac{2\pi}{z} - \varphi_r = \frac{2\pi}{z} - \frac{d_{oev}}{R_m} \quad (15)$$

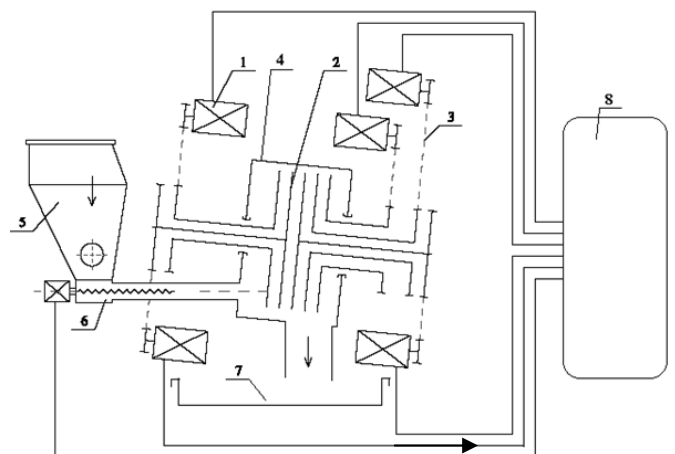


Figure 3: Scheme of the grinding machine with measuring accessories: (1) electric motors propel the blades; (2) discs with holes for bandwidth-grinding; (3) belt; (4) assembly body a grinding; (5) hopper batch dispenser; (6) screw the dispenser; (7) receipt of the product and (8) control system with computer.

Due to the small value of φ_p fluctuations of energy consumption, and therefore the irregularity of action, so that the discussed phenomena will be very small. We are dealing with a research system, where the uniformity of the grinding depends on the movement speed of the material in the dispenser team 6 (Figure 3). Researches show that the flywheel effect (fly-wheel moment) needed in this case is several dozen times smaller than that has a working-disc [3,6-9]. A similar analysis carried out

for other variables widely affecting the irregularity of grinding.

2.3 Indicators for Variables

To determine dependent variables, it was assumed motion variable indicators:

ω_1 - the angular speed of the input shaft of the grinder transmission (grinder gear box),

ω_2 - the angular speed of the output shaft of the transmission (gear box),

M_1 - torque on the input shaft of the grinder transmission (grinder gear box),

M_2 - torque on the output shaft of the transmission (gear box),

η_s - engine efficiency,

η_p - transmission efficiency.

N_1 -power at the input of the transmission (gear box),

N_2 -power at the output of the transmission (gear box),

$$N_1 = \omega_1 \cdot M_1 \quad (16)$$

$$N_2 = \omega_2 \cdot M_2 \quad (17)$$

The instantaneous transients of the above mentioned characteristics of uniformity and efficiency allow to determine:

i_k - kinematic ratio for grinder gear box:

$$i_k = \frac{\omega_2}{\omega_1} \quad (18)$$

i_d - dynamic ratio for grinder gear box:

$$i_d = \frac{M_2}{M_1} \quad (19)$$

The irregularity of the operation of the dosage (feeder) of the granular material (δ) can be calculated as below:

$$\delta = \frac{W_{\max} - W_{\min}}{W_{ev}} \quad (20)$$

where

δ - irregularity of the operation of the dosage (feeder) of the granular material,

W_{\max} - maximum capacity of the feeder (e.g. mass),

W_{\min} - minimum capacity of the feeder (e.g. mass),

W_{ev} - average capacity of the feeder (e.g. mass).

3. RESULTS AND DISCUSSION

For the occurrence of suboptimal constructional conditions of the uniformity grinding group of selected inhomogeneous materials (polymer thermoplastic materials from the waste) it was dried at 40-60°C before grinding, a mathematical model of uniformity including: operation of the grinding machine, power system, control, operation and variable quality of the feed (stock) in time. The influence of the characteristic machine, structural and geometrical has been proven in the case of different forms of samples, geometrical features of the feeding and multi-edge discs. On the uniformity of the quasi-shear process is important influenced by the shear rate and its run.

Figure 4 shows the dimensional irregularity of the grinding polymer product. Table 1 and Figure 5 show that the irregularity of the operation of the dosage (feeder) of the granular material (δ) depends on the diameter (D) and the screw pitch (S). The results display that lower $\delta\%$ is observed for the S/D (0.25 or 1.67). The lowest $\delta\%$ is observed for the S/D (1.67). While higher $\delta\%$ is observed for S/D from 0.29 to 0.5.

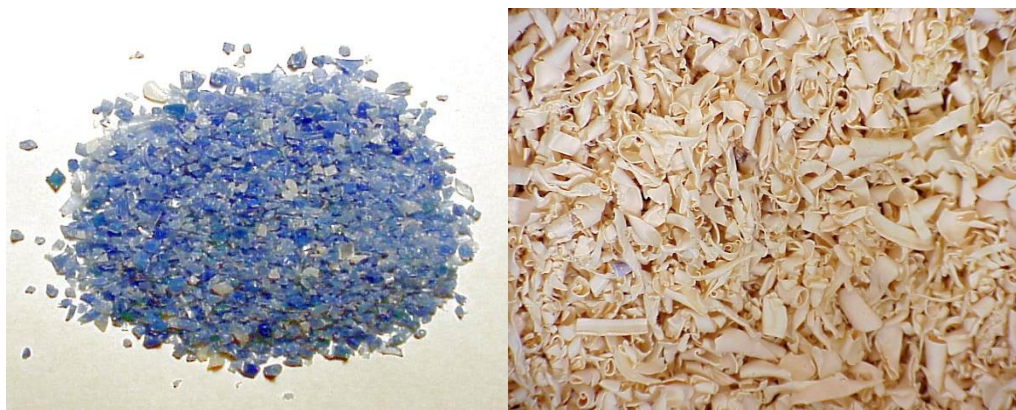


Figure 4: The dimensional irregularity of the polymers grinding

Table 1: the data of the irregularity of the operation of the dosage (feeder) of the granular material (δ) depending on the diameter (D) and the screw pitch (S).

No.	$W_{\max} - W_{\min}$	W_{ev}	δ	$\delta\%$	S	D	S/D
1	15	47.5	0.32	32	4	16	0.25
2	30	40	0.75	75	4	14	0.29
3	26	57	0.46	46	6	14	0.43
4	40	80	0.5	50	7	14	0.5
5	9	32.5	0.28	28	30	18	1.67

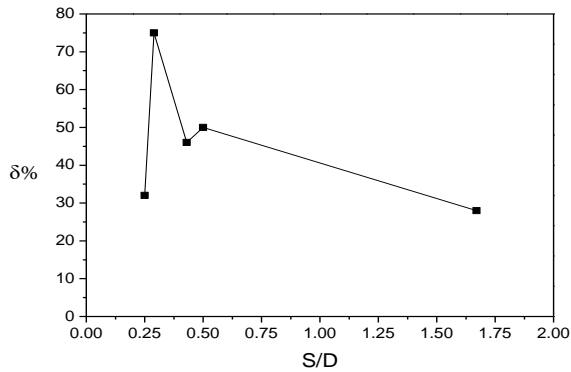


Figure 5: Irregularity of the operation of the dosage (feeder) of granular material ($\delta\%$) depending on the diameter and the screw pitch.

4. CONCLUSION

The irregularity of the operation of the dosage (feeder) of the granular material (δ) is affected by the diameter (D) and the screw pitch (S). The uniformity of grinding polymer materials increases when the S/D is 0.25 or 1.67. The highest uniformity of grinding polymer materials is seen for the S/D of 1.67. In contrast, the lowest uniformity of grinding polymer materials is seen for the S/D from 0.29 to 0.5.

5. RECOMMENDATIONS

It is recommended checking the mechanical properties of the materials before grinding. The feeding process of the grinding machine is necessary to be through the regulator of the feed. It is necessary to clean and dry the polymeric waste before grinding, because it gives positive results.

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