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EVALUATION OF THE EFFICIENCY OF THE ROTATIONAL MODE OF THE PROCESS OF GRINDING SOLID WASTE IN A DRUM MILL

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Abstract
A mathematical model of the grinding mechanism by breaking under shock load in a drum mill, which is implemented mainly when grinding solid waste, was built. The method of numerical modeling based on experimental visualization through a transparent wall of the behavior of granular loading in the cross section of a rotating chamber is applied. The initial characteristic of the shock is the averaged vertical component of the speed of loading movement in the flight zone at the boundary of contact with the shear layer. The formalization of the model revealed the impact on the energy intensity of the process of the mass fraction of the flight zone, loading reversibility and rotation speed. A rational condition for impact grinding at a relative speed of rotation ψ_ω*=0.75–0.9 has been established.*

Keywords: *solid waste, drum mill, intrachamber loading, impact action, energy consumption of grinding.*

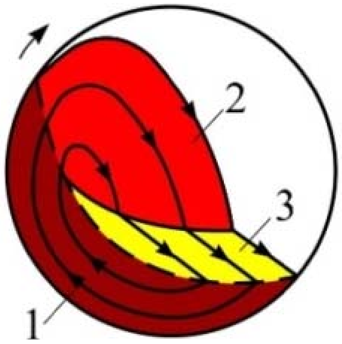
Fine grinding of solid waste is carried out in various disintegrators. The optimal type of shredder device is a drum mill [1]. It has a low specific grinding work of 151 kWh/t, compared to 3490 kWh/t for the planetary and 1110 kWh/t for the vibratory mill. At the same time, the drum mill provides a relatively high specific product surface of 11,300 cm^2/g. In the case of grinding industrial volumes of solid waste, such a mill has a much higher productivity.

However, grinding is a high-energy-intensive process due to significant frictional energy dissipation during the circulation of the intra-chamber load. Reducing the energy intensity of the working processes of drum mills remains a rather urgent problem [2].

A significant proportion of drum mills carry out high-performance coarse grinding by breaking due to the mainly impact action of internal mill grinding loading. Instead, the quantitative results of impact impact on the energy intensity of the grinding process are still unknown, which significantly limits the functionality of such equipment.

The aim of the work is to create a mathematical model of the impact action of grinding bodies of intra-chamber loading on particles of the material that is crushed in a drum mill. This will make it possible to establish the dynamic characteristics of the impact action of the grinding load and predict the parameters of the grinding process by implementing the impact interaction mechanism.

The loading of the drum mill carries out circulation movement in the cross-section of the chamber mainly in the three-phase flow mode [3] (picture 1).



Picture 1. Movement zones of the drum mill chamber loading:
1 – solid zone, 2 – flight zone, 3 – shear layer zone

At low rotation speed, the mass fraction of solid zone 1 prevails. As the speed increases, the fractions of flight zones 2 and shear layer 3 increase at the expense of solid zone 1. As the speed approaches the critical value, the fraction of flight zone 2 reaches its maximum value, and the fraction of shear layer zone 3 goes straight to zero At a high speed of rotation, a mode of motion occurs in the form of a wall layer consisting only of solid zone 1.

The duration of the shock interaction is very short. Since the shock impulse has a finite value, the force modulus of the grinding body can be quite large, which ensures the implementation of the grinding process by shock action. Impact interaction of loading elements can be considered completely inelastic. On the considered contact surface, which is the transition of loading movement zones, the influence of non-impact interaction forces on the grinding process can be neglected.

The dynamic impact effect of molar loading can be estimated by the impulse, work and power of the impact forces. Impulse characterizes the intensity of impact interaction, and work - the energy of crushing by impact action. The technological effect of the impact action is determined by the energy intensity of the impact crushing process, the value of which can be estimated by the power of the impact force.

Specific and absolute relative analogues of the dynamic parameters of impact interaction were used for the approximate implementation of such an assessment. The initial data for the determination of such parameters were obtained in a simplified way by means of visualization of loading movement patterns.

An approximate mathematical model of the impact grinding mechanism in a drum mill is built on the basis of data visualization. The power of impact forces was taken as an analogue of the energy intensity of grinding. The expression for the relative energy intensity of impact crushing E, which corresponds to the relative power of the vertical component forces of the impact interaction:

$$E = \frac{h_{fr}}{8\pi R} K_{fr} n_{to} \psi_{\omega},$$

h_{fr} is the vertical distance from the highest to the lowest point on the free surface of the loading flight area in the movement pattern,

R is the radius of the mill drum chamber,

$K_{fr}=1-(F_{sr}+F_{sl}/\upsilon_{sl})/(\pi R^2\kappa)$ is mass fraction of the loading flight area,

F_{sr} is the area of the solid zone in the picture of loading movement,

F_{sl} is the area of the shear layer zone in the picture of loading movement,

υ_{sl} is the dilatancy of the shear layer,

$\kappa=w/(\pi R2L)$ is the volume degree of filling the chamber with loading, w is the volume of the loading portion of the camera at rest,

l is the length of the drum chamber,

$n_{to}=[1-(Rc/R)^2]/\kappa$ is the reversibility of the load movement, which corresponds to the number of periods of circulation of the load in the chamber during one revolution of the drum,

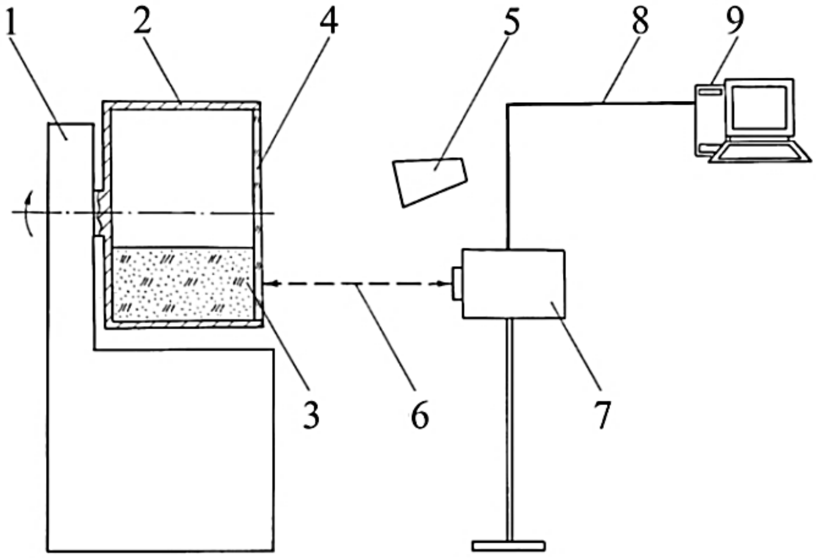
R_c is the radial coordinate of the load circulation center relative to the axis of rotation in the movement pattern,

$\psi_\omega=\omega/(g/R)^{0.5}$ is the relative speed of rotation of the drum chamber,

ω is the angular speed of rotation of the drum,

g is the gravitational acceleration.

The values of h_{fr}, F_{sr}, F_{sl}, υ_{sl} and R_c were approximately determined by the method of computer numerical modeling based on experimental visualization of the loading behavior in the chamber of a rotating drum by fixing through a transparent end wall and subsequent computer processing of movement patterns in the cross section of the chamber (picture 2).



Picture 2. Computer visualization of data:
1 – unit of drive and measuring devices, 2 – drum with removable chamber,
3 – granular loading, 4 – transparent end wall of the chamber, 5 – illuminator,
6 – videorecording of pictures of loading motion, 7 – video camera,
8 – information transmission channel, 9 – a computer for visualizing pictures of loading motion

The algorithm for implementing data visualization consists in the following stages:

1) filling the chamber of the loading drum with the degree of filling κ;

2) achievement of a stable mode of movement of the load during stationary rotation of the drum with the value of the relative speed ψ_ω;

3) performing video recording of the loading movement in the cross-section of the rotating chamber, which has a transparent end wall;

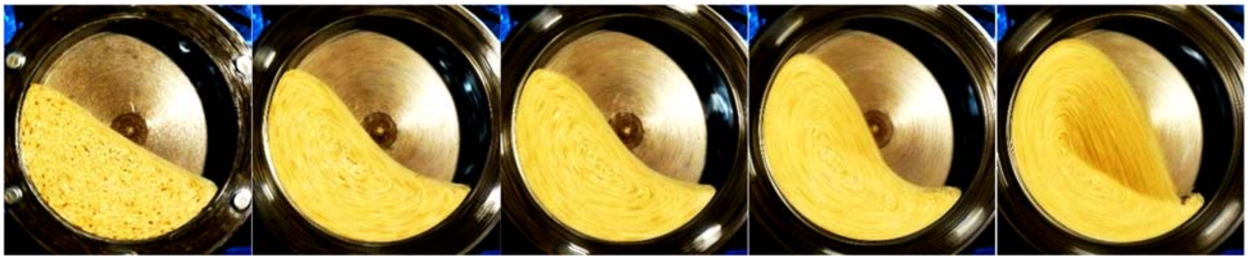
4) obtaining a picture of the loading movement;

5) selection of flat geometric shapes on the picture corresponding to the zones of movement - solid, flight and shear layer;

6) measurements on the picture R, h_{fr}, R_c, F_{sr}, F_{sl};

7) calculation of the values of loading interaction parameters.

Separate obtained pictures of the steady motion of loading in the chamber of a stationary rotating drum with the relative size of particles ψ_d=0.0104 and the degree of filling of the chamber κ=0.45 are shown in Fig. 3.

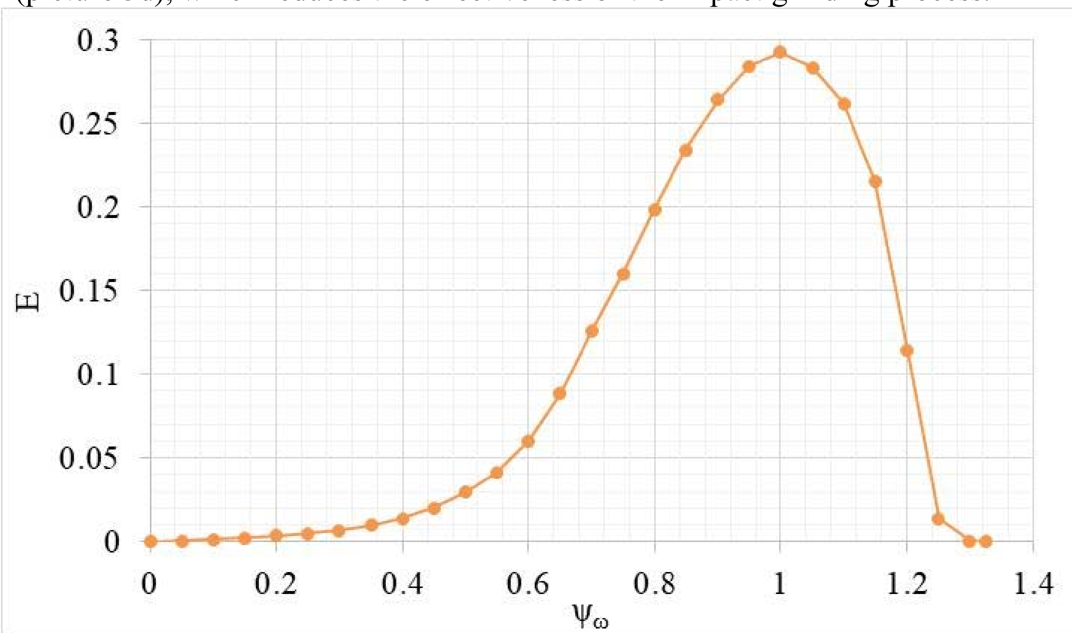


a b c d e

Picture 3. Visualized data of individual loading motion pictures:
a – ψ_ω=0.1; b – ψ_ω=0.3; c – ψ_ω=0.5; d – ψ_ω=0.7; e – ψ_ω=0.9

The graph of the obtained change in the analogue of the relative impact crushing energy E from ψ_ω is shown in picture 4.

It was established that the energy of grinding by impact acquires half or more of the maximum values at the value of the relative speed ψ_ω from 0.75–0.8 to 1.2. Instead, it was found that when ψω>0.9, the loading flight zone makes unproductive contact with the cylindrical surface of the chamber (picture 3d), which reduces the effectiveness of the impact grinding process.



Picture 4. Experimental dependence of the change in E on ψ_ω.

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The test proved the effectiveness of using computer visualization of data to evaluate dynamic and technological analogues of the impact interaction of the elements of the internal chamber loading of the drum mill. Verification of modeling results is implemented by comparison with numerical data of technical standards [4,5].

Therefore, the factor of impact loading of the drum mill is the averaged value of the vertical component of the speed of the flight zone before the interaction. The speed and mass fraction of the flight zone, the reversibility of the charge circulation in the chamber and its rotation speed are the determining parameters of the influence on the energy intensity of crushing by impact action. The rational range of the relative speed of rotation when crushing in a mill with an impact is 0.75–0.9.

References

1. Ildikó, F.; Mucsi, G. Comparative investigation of glass waste grinding in various mills. *Rudarsko-geološko-naftni zbornik* **2022**, *37*(3), 33-41. https://doi.org/10.17794/rgn.2022.3.3

2. Góralczyk, M.; Krot, P.; Zimroz, R.; Ogonowski, S. Increasing energy efficiency and productivity of the comminution process in tumbling mills by indirect measurements of internal dynamics – an overview. *Energies* **2020**, *13*, 24, 6735. https://doi.org/10.3390/en13246735

3. Naumenko Yu.V.; Deineka K.Yu. Theoretical foundations of working processes of drum type machines: a monograph. Rivne: NUWEE, **2014** [in Ukrainian].

4. International Organization for Standardization. Coal preparation plant – Principles and conventions for flowsheets (*ISO/IEC Standard No. 924:1989*). **2021**. https://www.iso.org/ru/standard/5340.htm

5. Deutsches Institut für Normung. Maschinen für die mechanische Aufbereitung von Mineralien und ähnlichen festen Stoffen – Sicherheit – Teil 3: Spezifische Anforderungen für Brecher und Mühlen (*DIN EN Standard No. 1009–3:2020*). **2021**. https://www.din.de/de/mitwirken/normenausschuesse/nam/veroeffentlichungen/wdc-beuth:din21:316006092.

ОЦІНЮВАННЯ ЕФЕКТИВНОСТІ РЕЖИМУ ОБЕРТАННЯ ПРОЦЕСУ ПОДРІБНЕННЯ ТВЕРДИХ ВІДХОДІВ У БАРАБАННОМУ МЛИНІ

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Ключові слова: *тверді відходи, барабанний млин, внутрішньокамерне завантаження, ударна дія, енерговитрати подрібнення.*

Анотація
Побудовано математичну модель механізму подрібнення розбиванням при ударному навантаженні в барабанному млині, який реалізується переважно при помелі твердих відходів. Застосовано метод чисельного моделювання, заснований на експериментальній візуалізації через прозору стінку поведінки зернистого навантаження в поперечному перерізі обертової камери. Вихідною характеристикою удару є усереднена вертикальна складова швидкості руху навантаження в зоні польоту на межі контакту з шаром зсуву. Формалізація моделі виявила вплив на енергоємність процесу масової частки зони польоту, оборотності навантаження та швидкості обертання. Встановлено раціональний режим ударного шліфування при відносній швидкості обертання $\psi\omega$=0,75–0,9.