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INFLUENCING PARAMETERS OF IMPACT GRINDING MILLS

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16. Abstract

Significant parameters for impact grinding mills were investigated. Final particle size was used to evaluate grinding results. Adjustment of the parameters toward increased charge load results in improved efficiency; however, it was not possible to define a single, unified set to optimum grinding conditions.

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PARAMETERS OF IMPACT GRINDING MILLS[1)]

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Freiberg

The fundamental working principles of grinding mills with rotating elements are the impact or rebound process between the particles for grinding and the elements applying a load [1]. The load is usually applied in this case in several stages. The intensity of the load through the particle size and kinetic energy of the particles in each stage depends on the preceding stages [2]. Furthermore, the passage through the mill as a result of centrifugal acceleration of the air-solid mixture through the rotor as well as the mixing process and turbulence diffusion in the load chamber belong to the working principles. These processes are influenced by a number of parameters, simultaneously determining the equipment realization, i.e. the design of the crushing machinery. Therefore, the parameters generally document the unity of process and equipment. There are three areas of interest for practical applications, influenced by the parameters: /213*

- results of fragmentation
- specific energy consumption
- machinery load (e.g. wear and tear in the working chamber).

The following descriptions are limited to the relationship between the results of fragmentation and parameters in impact grinding mills. The problems of energy are treated in [3]. A publication of the above-mentioned author on wear and tear is in press.

The fineness of the finished material is determined by parameters, characterizing the load chamber, the grinding

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1) Expanded version of a lecture at the "Conference on Problems of Fragmentation and Sorting."

2) Department of Machinery and Energy Technology of the Mining Academy in Freiberg

3) Research Institute for Preparation in Freiberg in the Academy of Sciences of the GDR.

* Numbers in the margin indicate pagination in the foreign text.

material and the surroundings. These include, among other things:

- rotor speed n
- outside diameter of the rotor D_R
- number of impact circles Z_{Kr}
- distance between the impact circles A_{Kr}
- shape, arrangement and distance of the impact elements
- further equipment, such as sieves, separators, impact plates, etc.
- strength, fineness and moisture of the material for grinding,
- throughput of the grinding material f and number of passes r
- properties of the ambient medium.

A number of further factors is of significance for unique characterization of the grinding process, expressed in the various designs of the mills. These include, for example, size and design of the grinding chamber, supply and delivery of the material for grinding and possibilities for connection to peripheral equipment.

The result of grinding can only be described precisely by an entire arrangement of measurement quantities. Since the correlation between these measurement quantities is not always independent of the parameters, it is often only possible to express tendencies even in impact grinding mills for the relationship between target size complex and load conditions. It is more favorable when the result of grinding can be expressed in only one measurement quantity, for example by the specific area according to BET or Blaine or by a characteristic of the grain size distribution.

Determination of the effect of the parameters was achieved through our own experiments. This was necessary, because a complex study of the parameters was previously missing in literature, giving only the relationship of individual parameters [4, 5, 6, 7] etc. as a rule.

The studies have shown, however, that the individual parameters may be considered as only conditionally independent of one another. The experiments were conducted according to a defined program at the Mining Academy in Freiberg, Department for Machinery and Energy Technology, and at the Research Institute for Preparation in Freiberg of the Academy of Sciences of the GDR.

The following results were obtained with an impact grinding mill with no sieve (laboratory pinned disk mill) and a semi-technical impact basket mill (disintegrator), both equipped with rotors running counter to one another. The materials studied were, among others, calcite, quartz sand, magnesite, coal, cement clincers, glass balls, crystalline sugar and iron powder. In the following, selected parameters are considered, represented as a rule with the main parameter of rotor speed.

Type of Material

Seven different materials for grinding are presented in Fig. 1 with a fragmentation behavior differing so greatly that they may be considered representative. In this case, a unified initial surface or grain size was consciously avoided to provide a comparison for the materials in their present condition. It can be seen that the load intensity tends to have the same effect O_S [BET] increases over the entire speed range). Iron powder is /214
provided as an example for materials, not made smaller or hardly affected in spite of great mechanical loads because of their fragmentation behavior and the very brief time in the machine (less than one second).

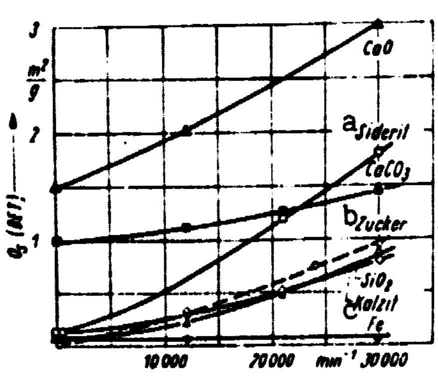

Fig. 1: Effect of the Type of Material and Speed n (Pinned Disk Mill f = 10 kg/h).

Key: a. siderite
b. sugar
c. calcite

Fineness of the Material Supplied

The results of grinding coal in a disintegrator is presented in Fig. 2 with two different sizes of the material supplied, d_A being less than or equal 6.3 mm and d_A being less than or equal 2.0 mm. The fragmentation ratio ε_m is achieved as the ratio of the average grain diameter of the material supplied to the finished material in the more coarse grains clearly exceeding the other value. The average grain diameter achieved is less in the case of coal at d_A being less than or equal 6.3 mm than in the grain size of the material supplied of d_a being less than or equal 2.0 mm.

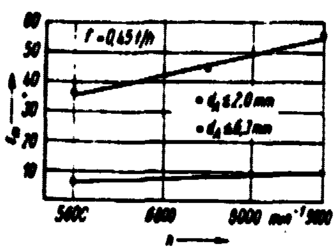

Fig. 2: Effect of the Initial Fineness of the Material and the Speed n (disintegrator, Coal).

Fig. 3 shows the same tendency in the fragmentation of calcite in the pinned disk mill. With a comparable load, the increase in specific surface decreases according to BET as the fineness of the initial material increases. The initial surface probably approaches an upper limit value with no more fragmentation occurring once this has been exceeded. The information is supplemented through Fig. 4 for the glass balls in that the distribution of grain size in the range of smaller sizes is almost independent of the grain size supplied or size class with the same intensity of the load. The greatest amount of fragmentation is therefore achieved with relatively coarse supplied material such that a prefragmentation step for this material need only be carried out to grain sizes (and should also be only carried out), necessary for entering the mill.

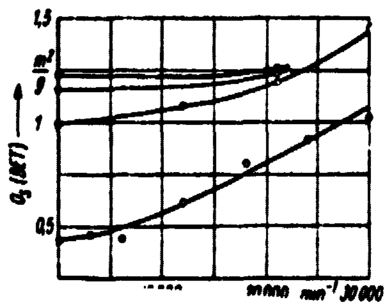

Fig. 3: Effect of the Initial Fineness of the Material and the Speed n (Pinned Disk Mill, f = 9 kg/h, $CaCO_3$).

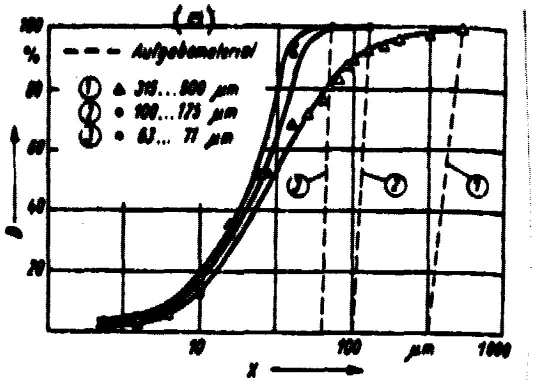

Fig. 4: Effect of the Initial Grain Size (Pinned Disk Mill, f = 12 kg/h Glass balls, n = 24 000 min^{-1}).
Key a - material supplied

Number of Material Passes Through the Machinery

In the case of impact grinding mills operating without a sieve, the final fineness of the material may be adjusted by the load conditions. If the material leaving the mill is returned to it, the product characteristics may be further improved. As can be seen from Fig. 5, the activity and fineness of calcite is increased by additional passes. In this case, it is demonstrated that the increase decreases in each pass, finally reaching zero. The effectivity of multiple passes through the mill may be substantially increased, if the portion of material, already achieving the required fineness, is separated between the passes.

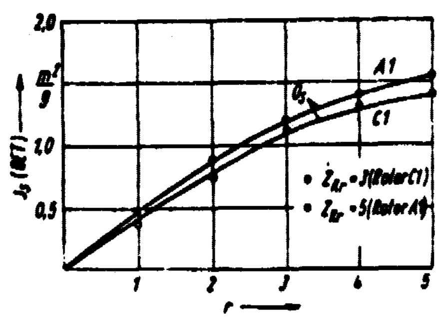

Fig. 5: Effect of Material Passes r (Pinned Disk Mill, f = 9 kg/h $CaCO_3$, n = 30000/min).

Outside Diameter of the Rotor

It is assumed that the outside diameter of the rotor disks is a measure for the average diameter of the impact circles. Two rotors are compared, differing only in the outside impact circle diameter, i.e. the impact element shape, size and distances (within and between the impact circles) are identical. Fig. 6 shows the higher specific areas O_S (BET) for the calcite grinding material with the greater rotor outside diameter (higher)

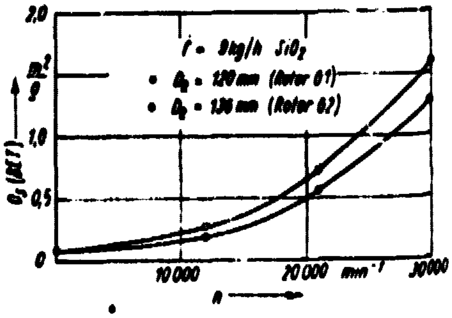

Fig. 6: Effect of the Rotor Outside Diameter D_R and Speed n (Pinned Disk Mill).

load intensity). It is remarkable that the effect of the rotor outside diameter is extensively independent of the speed and throughput.

Number of Impact Circles

The comparison of a rotor with four and with six series is illustrated in Fig. 7. The specific area has higher values for the calcite grinding material in the case of the rotor with six impact circles. It can be seen, furthermore, that the difference becomes greater with increasing rotor speed. The effect of the number of impact circles is not dependent on material throughput. The above-mentioned relationships are applicable both to the constant innermost and to the constant outermost impact circle diameter.

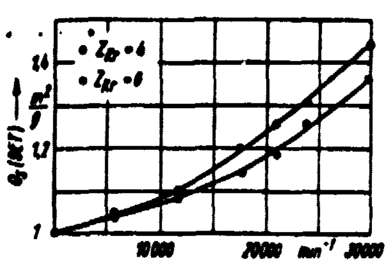

Fig. 7: Effect of the No. of Impact Circles Z_{Kr} and the speed n with Constant Diameter of the Outermost Impact Circle (f = 9 kg/h $CaCO_3$, Pinned Disk Mill).

Distance Between the Impact Circles

It can be seen from Fig. 8 for the example with calcite that the specific area increases as a rule as the impact circle distance decreases. This effect is intensified with increasing rotor speed and material throughput.

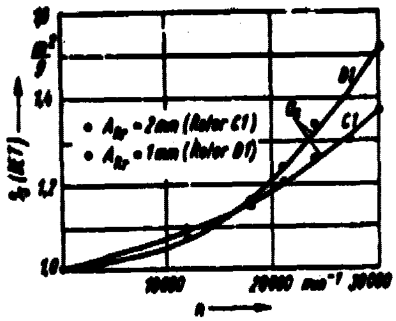

Fig. 8: Effect of the Distance Between the Impact Circles A_{Kr} and Speed n (Pinned Disk Mill, f = 9 kg/h $CaCO_3$).

Distance between the Impact Elements of an Impact Circle

It must be taken into consideration in this parameter that the distance within one impact circle also determines the number of impact elements in the case of unified impact elements. This is important because the number and speed of the succession of impact processes are of interest in the impact load in addition to the load speed. It can be seen from Fig. 9 that the most favorable impact element interval is situated within the examined range in the case of calcite. This is not generally applicable, however, as the optimal interval depends greatly on the material.

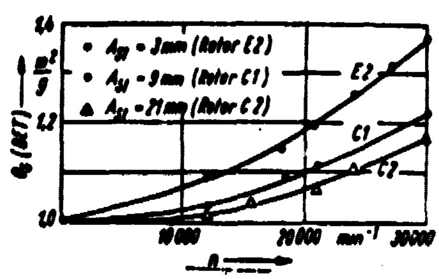

Fig. 9: Effect of the Interval Between the Impact Elements of an Impact Circle A_{St} and the Speed n (Pinned Disk Mill, f = 9 kg/h $CaCO_3$).

Shape of the Impact Elements

Generally, identical rotors with round (rotor H 2), square or rectangular impact elements, arranged tangentially to one another (rotor C 1), are compared with one another. This comparison is well-founded since the approach surfaces are almost equal in the case of a slanted approach. Fig. 10 shows that the shape of the impact element has no effect or hardly any influence on the specific area of quartz sand in the low and medium speed ranges.

Only at high rotor speeds is the increase in area in the case of round impact elements noticeably greater.

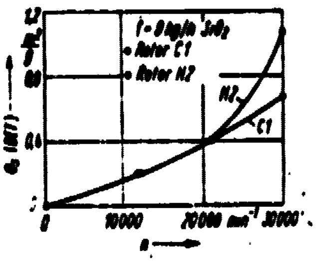

Fig. 10: Effect of Impact Element Shape and Speed n (Pinned Disk Mill).

Angle of the Impact Elements to the Rotor Tangent /215

This parameter is especially of substantial importance in plate-shaped impact elements. The studies with the desintegrator have demonstrated that there is an optimal angle in relation to the direction of motion with reference to the fragmentation results, independent of the load intensity. It can be seen from Fig. 11 that this is situated between 25 and 35 degrees. The design of a disintegrator with plate-shaped impact elements therefore always represents a compromise between a fragmentation and a flow machine.

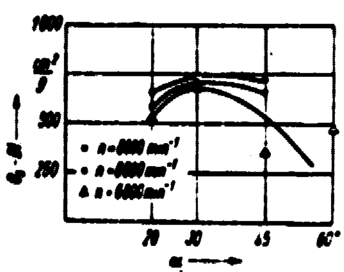

Fig. 11: Effect of the Angle of the Impact Element α to the rotor tangent (disintegrator).

Rotor Speed

The rotor speed is the main parameter in impact grinding mills. This determines the load rate in a given rotor size.

As already mentioned, the rotor speed can be considered the main parameter in relation to the other parameters. In contrast to many studies known from literature [4], etc., a large range was examined for the load rates - zero to almost 300 m/sec. This includes the entire subcritical range (less than 100 km/h). It applies for all cases studied (Fig. 12: coal grinding in a desintegrator; Fig. 13: calcite grinding in a pinned disk mill), that the fragmentation result is improved with higher speeds. An asymptotic approach to an upper limit surface, even in the case of high speeds, cannot be confirmed. On the other hand, there is almost always a lower grain size analogous to [1], dependent on the grinding conditions, beyond which there is no effect. In impact grinding mills, a relatively narrow band of grain size is generated in this case, attributed to the dominance of the impact load.

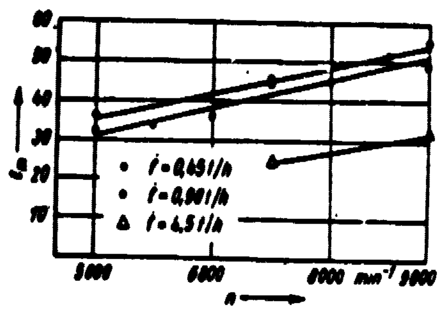

Fig. 12: Effect of Speed n and Material Throughput f (disintegrator, Coal).

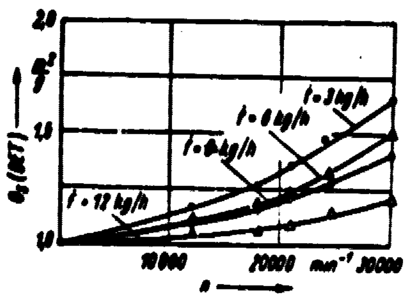

Fig. 13: Effect of Speed n and Material Throughput f (Pinned Disk Mill $CaCO_3$).

Grinding Material Throughput

It can be seen from Figs. 12 and 13 that the fragmentation result improves with less throughput. As a result of this effect, impact grinding mills should be operated in practical situations principally with dosing devices.

The study of the parameters can be summarized with the following points.

1. The fragmentation result improves when less grinding material is employed, often at a high speed in a small space (realization of high impact numbers in relation to time and location). This often requires, for example, impact grinding mills with engine speeds higher than the nominal speed of the flanged engine.

2. All parameters may not be separated from one another but may only be considered in relation to the others.

3. In spite of the proven clear tendencies of effect, general statements on optimal fragmentation conditions are not possible or only to a limited degree. Therefore, it is necessary to adjust the impact grinding process to the individual fragmentation task. This requirement demands machinery from the manufacturers with a certain amount of variation possible in the most important parameters, e.g. the rotor speed or rotor design. Furthermore, it follows for the operator of impact grinding mills that the optimal conditions must be tested experimentally for a certain grinding material or for a certain fragmentation task.

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