BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
BG PULSE JOURNAL

MODERN METHODS AND ENERGY EFFICIENCY OF THE SOLID MATERIAL GRINDING PROCESS

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https://doi.org/10.5281/zenodo.20473582

Annotation.
This article analyzes modern methods of solid material grinding and the energy efficiency of this technological process. Grinding is considered one of the key operations widely used in the chemical, mining, construction, metallurgical, and food industries. The paper explains the mechanical reduction of solid particle size under the influence of compression, impact, abrasion, splitting, and combined mechanical actions. Particular attention is paid to the factors affecting energy consumption during grinding, including the strength, hardness, moisture content, brittleness, and abrasiveness of the processed material. The article also discusses the main theoretical approaches used to evaluate energy costs, including Rittinger's law, Kick's law, and Bond's theory.

Keywords:
grinding, solid materials, energy efficiency, particle-size distribution, crusher, mill, Rittinger's law, Kick's law, Bond's theory.

Introduction. The process of grinding solid materials is one of the key technological operations widely used in the chemical, mining, construction, metallurgical and food industries. This process has a significant influence on the efficiency of subsequent technological stages, the quality of finished products, and the energy indicators of the production cycle. Therefore, the study of the regularities of solid material destruction and the improvement of grinding methods are of considerable scientific and practical interest.

Grinding is understood as a mechanical process aimed at reducing the size of particles of a solid material under the action of external mechanical forces. The main purpose of grinding is to obtain a material with a specified particle-size distribution that ensures the necessary technological properties of the raw material for further processing. Depending on the physical and mechanical characteristics of the material and the process conditions, particle destruction may occur under compression, impact, abrasion, splitting, or combined mechanical action.

From a physical point of view, the grinding process is accompanied by the formation of internal stresses in the structure of the material. When the ultimate strength is exceeded, interparticle bonds are destroyed and new interfacial surfaces are formed. It should be noted that a considerable part of the supplied energy is spent not only directly on material destruction, but also on overcoming internal resistance, friction forces, elastic deformations and heat losses.

The efficiency of the grinding process is characterized by the degree of grinding, which is the ratio of the average initial particle size of the material to its final size after treatment. An increase in the degree of grinding contributes to an increase in the specific surface area of the material, which

positively affects the intensity of heat and mass transfer processes, the rate of chemical reactions and the uniformity of the final product.

Various types of crushing and milling equipment are used to carry out grinding processes: jaw, cone, roll, hammer and rotary crushers, as well as drum, ball, vibratory and rod mills. The selection of a particular type of equipment is determined by the physical and mechanical properties of the processed material, the required productivity of the installation, the size of the final product and the technological operating conditions.

In modern conditions, increasing the energy efficiency of grinding processes is of particular importance. Since crushing and milling operations are among the most energy-intensive processes in the processing of solid materials, modern scientific research is aimed at reducing specific energy consumption, improving the design parameters of equipment and developing new methods for intensifying the material destruction process.

In industry, crushing and milling processes are considered among the most energy-intensive technological operations because a significant part of the consumed energy is spent on overcoming the internal resistance forces of the material, friction between the working parts of the equipment and the particles, as well as on heat losses.

The energy efficiency of the grinding process is determined by the amount of energy required to obtain a material with a specified particle-size distribution. At the same time, only a small part of the supplied energy is directly used to form new fracture surfaces, whereas the major part of the energy is lost in the form of heat, vibrations and elastic deformations of the material.

To assess energy consumption, the well-known theoretical relationships proposed by Rittinger, Kick and Bond are widely used. According to Rittinger's hypothesis, the work of grinding is proportional to the amount of newly formed surface area of the material. This theory most accurately describes fine grinding processes. Kick's law is based on the assumption that energy consumption is proportional to the degree of particle-size reduction and is applied mainly to coarse crushing processes. Bond's theory is considered an intermediate approach and has found the widest practical application in calculations of energy consumption in medium grinding processes.

The amount of energy consumption is significantly affected by the physical and mechanical properties of the processed material, such as strength, hardness, moisture content, brittleness and abrasiveness. An increase in the strength and hardness of the material leads to an increase in specific energy consumption, whereas the presence of internal structural defects contributes to more efficient particle destruction.

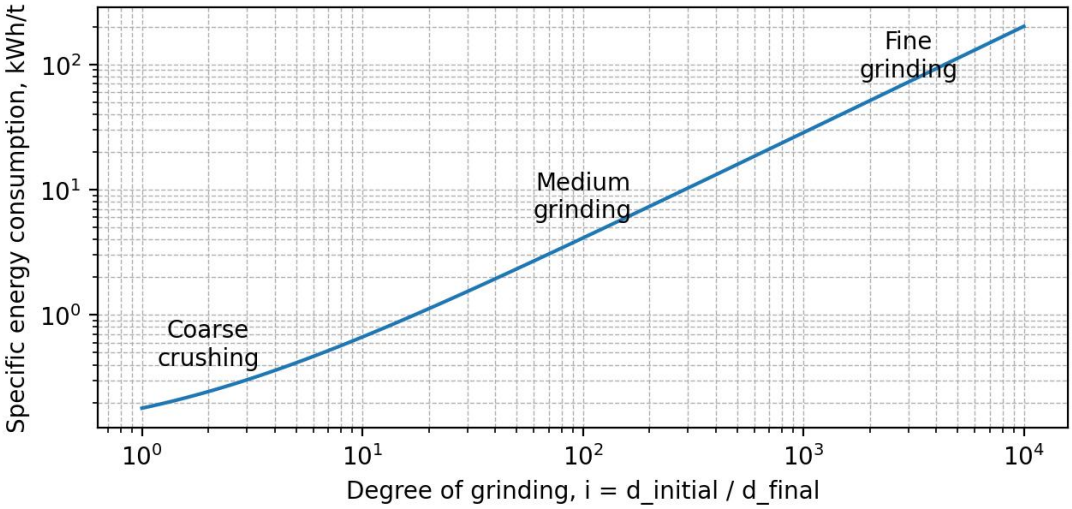


Figure 1 – Dependence of energy consumption on the degree of grinding

An important factor in improving energy efficiency is the proper selection of the equipment operating mode and the type of grinding machine. The use of modern crushers and mills with optimized designs of working elements makes it possible to reduce specific energy consumption and increase the productivity of the technological process. The application of multistage grinding is also of considerable importance, in which the process of material destruction is carried out sequentially at several stages with a gradual reduction in particle size.

Modern trends in increasing the energy efficiency of grinding processes are associated with the introduction of automated control systems, improvement of equipment designs, use of preliminary material preparation and optimization of technological process parameters. Special attention is paid to the development of energy-efficient grinding methods that ensure a reduction in operating costs and an improvement in the quality of the final product.

Thus, improving the energy efficiency of grinding processes is one of the most important tasks of modern industry. The rational selection of equipment, optimization of operating modes and application of modern technologies make it possible to significantly reduce energy consumption and increase the efficiency of solid material processing.

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