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NEW HYPOTHESIS OF ENERGY OF CRUSHING

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Abstract

Now the quantitative theory of crushing isn't developed yet. This can be explained not only by small interest or the insufficient number of the conducted researches, but also with a complexity of process of crushing. We consider the problem as the relationship between the energy consumption and particle size in processes of crushing and grinding.

We show that experiments are in the agreement with the theoretical estimation of the energy consumption in processes of crushing and grinding. It is well known that in a processes of crushing and grinding, a working parts of a machine are acting against the molecular interaction forces in the particles, which results in appearance of new surfaces, whose area depends on the strength of the environment, type of the mechanical impact, and the way it is applied. The known theories by many authors usually just try to describe the nature of the process. They do not take into account all the variety of the phenomena taking place in the material, and, hence, cannot be used for precise calculation of the parameters of a particular process. Therefore decrease in power consumption on process, especially in the field of thin and super thin crushing, is the major scientific and technical problem. Decrease in power consumption at a simultaneous intensification of process can be reached only on condition of a rational ratio between technological parameters of process of crushing and design data of the grinder. The made observations have allowed Professor Abdymanap Ospanov to offer some correction of the Rittinger and Kik laws**.** The above consideration suggests a correction to Rittinger's and Kick's are based on the assumption that the crushing unit energy consumption depend only on the linear sizes of the original particles and the product.

It is necessary to establish that on the sizes of parameters, it is possible to pick up values and, at that specific energy arrives at a minimum. Possibility of development of recommendation of the most rational (effective) use of grinding machines of certain having a special purpose construction appears thus, since the design feature of the grinding technology depends primarily on the nature of the material being crushed and the degree of its grinding.

***Key words**: Crushing process, Extent of crushing, Specific expense energy on crushing, Physico-mechanical and physical and chemical properties of the crushed materials, Fineness of particles, Hypothesis crushing, Design of the crushing cars.*

1. Introduction

All works in the field of crushing conditionally can be divided into four main directions [1]. Works which reveal interrelation between dispersion of the crushed bodies and energy costs of crushing process belong to the first direction. In works of the second direction researches regularities of destruction and calculation methods of particle size characteristics and its distribution in the crushed materials are presented. The third direction are researches in the field of constructive registration of mills. In the works relating to the fourth direction researches, physico-mechanical, physical and chemical phenomena occurring at mechanical impact (grinding, crush, and crushing) on the studied object are presented.

It is well known that in a processes of crushing and grinding, a working parts of a machine are acting against the molecular interaction forces in the particles, which results in appearance of new surfaces [1, 2], whose area depends on the strength of the environment, type of the mechanical impact, and the way it is applied [3, 4]. The known theories (by Kirpichev and Kick, Aphanasiev and Rittinger, Bond, Rebinder, Tanaka *et al.*) usually just try to describe the nature of the process. They do not take into account all the variety of the phenomena taking place in the material, and, hence, can not be used for precise calculation of the parameters of a particular process [5].

2. Materials and Methods

Power consumption on process of crushing it becomes essential noticeable in the field of thin and super thin crushing (the majority of loose masses in the food industry concerns those) when extent of crushing reaches more than 100. The high specific power consumption at thin and super thin crushing sharply changes conditions of power impact on particles of the small sizes and their strength properties. The smaller than a particle, there it is less of material for internal defects, they are stronger (since the smaller the particle size, the harder it becomes its further destruction), and, therefore, on their crushing big expenses of energy are required. In addition, with a decrease in particle size, it is more difficult to subject it to a load, which also contributes to an increase in the specific power consumption during processing [1, 3, and 5].

Therefore decrease in power consumption on process, especially in the field of thin and super thin crushing, is the major scientific and technical problem. Decrease in power consumption at a simultaneous intensification of process can be reached only on condition of a rational ratio between technological parameters of process of crushing and design data of the grinder [1].

Besides, all these theories are based (explicitly or implicitly) on the assumption that the material strength is a physical constant, though in fact in can change as much as up no 10^3 - 10^4 times and it depends on the material properties, mill design, and a working parts of a machine working condition [3]. That is why the desired relationship is usually found experimentally, using the material properties, desired product size, and type and design of the working parts of a machine.

3. Results and Discussion

According to Rittinger law (1867), the unit energy E required for crushing, is proportional to the new surface area appeared in the process. It is given by this equation:

$$E = k\left(\frac{1}{x_2} - \frac{1}{x_1}\right) \quad (1)$$

Where: x_1 and x_2 are the linear sizes of the original particles and the resulting product respectively, and *k* is a constant.

It is assumed that Rittinger law holds for fragile materials, which have destruction planes and are characterized by new clefts appearing.

If crushing of a solid immediately results in one class of particles, no matter what the original size x_1 is, Kicks law holds:

$$E = k_1 \lg \frac{x_1}{x_2} \quad (2)$$

Both (1) and (2) show that infinite energy is required only when particles are crushed to certain minimal size $x_2 = x_{min}$, which is determined by technological reasons so that further crushing does not make sense. It is visually visible from the schedule of dependence of change of efficiency of process of crushing on fineness of the crushed particles (Figure 1) [7].

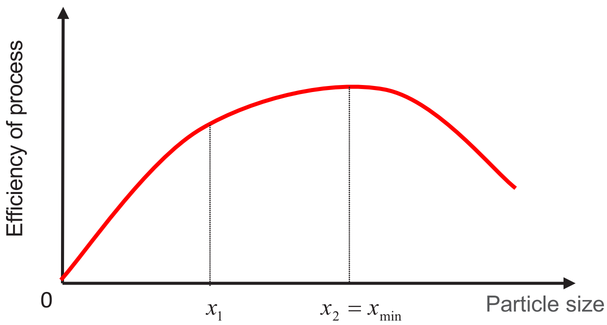

Figure 1. Change of efficiency of crushing depending on fineness of particles

For this reason, Tanaka T. [6], suggested the following crushing law:

$$\frac{dS}{dE} = k(S_\infty - S) \quad (3)$$

Where: *S* is the material surface area per unit, and S_∞ is the limit area, after which the process practically stops.

Made observations have allowed Abdymanap Ospanov to offer some correction of laws of Rittinger (1) and Kik (2) [1]**.** The above consideration suggests a correction to Rittinger's (1) and Kicks (2) formulas are based on the assumption that the crushing unit energy consumption depend only on the linear sizes of the original particles and the product, i.e., $E = f(x_1, x_2)$.

Considering the latter statement, it seems more reasonable to assume that, in fact, the unit energy depends on the deviation of the linear sizes from their minimal limit value. Then Rittinger's law takes this from:

$$E = k\left(\frac{1}{\Delta x_2} - \frac{1}{\Delta x_1}\right) \quad (4)$$

Where: $\Delta x_1 = x_1 - x_{min}$ *and* $\Delta x_2 = x_2 - x_{min}$ (see Figure 1).

Similarly, Kicks law changes to:

$$E = k_1 \lg \frac{\Delta x_1}{\Delta x_2} \quad (5)$$

From (4) and (5) one can see that, when x_1 increase, the unit energy grows at the rate $V_E = k/x_2^2$ to its limit value k/x_2, but not more. On the other hand, experiments show that unlimited increase of the original product linear sizes results in also unlimited growth of the unit energy required for crushing to the size $x_2 = x_{min}$. That is why it is reasonable to suggest a dependence of x_1 on and x_2 which would give linear energy consumption.

Among such mathematical function the most suitable seems to be the following:

$$E = k^* \left[\left(\frac{x_1}{x_2} \right)^{\alpha^*} - \left(\frac{x_2 - x_{\min}}{x_1 - x_{\min}} \right)^{\beta^*} \right] \quad (6)$$

Where: k^*, α^*, β^*, are some parameters which depend on the material to by crushed and its strength and mechanical characteristics. They are to be found in an experiment.

The amendment made by Abdymanap Ospanov to the existing scientific hypothesis is following:

$$\frac{x_2 - x_{\min}}{x_1 - x_{\min}}$$

Values of making dependences (6) hesitate in next ranges:

$$1 \le \frac{x_1}{x_2} \le \frac{x_1}{x_{\min}} \qquad 1 \ge \frac{x_2 - x_{\min}}{x_1 - x_{\min}} \ge 0 \quad (7)$$

$$0 \le E \le k^* \frac{x_1}{x_{\min}} \qquad \frac{k^*}{x_2} \ge V_E \ge \frac{k^*}{x_1^2} \quad (8)$$

4. Conclusions

- It is necessary to establish that on the sizes of parameters, it is possible to pick up values and, at that specific energy arrives at a minimum in a range (8). Possibility of development of recommendation of the most rational (effective) use of grinding machines of certain having a special purpose construction appears thus, which is primarily determined by the nature and degree of grinding of the crushed material.

- Given k^*, α^*, β^*, is one can find the values and x_1 and x_2 which minimize the unit crushing energy. This enables one to work out certain recommendations on the most rational usage of a mill of a particular design.

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