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Mineral

Effect of cavitation on comminution of mica powder

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Abstract: The cavitation abrasive water jet was used in the comminution of mica. By applying a cavitation nozzle in the abrasive water jet system to enhance the effect of cavitation and friction, better comminution results were obtained. The JME-200CX transmission electron microscope was used for observing the size distribution of particles. As using cavitation abrasive water jet, the relative comminution effect is raised by more than 25% compared with using abrasive water jet only. It can be concluded that the effect of cavitation is much more significant than that of impacting in the comminution of mica.

Key words: mica; comminution; cavitation; abrasive water jet

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There are various ways for powder comminution. For example, there are dry comminution and wet comminution according to the state of powder during comminution, and there are different comminution styles with and without abrasive medium according to different comminution devices.

In dry comminution, with the particles becoming finer, both their broken strength and surface energy increase significantly. The particles tend to agglomerate or adhere to the inner surface of the comminution device, forming a buffer layer. So that comminution efficiency becomes lower because the comminution energy cannot be concentrated on a single particle. However, in wet comminution, water will lower the surface energy of particles to prevent particles from agglomerating. Therefore, from the point of diminishing the particle size, wet comminution is thought to be better than dry comminution [1].

However, the abrasive medium will cause pollution to the powder although its comminution effect is good [2]. Comminution with abrasive medium is not suitable for requirement of high purity. Comminution with abrasive water jet is a kind of wet comminution without abrasive medium. It mainly depends on the high speed impacting between particles and a target or between particles themselves. According to theoretical analysis and experimental results, there are also cavitating effect and shearing effect in this way of comminution [3].

1 Theoretical analysis

Mica powder is a mineral difficult to be comminuted due to its stratified structure. The effect of cavitation and friction in the comminution of mica powder is much better than that of impact [4]. Based on elastic theory, the impacting model has shown that the maximum stress inside the particles caused by colliding between two particles is [5]:

$$\sigma_{max} = 0.085\,6\rho^{0.2}k^{-0.8}V^{0.4} \tag{1}$$

Where ρ is the mass density of particle; V is the impacting speed; k is a physical coefficient related with modulus of elasticity (E) and Poisson ratio:

$$k = \frac{2(1-\nu^2)}{\pi E} \tag{2}$$

The finer the particle is, the less the inner defect, hence, the higher the broken strength is. Therefore, the stress caused by direct impacting will not be large enough for breaking the particle. In other word, the effect of impact becomes less and has a limitation.

Especially for the comminution of powder with stratified structure like mica (**figure 1**), enhancing the effect

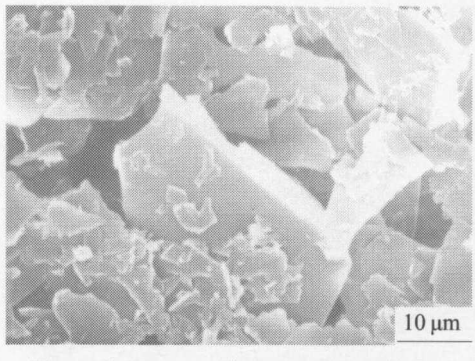

Figure 1 The stratified structure of mica.

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of cavitating and shearing will greatly improve the comminution results.

Figure 2 is a cavitation nozzle. It has a divergent angle at its outlet. In order to induce cavitation, it must be used under submerged condition. The divergent angle causes shearing between water jet and surrounding water so as to induce cavitation. Because it can not only cause shearing but also induce cavitation, this kind of nozzle is most suitable for comminution of mica powder. By applying this nozzle in an abrasive water jet system, a new kind of water jet, called cavitation abrasive water jet, is gotten.

According to calculation, the time for a cavitation bubble from growing till collapsing is in the order of millisecond. The impacting force caused by the collapsing of a cavitation bubble is extremely large. Collapsing of numerous cavitation bubbles will exert a high frequent impact on the powder particles. Moreover, the violent shearing at the nozzle outlet is also benefit to the comminution of the powder.

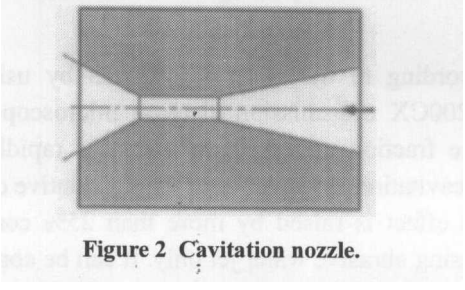

Figure 2 Cavitation nozzle.

2 Experimental device

In order to study the effect of cavitation on the comminution of mica powder, an abrasive water jet system was used as shown in **figure 3**.

The mica powder to be comminuted is stored in the high-pressure container. In considering that the main purpose of the experiments is to compare the comminution effect between cavitation abrasive water jet and abrasive water jet, a relatively simple nozzle set was used as shown in **figure 4**. The impact target is made of carbon tungsten material. The nozzle can be changed to form different system. During experiments, the nozzle was set upward to create the submerged condition that required by inducing cavitation.

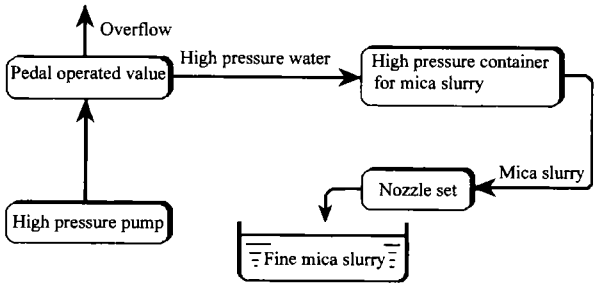

Figure 3 System of comminution.

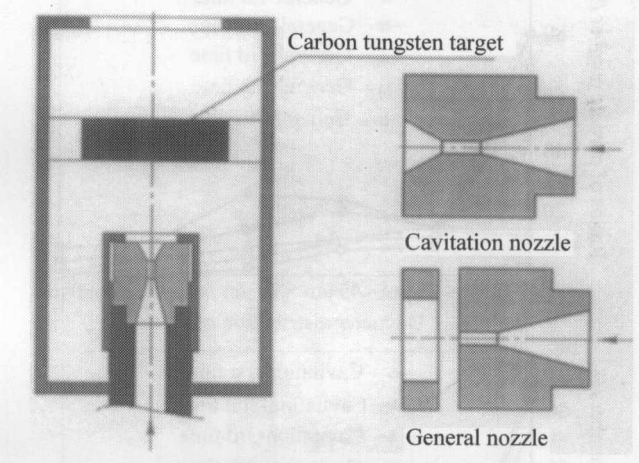

Figure 4 Structure of nozzle set.

3 Experimental results and discussion

The experimental parameters are shown in **table 1**.

Table 1 Experimental parameters

Nozzle type	Nozzle diameter /mm	Divergent angle	Pressure / MPa	Flow rate /(L·min^{-1})	Number of comminution /time
General nozzle	1.8	None	30	50	5
Cavitation nozzle	1.8	60°	30	50	5

Two types of nozzle were used in the experiments for comparison. As mica powder cannot be comminuted to the desired size at one time, the powder is comminuted over and over for five times . After each time of comminution, a sample was taken for granularity analysis with JME-200CX transmission electron microscope (shown in **figure 5**). The samples were magnified by 1 000 times for measuring their particle size and thickness (shown in **table 2**). The average size of mice powder before comminution is 150-300 μm.

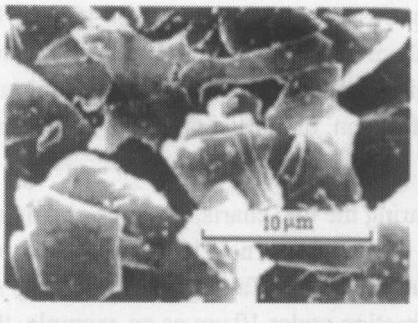

Figure 5 Comminuted mica particles.

Table 2 Thickness of mica particles

Diameter /μm	10	25	45	90	150	300
Thickness /μm	0.818	1.010	2.220	6.725	11.363	20.764

By applying the transmission electron microscope, only the particle size distribution can be obtained. It can be changed into volume fraction distribution by the following formula:

$$\phi_i = \frac{\alpha_i h_i d_i^2}{\sum_{j=1}^{n} \alpha_j h_j d_j^2} \tag{3}$$

Where d_i is the typical diameter of particles as shown in table 2; α_i is the percentage of the particle number with diameter d_i; h_i is the typical thickness of corresponding diameter; ϕ_i is the volume fraction.

The experimental results are shown in **figure 6**.

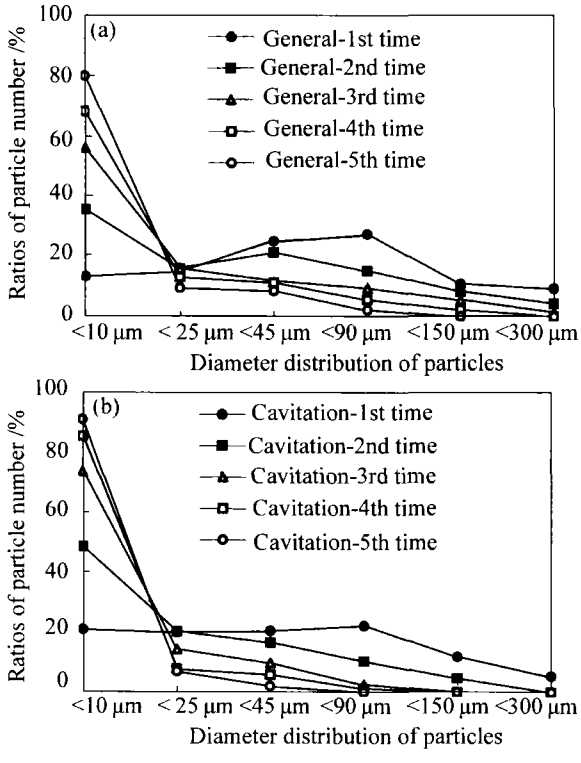

Figure 6 Volume fraction distribution of mica, (a) general nozzle; (b) cavitation nozzle.

In the two charts, the size of particles diminishes rapidly after one time of comminution although there are still about 50% particles larger than 45 μm. However, most of them are smaller than 45 μm after three times of comminution. After each time of comminution, the volume fraction of particles under 45 μm increases quickly.

Comparing the two charts, it can be clearly seen that applying the cavitation nozzle can largely improve the comminution result. Taking the increasing speed of volume fraction under 10 μm as an example, the effect of cavitation on comminution is very significant. The result after three times of comminution by cavitation abrasive water jet is equivalent to four times of comminution by general abrasive water jet. Under the same working conditions, the relative comminution effect can be raised by about 25% by applying the cavitation nozzle. This clearly shows that cavitation and friction are very effective to the comminution of mica powder because it has the stratified structure.

4 Conclusion

There are three kinds of comminution effects on mica powder by applying abrasive water jet, that is, the collision between particles, cavitation and friction or shearing. For the comminution of mica powder, the effect of cavitation and shearing or friction is much better than the effect of impacting due to its stratified structure.

According to the observing results by using the JME-200CX transmission electron microscope, the volume fraction under 10 μm increases rapidly. As using cavitation abrasive water jet, the relative comminution effect is raised by more than 25% compared with using abrasive water jet only. It can be concluded that cavitation and friction are very effective to the comminution of powders with stratified structure such as mica.

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