Novel Nanoparticles Dispersing Beads Mill with Ultra Small Beads and its Application

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ABSTRACT

Kotobuki Industries has developed a new type of beads mill which has successfully solved many problems related to nanoparticle dispersion such as reaglomeration and damage to the crystal structure of nanoparticles. The Ultra Apex Mill uses centrifugation technology which enables the use of ultra small beads with a diameter of less than 0.05mm for the first time in the world. Now 0.015mm beads are available. This technology has pioneered practical applications for nanoparticles in various areas, such as composition materials for LCDs, ink-jet printing, ceramic condensers and cosmetics.

Fig.1 UAM-5

Keywords: beads mill, dispersing, dispersion, nano, fine particle, nanoparticles, beads

1 STRUCTURE and OPERATION

The Ultra Apex Mill (UAM) consists of a vessel with a cooling jacket and rotor. The bead separator is located at the top of the rotor and rotor pins are located on the lower section of the rotor. The separator has the function of separating the beads using centrifugal force. The rotor pins are used to agitate the beads. Both the rotor and the vessel are sealed with mechanical seals. The dispersion of nanoparticles occurs during operation as the beads are agitated by the rotor pins inside the mill chamber while the material slurry is fed into the mill chamber from bottom. The slurry is dispersed by the impulse from the beads inside mill. Finally the milled slurry will exit the mill chamber at the top after passing through the separator to remove the beads. The difference in density will allow the milled slurry to pass through the separator while the beads are kept inside the mill chamber.

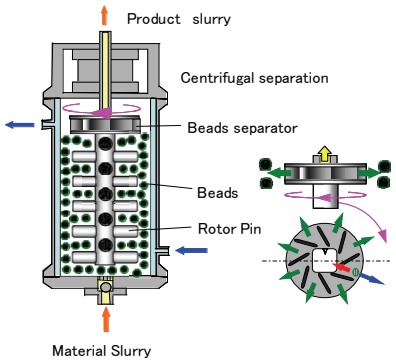

Fig.2 Structure of UAM

2 FEATURES

2.1 Utilizing centrifugal force for bead separation

The use of ultra small beads (0.015mm~0.1mm size) can only be realized using centrifugal force for bead separation. Despite the probability, bead leakage is rare and easily controlled.

2.2 Realizing nano particle dispersion

Nano particle dispersion is achieved by using ultra small beads. Dispersing speed is very fast and attained particle sizes will also become much smaller. Dispersion down to primary nano particle size is now possible.

2.3 Feed pressure is very low

Pressure loss is kept very low when using centrifugal separation. Feed pressure of the UAM is around one tenth when compared with conventional mills. This allows continuous, stable operation.

2.4 No need to pre-disperse a material slurry

Clearance of all internal passages is set to a minimum of 5mm. This eliminates the need to pre-disperse the material slurry and also contributes to the stable operation of the mill.

2.5 Simple Structure

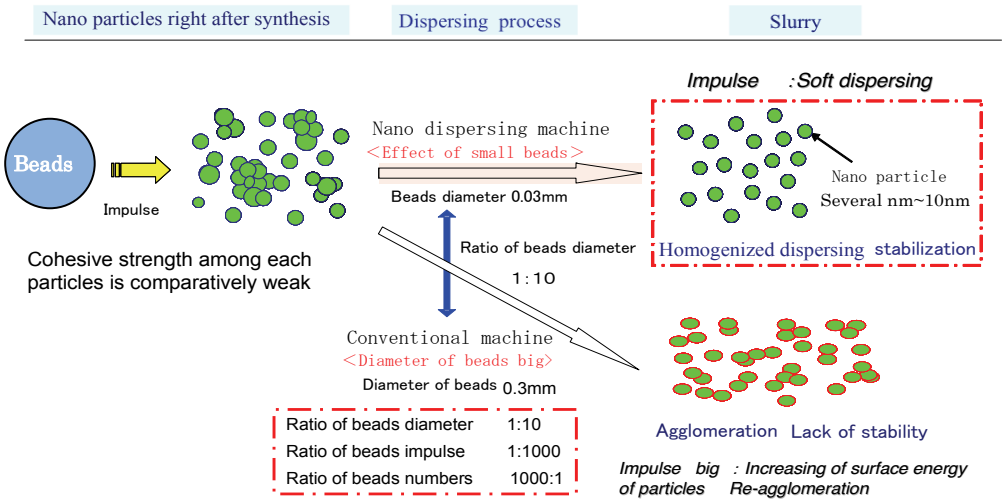

Fig.3 Principle of Nano particle dispersion

The UAM structure is simple. So, disassembly, cleaning and maintenance is very easy. The vertical type mill offers many operational advantages to conventional mills.

3 PRINCIPLE of NANO PARTICLE DISPERSION

Why is the Ultra Apex Mill superior in comparison with conventional machines in the nano dispersing field? The reason is simply because the Ultra Apex Mill can use the smallest beads in the world.

When dispersing agglomerated nano particles, the beads impulse is very low because the beads are very small. There is little influence on the nano particle. The surface energy of the nano particles hardly increases and the property is not likely to change. As a result, stable nano particles can be achieved without re-cohesion. On the other hand, conventional machines cannot use small beads. So, the impulse of the beads is very high and the result is strong influence on the nano particles. The surface energy increases and the properties are changed. As a result, stable nano particles cannot be achieved. Here, let us compare the difference of the dispersing performance between 0.03mm beads and 0.3mm beads.

The rate of beads diameter is one-tenth. Rate of beads impulse is one-1000th.Rate of beads number is 1000 times. That means the Ultra Apex Mill has one-1000th impulse, and is 1000 times more likely to make contact with the nano particles. It proves to be very effective. See Fig.3

4 The difference of structure between UAM and Conventional Mill

The Ultra Apex Mill is able to use very small beads because the bead separation is accomplished utilizing centrifugal force. Conventional mills are not likely to achieve stable operation because of clogging issues with the screens used for beads separation. See Fig.4.

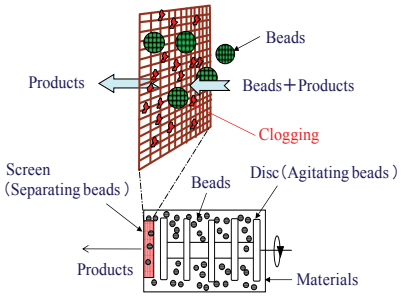

Fig.4 Conventional beads mill with screen

5 PRACTICAL EXAMPLE

5.1 Dispersion of TiO2

We would like to demonstrate the high-dispersing performance of the UAM using data from an actual experiment and then compare it with a conventional beads mill. The UAM used 0.03mm beads and the conventional beads mill used 0.3mm beads. As a result, there was the big difference in performance. The UAM achieved a primary particle size of 15nm and the slurry was transparent. On the other hand, in the conventional beads mill the particle size of product attained was 150nm and it was re-cohesive. You can see the result from TEM photograph too. See Fig.5

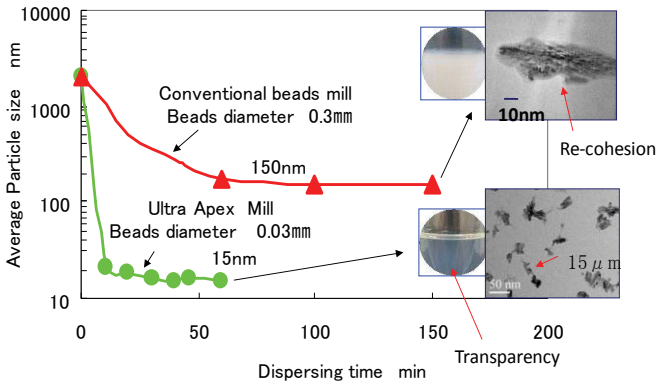

Fig.5 The effect for particle size as related to beads size

5.2 Dispersion of Organic pigment

First, the peripheral speed of the rotor-pins was set to 11m/sec. Under this condition, the particle size remained unchanged after reducing to 70nm. Next, raising the peripheral speed to 13m/sec immediately caused the particle size reduced to 10nm. Finally, the peripheral speed was increased to 14m/sec. Due to the increased peripheral speed, agglomeration of the particles occurred. See Fig.6.

Fig.7 shows the change of the particle size distribution. Particle size distribution is very sharp at optimum dispersing time.

Judging from these results, you can see the optimal rotation speed exist even if using ultra small beads.

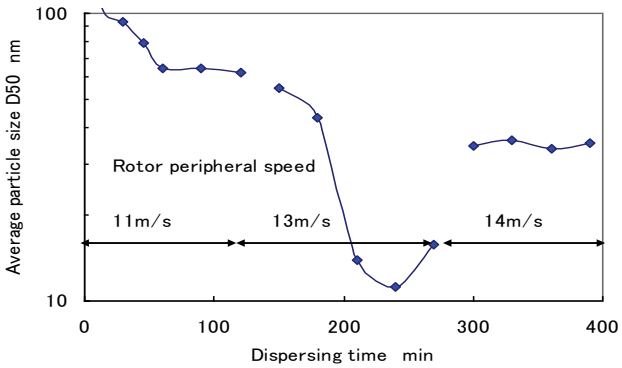

Fig.6 The effect of rotation speed of rotor

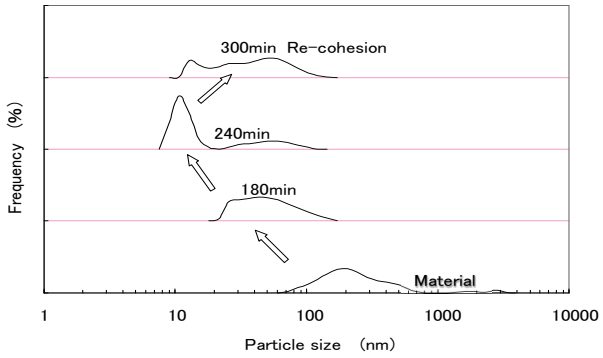

Fig.7 The change of particle size distribution

6/ APPLICATION

Material	Application	Purpose of dispersing	Attained particle size nm
Organic pigment	LCD color filter	Transparency, Contrast-up, Grain size refinement	20
	Ink jet printer ink	Grain size refinement	30
ZnO	Cosmetics : UV cutting	Transparency , Grain size refinement	10
Al_2O_3	Silicon wafer polishing	Grain size refinement, Sharpness of PSD	15
	Hard coating	Grade-up of hardness	10
ZrO_2	Anti-reflection coating	High refractive index, Grain size refinement,	15
SiO_2	Nano-composite	Strength up, Transparency	10
	Abrasive finishing	Grain size refinement, sharpness of particles size	10
ITO, ATO	Transparent electrode	Conductivity, Transparency	30
	Heat absorbing film	Transparency	30
	Anti-reflection coating	Transparency	30
TiO_2	Photocatalyst	Keeping crystal form, Grain size refinement	10
	Cosmetics : UV cutting	Transparency	10
$BaTiO_3$	MLCC (Ceramic condenser)	Keeping crystal form, Primary particle size	20, 200
Nano diamond	Polishing	Sharpness of PSD, Grain size refinement	8
Carbon nano horn	Fuel cell catalyst	Leveling	5
Cu paste	Print base wiring	Keeping primary particle form	200
Ni	Print base wiring	Keeping primary particle form	200
Nano-Ag	Transparent electrode	Conductivity, Transparency	10

SUMMARY

The Ultra Apex Mill has realized a breakthrough in conventional dispersing limits. Particle size limitation in the nano-fields has become much smaller by using 0.015 ～ 0.03mm dia. beads. Re-agglomeration is prevented and new products can be developed from common materials. The basic concept is that the impulse power of the small beads is very low which allows the crystal shape of the material to be maintained during milling. This allows the UAM to create new products with special properties that are not attainable with conventional machines. This breakthrough technology has attracted much attention in the nano technology field. As a result, Kotobuki Industries has supplied over 400 machines to various universities, research institutes and private companies around the world.

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