How can nanodispersion of pigments and extenders be achieved by milling technique?

Despite primary particles being nanosize, their high surface energy leads to rapid agglomeration which necessitates an effective dispersion process to bring about spatial resolution through de-agglomeration.

There have been recent developments in the media milling equipment worldwide to specifically enable production of nanodispersion of pigments. These advances pertain to three aspects: a. Bead size b. Chamber-rotor design c. Bead separator

- Bead size

Agitated media mills bring about dispersion through shear and impact forces exerted by the beads on the agglomerated powders suspended in a medium. These mills conventionally use ceramic/ zirconia beads with diameter of the order of ~1.0 mm. These mills are able to give dispersions with mean particle size in the range of 0.5~ 1.0 µm depending upon the characteristics of pigment- resin-dispersant system and the residence time in the mill. However, these mills are unable to attain nanosize dispersion closer to primary particle size of 20~50 nm. This limitation arises due to the vast difference in the size of the grinding beads and pigment particles. It is an established relationship that smaller the size of the grinding beads, the finer will be the particle size of the resultant dispersion. Empirically, it has been found that resultant mean particle size of dispersion is about $1/1000^{th}$ of the diameter of the beads. Based on this principle, the modern nano-mills employ very fine beads of 30~100 µm which can produce dispersions with particle size of 30~100 nm.

As the bead size gets finer the number of beads in the given shell volume increases hugely by inverse cubic relationship. This higher number of beads provides higher number of contact points with the particles in the slurry. Mean void size between the beads also reduces significantly thereby enhancing the energy imparted to the agglomerates to bring about finer dispersion.

- Chamber-rotor design:

To achieve fine particle size of the dispersion with narrow distribution, it is essential to ensure plug flow of the slurry through the mill at high flow rates repeatedly using multiple pass process. In conventional mills there is compaction of the grinding media towards the outlet due to the high pressure at high flow rates. This hydraulic packing disturbs plug flow and uniform transfer of energy to the particles. Modern nano-mills provide variety of design features for the chamber and the rotor in terms of accelerators, pins, slots and exit geometry to maintain plug flow, prevent bead packing and ensure uniform energy density at high flow rates.

- Bead separator:

As seen above, nanosize dispersions require fine grinding media with bead size in the range of 30~ 100 μm. This poses a challenge to separation of the grinding media from the slurry at the exit of the mill. Conventional gap separators and sieves are replaced by centrifugal separation mechanism in the modern nano-mills which claim to successfully accomplish the separation.

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