Sand and beads: Best dispersing results with attrition ball mills

This contribution to the FARBE&LACK (ECJ) Inline series is devoted to the themes of the general construction and function of attrition ball mills. Furthermore special aspects concerning the dispersing parameters, the varying constructions and the variations of the grinding media will be elucidated.

Dispersing with attrition ball mills
Whereas high speed mixers and triple roll mills are dispersing equipment which work without grinding media, grinding media are used in the mill category. Apart from the ball mill, which we have already presented and which is hardly ever used nowadays, the attrition ball mills also belong in this category.

In the past the first mills were open machines but the new machines entering the market only have closed systems. The most obvious advantage of closed machines is protection from emissions. Moreover there is no danger of overflowing and higher throughputs can be dealt with. Attrition ball mills mainly consist of a cylindrical grinding compartment filled approximately 70 to 80 % with grinding media and an impeller shaft equipped with mixing discs. The grinding compartment is fitted with a cooling jacket through which cooling water flows to provide better temperature control during the dispersing process. As far as the arrangement in the grinding compartments is concerned we must differentiate between:
- horizontal and vertical construction methods.

The “horizontal mills” as opposed to the “vertical mills” have several advantages e.g. easier starting up, a higher filling rate of grinding media (up to 85 %) and the possibility of using smaller sized beads (from 0,1 mm). Unlike dispersion with the attrition ball mills, which usually occurs in the laboratory in a step by step process, in production a continuous working process is usually used.

In the continuous working process the material to be dispersed is pumped through the grinding compartment and simultaneously circulated by the impeller shaft blades. The dispersing effect takes place by abrasion, shearing and impact between the surfaces of the grinding media and also between the grinding media and the grinding compartment walls. After that the material to be ground is either separated by the grinding media by:
- a slot or
- a filter.

With the slot separation method there is a 0,1 to 0,4 mm wide slot between the grinding compartment and a cutting disc attached to the impeller shaft and it is this slot which holds back the grinding media. With the filter separation method a fine-meshed filter over the emitting aperture for the dispersed coating material holds back the grinding media. The width of the slit is between 0,1 and 0,75 mm. A rule of thumb says that the width of the filter slits should be approximately 1/3 of the diameter of the grinding media. Depending on the grinding media used we should differentiate between:
- sand mills and
- bead mills.

Sand mills
For several years the sand mill was considered to be the classical dispersing unit for the wet grinding of low to medium viscosity grinding material. As the name of the apparatus implies silica sand is used as a grinding medium in this apparatus. Ottawa sand was the most commonly used sand here and is particularly suitable due to its round and evenly sized grains (0.6 to 0.8 mm diameter). The usual volume of grinding media in sand mills is a maximum of 60 %.

Bead mills
In the first attrition ball mills beads made out of:
- porcelain
- tempered glass were used.

Nowadays it is usual to use more abrasion resistant beads for instance consisting of:
- ceramic,
- aluminium oxide,
- zirconium oxide (stabilised with cerium oxide and known as “Zirkonox” beads) or
- silicon aluminium zirconium mixed oxide (SAZ beads).

Compared with porcelain or glass these beads have the advantage of having a higher specific density and hardness. In addition it is also possible to stabilise the beads using yttrium oxide or zirconium oxide but this leads to higher material costs. The diameter of the beads, which is between 0,1 and 3 mm, has a great importance for the dispersion result. Whereas beads with a relatively wide diameter are required for large pigment particles to guarantee the particles’ being fed into the grinding media, small diameter beads should be used for small pigment particles. Normally dispersion is carried out using several bead mill elements so that from element to element smaller sized beads can be used.

Other factors having a bearing on the dispersing result are the blade speed of the impeller shaft and the shapes of the mixing discs. As a general rule: "The higher the blade speed the better the dispersing result is". However this increased abrasion is not good for the grinding compartment, the impeller shaft or the beads. Thus there are limits to the speed caused partly by the firmness of the beads. Most bead mills allow a blade speed of between 8 and 12 m/s depending on the mixer and the type of bead used. There is a wide range of different types of mixing discs. A typical example is illustrated by the transition from the full disc to the perforated disc. Unlike the full disc the perforated disc produces higher turbulence and this causes the air produced during dispersing to be drawn off. The following factors should be considered as further dispersing parameters (factors which have an effect on the dispersing result):

- volume of grinding media
- throughput rate
- number of grinding processes
- viscosity of the material to be ground
- dispersing temperature

As a general definition one can say that the higher the amount of energy put into the material to be ground the better the dispersing result will be. On the other hand one must take account of the fact that too high an amount of energy can also cause the following disadvantages:
- increased sedimentation of the pigments,
- binding agent crosslinking, incompatibilities or side reactions due to too high dispersing temperatures,
- higher production costs.
A substantial factor affecting the dispersing result is the residence time of the pigment particles in the mixer. As this period is not and cannot be the same for all the particles it is best described be means of a residence time spectrum. The average residence time is denoted by a calculable factor ($t_m$) which can be calculated from the free volume of the grinding compartment ($V_f$) and the volume throughput ($V_P$):

$$t_m = \frac{V_f}{V_P}$$

With a tight residence time spectrum all the pigment particles are evenly dispersed. This can be achieved by:
- a long and as narrow a grinding compartment as possible,
- relatively large and closed discs and also
- as high a number of discs along the impeller shaft as possible.