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Modern Air Classifiers

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Summary

Using the spiral air classifier as a model, the internal processes in a classifier rotor with vanes are discussed and test results compared. The test data was obtained from rotors with an external diameter of 260 mm and 360 mm. Fine materials were produced with d_{97} of approximately 2.5 μm. The comparison illustrates that results achieved in practice can be interpreted from the described model. The new classifier rotors are already in use in air classifiers and classifier mills; the Superfine Classifier CFS and the Fluidized Bed Opposed Jet Mill CGS are presented.

Nomenclature

D	Diameter	[m]
d_T	Cut size (All particle sizes are given in settling rate equivalent diameters)	[μ]
d_{97}	Particle size for 97% passing	[μ]
H	Height of classifier chamber	[m]
n	Running speed of classifier rotor	[s^{-1}]
r	Radius	[m]
V_L	Gas throughput	[m^3/s]
V_r	Radial gas velocity	[m/s]
V_u	Peripheral component of velocity	[m/s]
η	Dynamic viscosity	[Ns/m^2]
ρ_s	Density	[kg/m^3]
ξ	Index number	[$s^{0.5}$]

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Indices

a	related to outer edge of vane
F	related to discharge of fine material
i	related to inner edge of vane

1. Models for Air Classification in a Vaned Classifier Rotor

Vaned classifier rotors are used in a great number of classifier designs [1].

The flow properties between the vanes and in the vane-free internal area of the rotor have been studied by *Leschonski* and *Legenhausen* [2]. They discovered that the flow between the vanes is generally steady when entry is shock-free. The formation of turbulence between the vanes is detected on non-shock-free entry. On the other hand, the flow in the vane-free internal area is correctly described as vortex flow – with the exception of the boundary layer on the front surface.

Assuming classification by centrifugal forces within the Stokes range, the following equation can be applied to determine the cut-point d_T:

$$d_T = \sqrt{18\,\eta\,\frac{V_r}{V_u^2}\,r\,\frac{1}{\rho_s}} \qquad (1)$$

Using this equation and the results found in [2], it is possible to show in a qualitative curve the cut-point d_T as a function of the radius of the classifier rotor, in the case of shock-free entry (Fig. 1). It can be seen that the cut-point d_T increases initially along the gap between the vanes and then decreases again in the vane-free internal area of the classifier rotor.

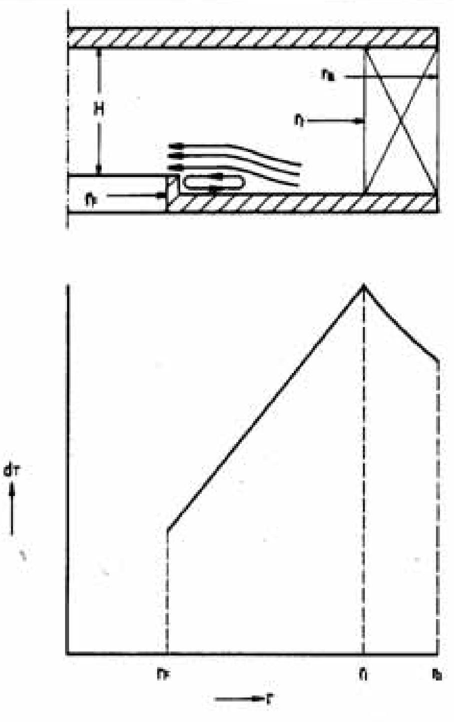


Fig. 1: Qualitative curve showing the cut-point d_T as a function of the radius r of the classifier rotor for steady flow between the vanes and vortex flow in the vane-free inner area. Calculation of the particle cut-point d_T using Eq. (1)

Therefore – under the conditions assumed – it is possible to design a classifier rotor in which classification takes place between the vanes or, in which the internal vane-free area is used for separation.

The latter offers several practical advantages:

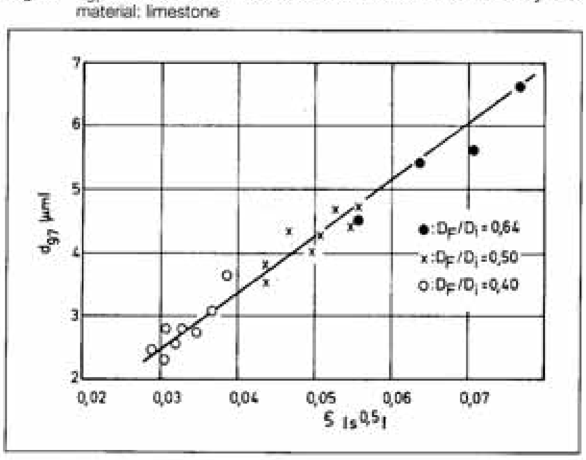
- The conditions of flow entry can be selected relatively freely since the condition of shock-free entry does not need to be fulfilled. The combination with a mill, for instance, can be realized without any problems to form a classifier mill.
- Same fineness can be obtained with a lower rotor peripheral speed when the unit is designed accordingly. In particular, it is then easier to master problems of rotor wear and durability.

When designed for classification in the vane-free internal area, the flow in the gap between the vanes transports the feed material inwardly and outwardly (particles that are too large must be transported out of the classifier wheel again). The vanes have the task of accelerating the entering air stream loaded with material, if possible without losses, to the peripheral speed of the rotor at the vane's inner edge. For this reason, a critical load of the vane-area should not be exceeded.

To minimize the effects of delay in the boundary layers on the front surfaces of the classifier rotor, the use of an immersion tube, fitted in the discharge opening for the fine material and classifier air, has proved to be successful [4]. As an analogy, the effect of the immersion tube can be explained by a vortex created on the side of the immersion tube facing the classifier zone. This vortex prevents oversized particles carried inwards in the boundary layer from entering the fine material discharge (Fig. 1)

Finally, it can be assumed, that even when the classifier rotor is designed for "internal classification", preliminary classification will take place at the outer edge of the vane, thus preventing particles that are much too coarse being drawn in to the rotor. This assumption explains why rotors of this design operate almost independent from the product load of the classification air.

Fig. 2: d_{97} of classified fine material as a function of index number ξ. Test material: limestone



2. Comparison of the Theoretical Proposition and Test Results

To compare the practical results with the theory for the investigated "internal classification", it is necessary to relate the parameters from Eq. (1) to the conditions prevalent at the fine material discharge of the classifier rotor.

The peripheral component for the air velocity in the assumed case of a vortex flow can be given as

$$V_{u,i}\, D_i = V_{u,F}\, D_F \qquad (2)$$

with

$$V_{u,i} = D_i \pi n \qquad (3)$$

provided that the loaded classification air at the inner edge of the vanes is accelerated without losses to the peripheral speed of the rotor.

The radial component of the air velocity is calculated for the incompressible flow in accordance with the equation of continuity as

$$V_{r,F} = \frac{V_L}{D_F H \pi} \qquad (4)$$

Applying Eqs. (2 to 4), Eq. (1) becomes

$$d_T = \sqrt{\frac{9}{\pi^3}\,\frac{\eta}{\rho_s}\,\frac{D_F^2}{D_i^4 H}\,\frac{V_L}{n^2}} \qquad (5)$$

Assuming the material data are constant, it is thus possible to write Eq. (5) as

$$d_T \sim \xi = \frac{D_F}{D_i^2 H^{0.5}}\,\frac{V_L^{0.5}}{n} \qquad (6)$$

(In cases of considerable temperature variations, e.g. jet mills operating with hot gas, it is necessary to apply a correction for the change in viscosity of the gas.)

In Fig. 2 the obtained d_{97} values from the classified fine material are plotted against the index number ξ. The tests were carried out using rotors with a peripheral diameter of 260 mm and 360 mm. The throughput of fine material achieved was between 50 kg/h and 500 kg/h, dependant upon the fineness and the size of classifier. The Reynold's numbers for the particle flow (related to d_{97}) was between approximately 0.5 and 2, which is close to the Stokes range.

As seen in the figure, a linear relationship exists between d_{97} and the index number ξ which, in particular, is also valid for the varied values of D_F/D_i. This fact leads to the conclusion that classification into the range of extreme finenesses is possible in the vane-free internal area of the classifier rotor. It is worthy of note that finenesses of d_{97} up to = 2.5 µm were achieved, and this using rotors of relatively large diameter and with the corresponding throughput. It has thus become possible to shift the working range of air classifiers with vaned rotors into an area of even greater fineness.

3. New Classifier Rotors in Processing Plants

The new generation of vaned classifier rotors are used in air classifiers and classifier mills. As an example, the following two new machines are described: the Superfine Classifier CFS and the Fluidized Bed Jet Mill CGS.

Fig. 3 illustrates a schematic of the Superfine Classifier CFS. The classifying air is drawn in through a spiral shaped air inlet (1) and flows in a spiral flow along the classifier housing (2) to the classifier rotor (3). The material to be separated is fed through a vertical chute (4) from above and is dispersed in the primary air stream fed from below. This process is enhanced by an integrated dispersion zone (5) in the air inlet (1). Separation into fractions of fine and coarse material is carried out in the classifier rotor (3): the fine material leaves the classifier with the air through an expansion chamber (6) in the discharge outlet (7). The coarse material is sent to the wall of the classifier housing (2) by the rotation momentum where it creeps down against the ascending air flow to the dispersion chamber (5) and on to the coarse material discharge (8). Extremely sharp separation is achieved on account of the opposed flow of the air stream and the coarse material close to the classifier wall.

Fig. 4 shows the particle size distribution of the feed material, coarse material and the fines from limestone classification. The Tromp separation curve for the same classification example is shown in Fig. 5. It can be seen that an extremely sharp cut-point can be achieved even when the material load of the air is increased.

Fig. 6 is a schematic illustration of the Fluidized Bed Jet Mill CGS. The design and mode of operation of the integrated air classifier are identical to the one described above. However, the coarse material from classification is not discharged but transported, until it is completely comminuted, along the wall surface (2) to a particle bed (5). High velocity jets of

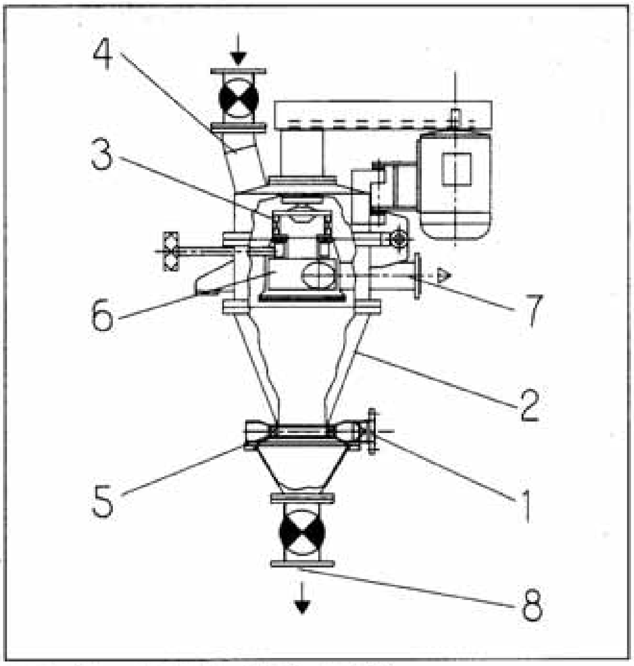


Fig. 3: Schematic illustration of Air Classifier CFS
1: primary air inlet; 2: classifier housing; 3: classifier rotor; 4: feed chute; 5: dispersion zone; 6: expansion chamber; 7: fine material discharge; 8: coarse material discharge

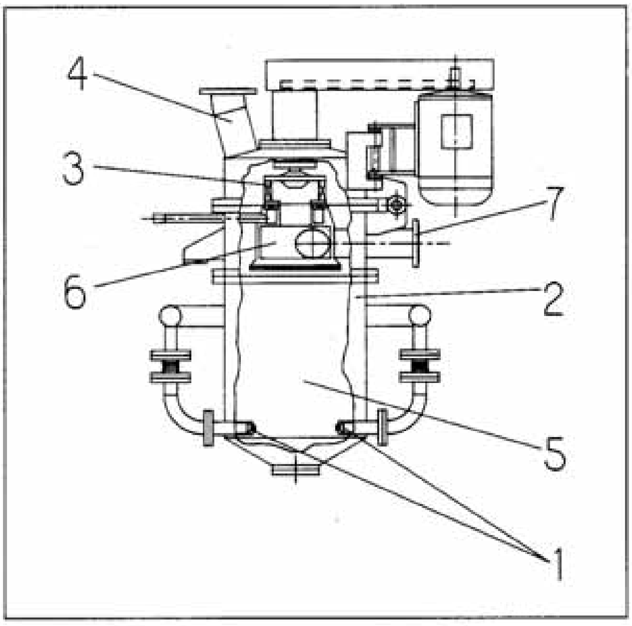


Fig. 6: Schematic illustration of the Fluidized Bed Jet Mill CGS
1: nozzles; 2: grinding chamber; 3: classifier rotor; 4: feed chute; 5: particle bed ("fluidized bed"); 6: expansion chamber; 7: fine material outlet

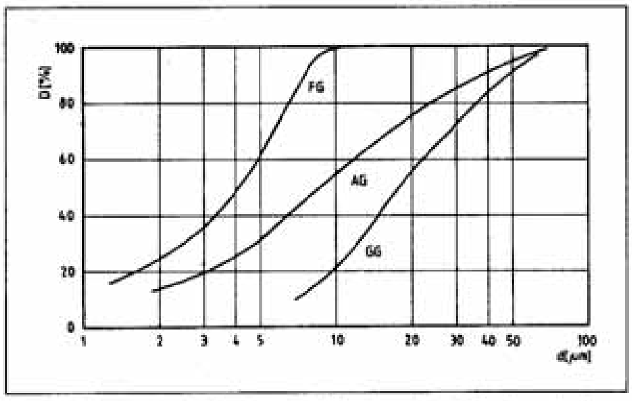


Fig. 4: Example of classified limestone. Feed capacity: 1 t/h; fine material capacity: 450 kg/h; material load of classifier air: 0.8 kg/m³

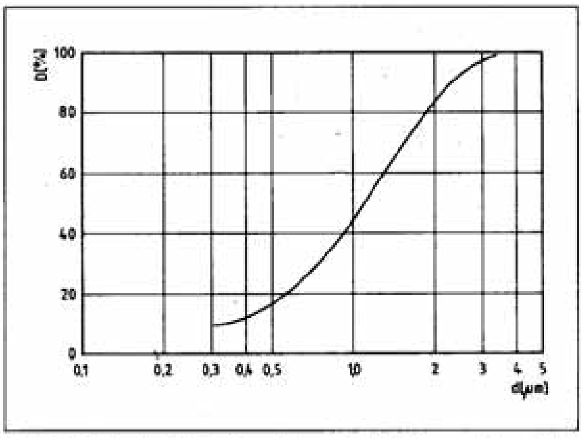
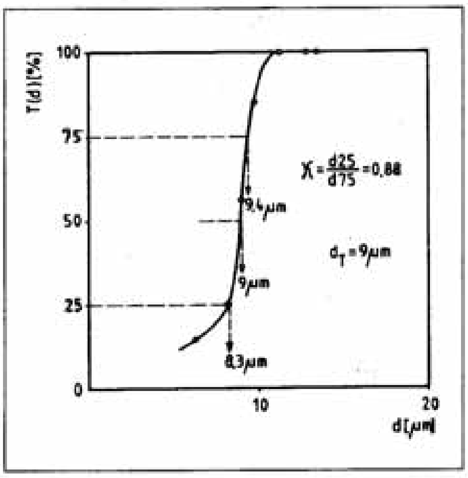


Fig. 7: Particle size distribution of aluminium hydrate ground in a Fluidized Bed Jet Mill CGS with integrated classifier

Fig. 5: Tromp's separation curve for the classification shown in Fig. 4



gas, created by the expansion of gas under high pressure in a nozzle (1) enter the particle bed – often referred to as a fluidized bed. Particles are picked up from the bed and accelerated to high speed by the jets. Comminution takes place solely by particle – particle impact in the gas jets and their focal point. The expanded gas loaded with material flows to the classifier rotor (3) where the separation of fine and coarse material takes place in usual manner.

Fig. 7 shows the particle size distribution of a sample of ground aluminium hydrate with 97% finer than 2.9 μm.

As can also be seen from this example, very high degrees of finenesses can be achieved with the new classifier rotors in conjunction with a suitable grinding process.

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