ELSEVIER Int. J. Miner. Process. 44–45 (1996) 723–731

INTERNATIONAL JOURNAL OF MINERAL PROCESSING

CFS–HD: A new classifier for fine classification with high efficiency

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Abstract

The CFS–HD classifier uses a combination of the free vortex and the forced vortex models to achieve cut points down to less than 2 μm. The classifier rotor has a new design for theoretically constant radial velocity in the vane-free internal area; it is surrounded by a cage of static vanes, creating a steep spiral flow in order to give good dispersion and deagglomeration to the material to be classified.

Cut points obtained from experiments are compared with a modified classifier equation, showing a linear relation even in the very fine range. The efficiency of the classifier is evaluated by means of Tromp's κ-values and fines-yields. (Cut point and κ-value are related to the Tromb curve, which is derived from the mass balance and the particle size distributions of coarse and feed fraction of a classification: $T(d) = g \cdot q_g(d)/q_A(d)$. The cut point is then defined as d_{50}-value of the Tromb curve; the κ-value is formed as quotient of the d_{25} and the d_{75} value: $\kappa = d_{25}/d_{75}$.)

1. Historical background

Spiral classification was first investigated systematically by Rumpf (1939). A well known classifier using this principle was the Alpine Mikroplex, Fig. 1.

This was the first industrial classifier design that allowed cut points in the 10 μm range. Besides that, a characteristic advantage of this classifier was the good dispersion and deagglomeration of the feed material in the gasflow; thus a high sharpness of the cut could be attained. A disadvantage of free vortex classifiers is the fact, that their cut point is strongly influenced by the product to air ratio (Nied and Horlamus, 1988). The so called deflector wheel classifiers (see Fig. 2) use a vaned rotor to create a forced vortex, where the circumferential velocity component is mainly determined by the rotor speed. The dependence of the cut point on the product to air ratio is thus avoided.

0301-7516/96/$15.00
SSDI 0301-7516(95)00078-X

2. The CFS–HD classifier

Fig. 3 shows a schematic drawing of the CFS–HD classifier. The classifying air enters through the air inlet (2), being distributed to the static vanes (6) in a spiral shaped housing. The flow around the guide vanes (6) forms a steep spiral flow with a high radial velocity component in the ring shaped area between the static vanes (6) and the rotor (5). The material to be classified (1) is fed to this ring shaped area, being properly dispersed in the airflow and transported to the classifier rotor (5), where the classification takes place. The coarse fraction is peeled off by a cutting blade and discharged through a hole (3) in the backside of the housing. The fine fraction leaves the classifier together with the air through the central fines outlet in the classifier wheel.

3. Model for the classification in a vaned classifier rotor

As mentioned before, the static guide vanes (6) of the CFS–HD classifier serve only to give good dispersion and deagglomeration of the material in the classifying air and to carry it to the rotor. The true classification process happens in the vaned rotor (5). Fig. 4 shows the qualitative graph of the cut point in a vaned rotor as a function of the radius. The curve has been calculated by using the classifier equation (deduced from the equilibrium of mass force and drag force on an individual particle) within the Stokes-range:

$$d_\mathrm{T} = \left(18 \cdot \eta_F \cdot \frac{v_\mathrm{r}}{v_\mathrm{u}^2} \cdot r \cdot \frac{1}{\rho_\mathrm{s}}\right)^{0.5} \tag{1}$$

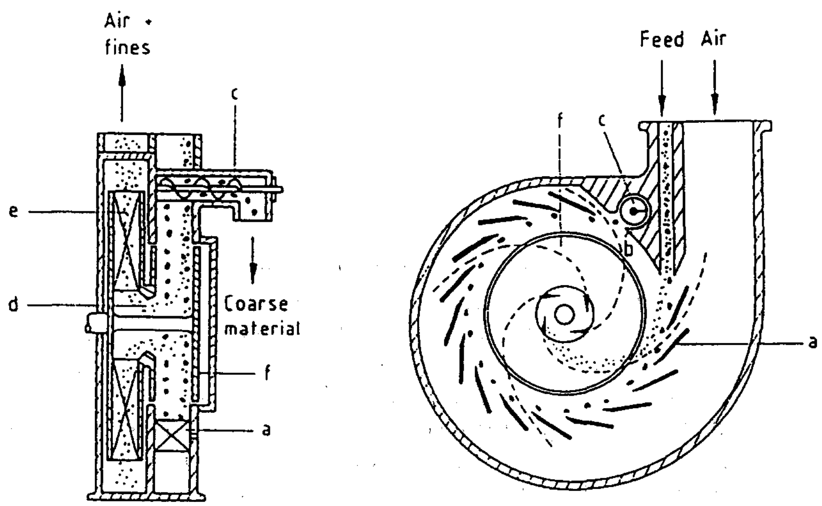

Fig. 1. Free vortex classifier Alpine Mikroplex. (a) Adjustable guide vanes; (b, c) coarse fraction discharge; (d) fines outlet; (e) fan; (f) rotating walls.

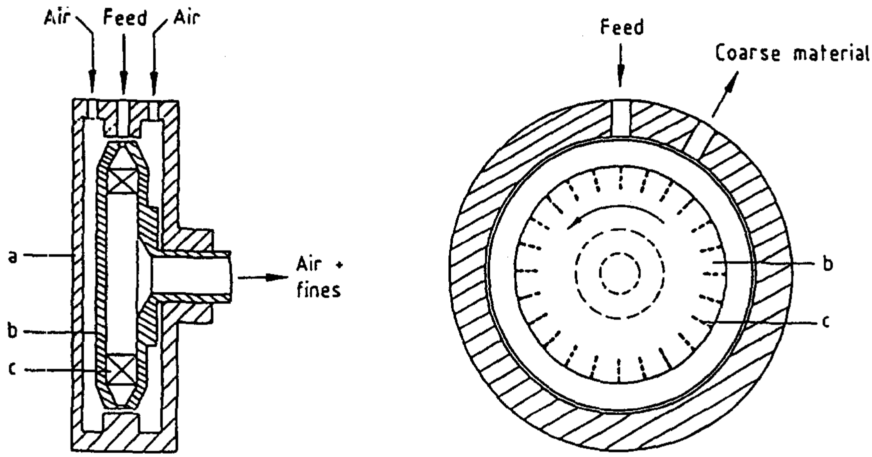

Fig. 2. Deflector wheel classifier Donaldson Acucut. (a) Housing; (b) rotor; (c) vanes.

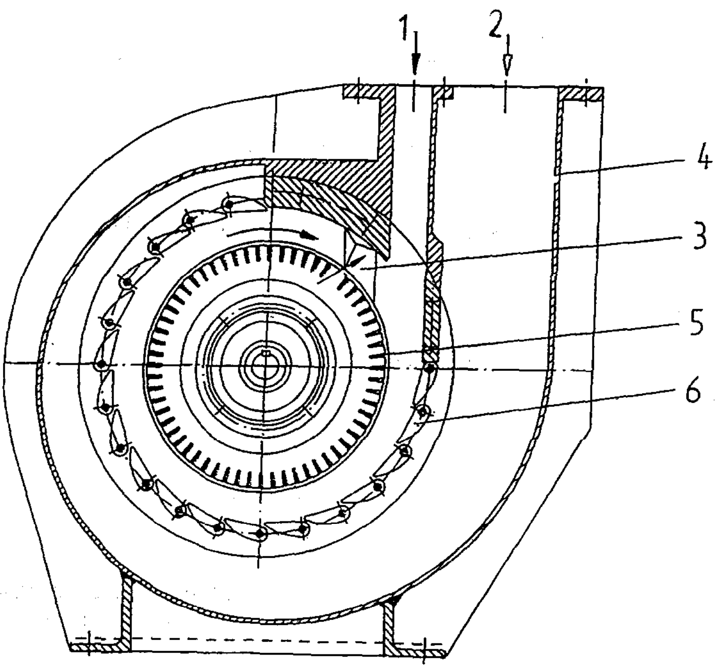

Fig. 3. Schematic drawing of the CFS-HD classifier. 1: Product feed; 2: Air inlet; 3: Coarse fraction discharge; 4: Housing; 5: Rotor; 6: Static vanes.

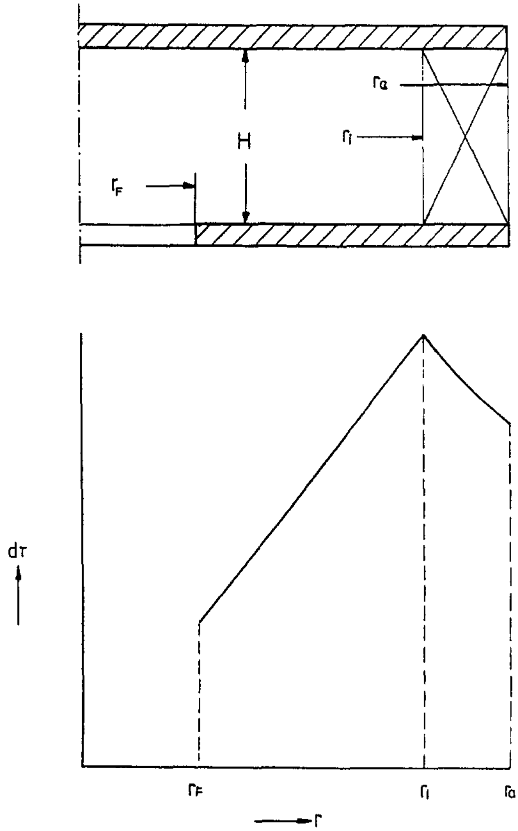

Fig. 4. Qualitative graph of the cut point versus the radius in a vaned classifier rotor.

For calculating the radial velocity component, the validity of the continuity law was assumed:

$$v_r \sim V/A \tag{2}$$

The circumferential velocity was calculated by supposing:

– solid body rotation between the vanes:

$$v_u/r = \text{const.} \tag{3}$$

– and free vortex flow in the vane free internal area:

$$v_u \cdot r = \text{const.} \tag{4}$$

As the graph indicates, the cut point d_T increases initially along the vanes and then decreases in the internal vane-free area. Following that, two possible locations for the classification process can be defined:

– the radius of the outer edge of the vanes, if the fines outlet is located immediate behind the inner edge of the vanes;

– the radius of the fines outlet, if it is significantly smaller than the radius of the inner edge of the vanes.

Experimental results evaluating the flow conditions in a vaned classifier rotor have been presented by Legenhausen (1991). For this water based experiments, observing the laws of similarity of flow, a rotor with a diameter of 440 mm at the outer edge of the

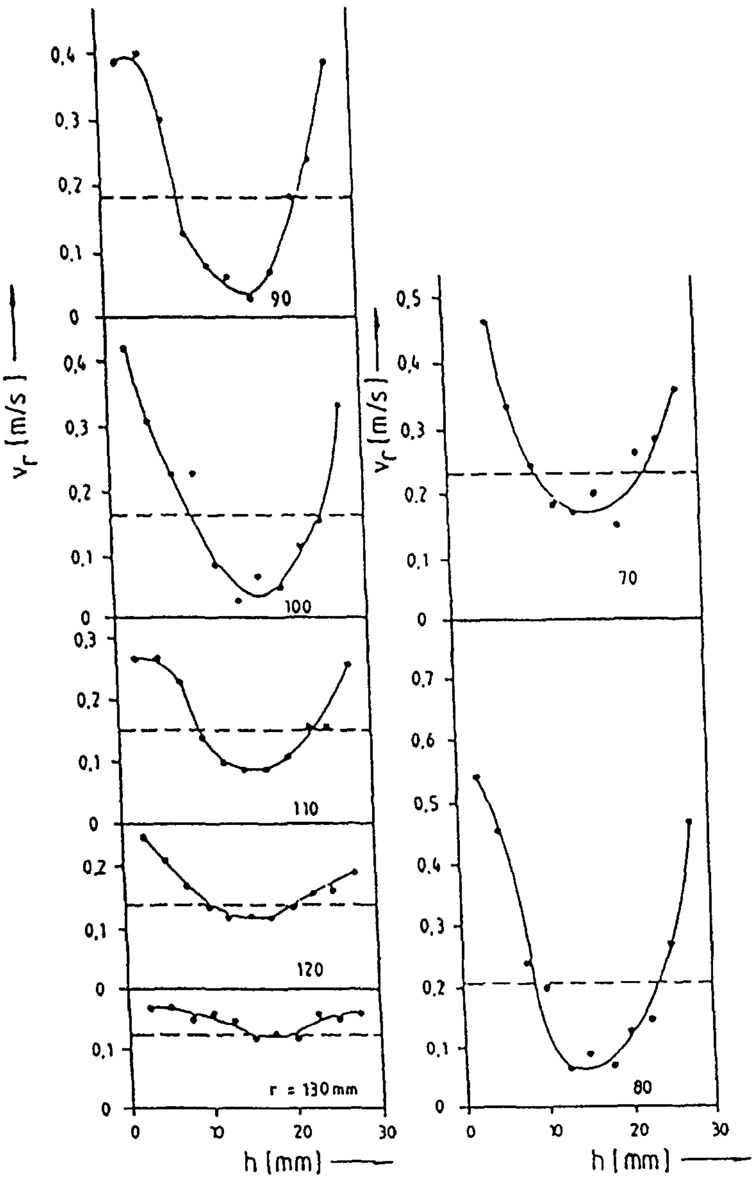

Fig. 5. Radial velocity profile in the vane-free internal area of a cylindrical rotor.

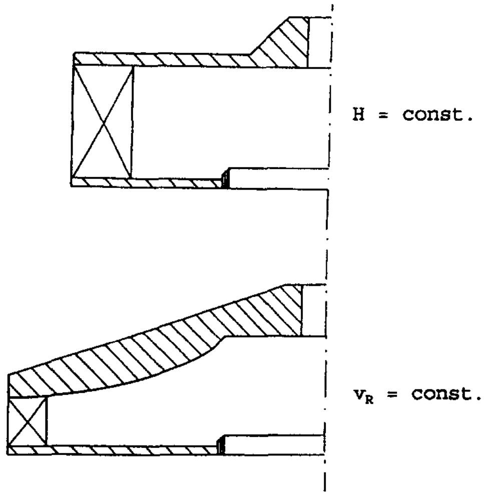

Fig. 6. Schematic view of a cylindrical rotor (top) and a rotor of theoretically constant radial velocity (bottom).

blades and 280 mm at the inner edge was used. The internal height of the rotor was 30 mm; the number of vanes 64. The velocity measurements have been carried out by means of a Laser–Doppler-Anemometer.

Legenhausen found, that in the vane-free internal area the circumferential velocity conforms to the results deduced from the free vortex theory (Eq. 4).

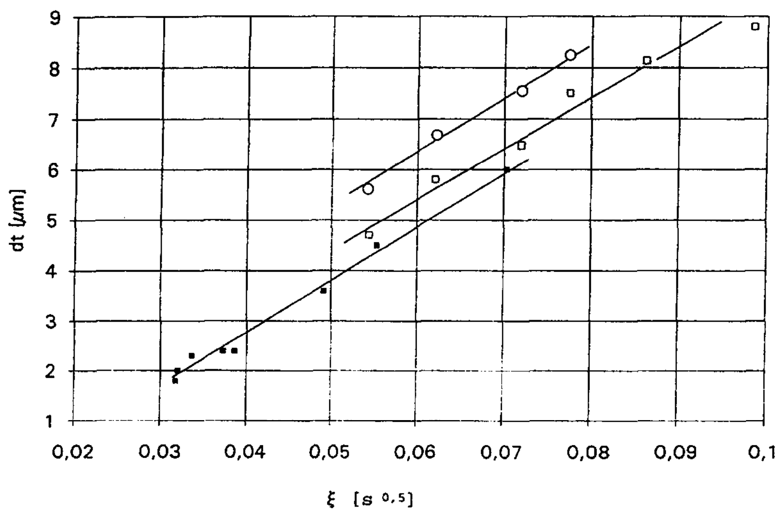

Fig. 7. Cut point of a vaned rotor as a function of the index number ξ. (○) Cylindrical rotor without immersion tube. (□) Cylindrical rotor with immersion tube. (■) $v_{r,const}$-rotor with immersion tube.

The radial velocity, however, showed substantial deviations from the theory as given per Eq. (2):

From Fig. 5 can be seen, that the flow profiles become more and more uneven as radius decreases. The radial velocities near the rotating walls of the rotor become significantly higher compared to the calculated median values (broken lines in Fig. 5).

4. The design of a new rotor for the CFS–HD classifier

To solve the problem with the uneven radial flow profile, two items of the classifier rotor have been changed (Fig. 6):

– The fines outlet has been equipped with a co-rotating immersion tube, which extends into the internal area of the rotor. This prevents coarse particles, which have been carried by the comparatively high radial velocity near the wall, from being discharged through the fines outlet.

– The internal contour of the rotating walls has been shaped in such a manner, that the surface of the virtual cylinders is a constant for any radius. The radial velocity component of the flow should thus stay constant from the inner edge of the blades to the fines outlet, and the accelerated radial flow is avoided.

5. Experimental results

The experiments have been performed on a CFS–HD 85 with the following parameters:

Diameter of the rotor:	320 mm
Rotor speed:	1.000 to 5.100 rpm
Air flow rate:	800 to 1.200 m^3/h
Feed rate:	100 to 400 kg/h
Pressure drop of classifier:	80 to 300 mbar
Test material:	limestone
Feed size:	$d_{97} = 35\ \mu m$, $d_{50} = 4\ \mu m$
Particle size analysis:	Sedigraph 5000 D.

Fig. 7 represents the cut point d_T as a function of the index number ξ [1] for a cylindrical rotor with and without immersion tube as well as for a "$v_{r,const}$"-rotor. The

[1] The index numer ξ is a modified classifier equation, corresponding to Eq. (1). Following the conditions for classification in the vane-free internal area, the radial velocity component becomes

$$v_{r,F} = V_L/(D_F \cdot H_F \cdot \pi) \tag{5}$$

The circumferential velocity component can be calculated as

$$v_{u,F} = D_i \cdot \pi \cdot n \cdot \left(\frac{D_i}{D_F}\right) \tag{6}$$

Applying Eq. (5) and (6) to (1), one obtains:

$$d_T \sim \xi = D_F \cdot V_L^{0.5}/\left(D_i^2 \cdot H_F^{0.5} \cdot n\right) \tag{7}$$

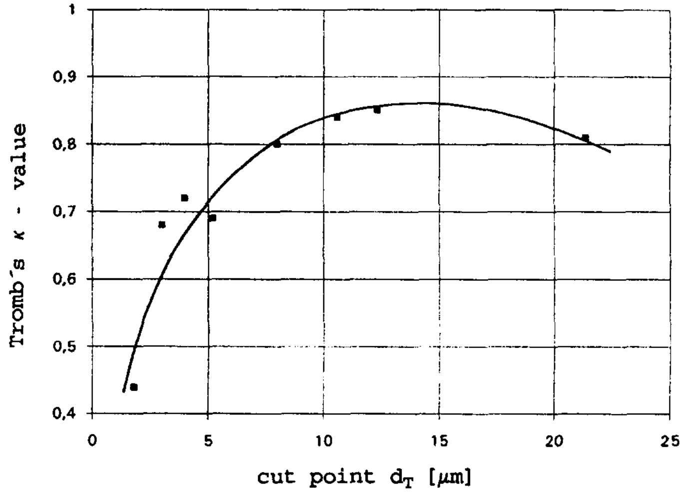

Fig. 8. Sharpness of cut as a function of the cut point for the CFS-HD classifier.

graph shows the effect of the immersion tube and the advantage of the $v_{r,const}$-rotor: at the same index number ξ the cut point is reduced by about 20% by applying the immersion tube and by another 10% with the $v_{r,const}$-rotor, whereas the range of fineness reaches less than 2 μm.

Fig. 8 demonstrates the sharpness of cut by plotting Tromb's κ-values against the cut

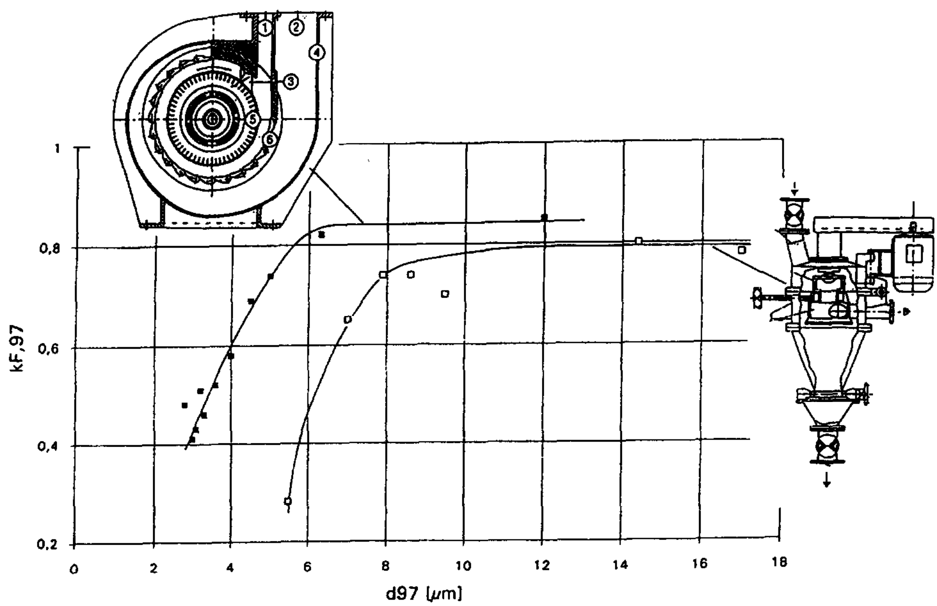

Fig. 9. Fines yield $k_{F,97}$ as a function of d_{97} of the fine fraction.

point d_T. It shows, that the CFS-HD classifier offers high κ-values, even at cut points below 5 μm.

Finally, Fig. 9 compares the fines yield of a CFS-HD with that of a standard classifier. Again, the new classifier shows a much better efficiency in the fine and the very fine range.

6. Nomenclature

D	diameter
d_T	cut point
d_{97}	particle size for 97% passing
g	mass portion of coarse material
$k_{F,97}$	yield of fines
H	height of rotor
n	running speed of rotor
$q_A(d)$	cumulative particle size distribution of feed fraction
$q_g(d)$	cumulative particle size distribution of coarse fraction
r	radius
$T(d)$	Tromb function
v_L	gas flow rate
v_r	radial velocity component
V_u	circumferential velocity component
η_F	dynamic viscosity
ρ_s	density of solid
ξ	index number

Indices:

a	*related to outer edge of vane*
F	*related to fines outlet*
i	*related to inner edge of vane*

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