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SEPARATION OF B_4C POWDER BY AIR CLASSIFICATION

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SEPARATION OF B_4C POWDER BY AIR CLASSIFICATION

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ABSTRACT

Large quantities of bulk powder can be separated according to particle size and density by air classifiers. Classifiers disperse the powder and usually achieve size differentiation by drag and centrifugal forces acting on individual particles in the gas stream. In this report we evaluate a Donaldson "acucut" Classifier for the separation of a B_4C powder. Experimental tests were conducted to determine the particle cut sizes and powder yields obtained by variation of operating parameters. To further assess the classifier's performance, results of the sharpness of the powder cuts were evaluated and compared to vendor's prediction.

INTRODUCTION

The Donaldson "acucut" Classifier (Fig. 1), received in the particle characterization laboratory in June 1975 is designed for uniform dispersion and efficient separation of powders 0.5 to 35 μm in diam into a fine and coarse size fraction. Powder feed rates of up to 9.07 kg/hr (20 lb/hr) are advertised, with sharpness indices of 1.3 to 1.7.¹ Basic components of the acucut include a feeder, blower, classifier, and two collection containers. These and other system components are shown in block-diagram form in Fig. 2. A blower draws the primary air supply through an orifice into the classifier. The blower speed can be varied to obtain typical air flow rates of 0.57 to 2.55 m^3/min . (20-90 cfm). To indicate flow rate, the pressure drop across an inlet orifice is measured in inches of H_2O .

The feeder mechanism can be varied to control the powder flow rate into the airstream of the classifier section. Air at 0.207 MPa (30 psia) is also introduced into the classifier to achieve better dispersal of the particles prior to separation. In the classifier (or rotor) section, the dispersed particles experience an outward centrifugal force and an inward drag force. These forces can be varied by adjusting the rotor speed and air flow. Rotor speed is variable from 500 to 5000 rpm and air flow from 0.57 to 2.55 m^3/min . (20-90 cfm).

The coarse size fraction is ejected from the circumferential airstream of the rotor into the coarse collection container. Concurrently, the particles in the fine fraction spiral inward and exit through a central duct. The fines

Fig. 1. Donaldson "acucut" Classifier Model A.

are captured by a cyclone separator while the main air flow passes through filters and then the blower. The pressure drop across the rotor and fine cyclone collector is measured in inches of mercury. This pressure difference in conjunction with that of the inlet orifice determines the primary air-flow rate.

By choosing the correct air flow and rotor speed, a specific cut-point for the inlet or feed powder can be attained. The cut-point is defined as that particle size that has an equal probability of being separated into either the coarse or fine fraction. In general, lower rotor speeds and higher flow rates cause an increase in the cut point, with the former having the greater influence. Since the classifier separates into two size fractions, a center cut of a feed powder would require two passes through the instrument. At this time, because of limited experience, maintenance problems are still a question. A thorough cleaning of the acucut takes approximately 8 hr.

To operate the acucut, a cut point that will give the desired classification must be determined. To obtain approximate operating conditions for a given cut point and inlet powder, calibration curves provided by Donaldson in Fig. 3 are used. These curves relate the cut-size (or cut point) to rotor speed and air flow and are for a powder having a specific gravity of 2.65 Mg/m^3 . For powders having a different density, the following adjustment is made:

$$D_c = D_x \sqrt{\frac{\rho_x}{\rho_c}} \quad (1)$$

where

$$\begin{aligned} D_c &= \text{calibrated cut point of a powder having density } \rho_c, \\ D_x &= \text{desired cut point for a powder with density } \rho_x, \\ \rho_c &= 2.65 \text{ Mg/m}^3. \end{aligned}$$

The calculated settings are approximate; only experience with the specific powder will yield the actual settings.² Because the particles are separated according to Stoke's diameter, irregular shapes also have an influence on the cut point. For example, materials composed of flake-shaped particles will cause the cut point to increase for a given instrument setting. Initial tests were made on irregularly shaped B_4C particles to represent typical powders received for separation.

Fig. 3. Cut size vs rotor speed.

TEST PROCEDURE

A series of test experiments of the Donaldson acucut were undertaken to determine the most productive operating conditions to achieve a yield and given cut size for B_4C powder. The Donaldson calibration curve (Fig. 3) was used as a guide. Percentage yields and size distributions of the coarse- and fine-powder fractions were determined for most of these experiments. Size distributions by weight were measured with the Mines Safety Appliances (MSA)³ centrifugal sedimentation technique.

The inlet or feed powder used was Ceradyne* B_4C (PO 8551205) having a density of 2.51 Mg/m^3 . This particular powder has a weight median size of $7.6 \text{ }\mu\text{m}$, with 80% of the weight between 3 and $25 \text{ }\mu\text{m}$. The complete weight distribution along with the cumulative distribution as determined by the MSA are shown in Fig. 4, a and b, respectively. Approximately 300 to 400 g of B_4C were used in each test run, with powder flow rates of approximately 1.8 kg/hr .

While rotor speeds varied between 750 and 5000 rpm, a series of various air flow rates at 3000 rpm were also conducted. Each series of tests contained one run at 900 rpm with the same air flow setting to check reproducibility. In Table 1, percentage yields of the powder collected in the coarse and fine fractions are presented along with the weight median diameter for the size distribution of each fraction. The percentage yields are given by

$$Y_c = \frac{w_c}{w_T} \times 100,$$

$$Y_c = \text{yield of coarse powder}, \quad (2)$$

$$w_c = \text{weight of powder collected in coarse fraction},$$

$$w_T = \text{weight of total inlet powder},$$

$$Y_f = \frac{w_f}{w_T} \times 100,$$

$$Y_f = \text{yield of fine powder}, \quad (3)$$

$$w_f = \text{weight of powder collected in fine fraction}.$$

*Ceradyne Inc., 3030 South Red Hill Ave., Santa Ana, CA 92705

Fig. 4. B₄C feed powder distribution: (a) weight distribution;
(b) cumulative weight distribution.

Table 1. Yield and median size of B₄C powder fractions for various operating conditions.

Run	Rpm	Cfm	Air flow, H ₂ O	Classifier, Hg	D ₅₀ fine, μm	D ₅₀ coarse, μm	Fine yield	Coarse yield	Total powder used, g
4	750	70	13.5	3.75	6.8	23	-	-	300
1	900	70	12	3	6.5	16.5	-	-	300
8	900	70	12	3	6.5	18	157 gr 52.5%	142 gr 47.5%	299
12	900	70	12	3	5	15	183.5 gr 45.6%	219 gr 54.4%	402.5
2	1200	70	11.5	3	3.7	16	-	-	300
9	1500	80	13.5	4.5	4.7	12	104.5 gr 26.2%	295 gr 73.8%	399.5
10	2000	90	14.5	5.5	4	9.2	49.5 gr 12.4%	350 gr 87.6%	399.5
11	2500	90	14	6.25	3.8	10	32.5 gr 8%	375 gr 92%	407.5
5	3000	80	11.5	6	2.5	13	3 gr 1%	295 gr 95%	298
6	3000	50	6	4	3.2	9.5	3 gr 1%	283 gr 99%	286
7	3000	60	5.1	3.6	2.4	9.5	3 gr 1%	282 gr 99%	286
13	5000	80	9	9	3	9.1	0.5 gr 0.1%	392 gr 99.9%	392.5

A measurement of the effectiveness of separation is based on the yield of the powder for each fraction given by Leschansk:⁴

$$YE_f = \frac{(w_f)(C_f)}{(w_T)(P_f)}, \quad (4)$$

$$YE_c = \frac{(w_c)C_F}{(w_T)(P_c)},$$

YE_f = fine yield effectiveness,

YE_c = coarse yield effectiveness,

C_f = % collected less than cut size,

C_c = % collected greater than cut size,

P_f = % of parent powder less than cut size,

P_c = % of parent powder greater than cut size.

Since the effective yield is dependent on not only the chosen cut size but also the distribution of the feed powder, these equations compare the actual yield to the maximum possible from the powder being separated. The effectiveness of separation indices are listed in Table 2 where the information allows a requester the prerogative to place emphasis on effectiveness and/or yield.

For each experiment a coarse-grade efficiency curve⁵ as a function of particle size is determined according to the relation

$$N(d) = \frac{100 \text{ (weight of size } d \text{ in coarse fraction)}}{\text{sum of weight of size } d \text{ in coarse and fines}} \quad (5)$$

The 50% point on this grade efficiency curve determines the cut size. A sharpness index is defined as the ratio of the 75% size to the 25% size on the grade-efficiency curve. This quantity is an indication of the exactness with which the powder has been separated into the two fractions. The ideal cut, where no overlap between the fine and coarse fractions exists, would have a sharpness index of 1.0. Although this ideal is unattainable, values

Table 2. Effectiveness of operation indices for operating conditions.

Run	Rpm	Fine yield ($<5 \mu\text{m}$), %	Efficiency, %	Fine yield ($<10 \mu\text{m}$), %	Efficiency, %	Fine yield ($<15 \mu\text{m}$), %	Efficiency, %	Estimated cut-size, μm	Yield, %	Efficiency, %
1	900	50.8	30	72	85	64	99	10	72	85
12	900	70.6	48	69.5	94.5	55.7	99	10	69.5	94.5
9	1500	48.1	57	41.3	98	32.3	99.9	7.5	44.3	88
10	2000	33.2	83	19.6	98	15.3	99.9	6.1	25.7	83
11	2500	20.3	79	12.7	99	9.8	99.9	6	18	85
5	3000	2.7	83	1.5	95	1.2	98	4.7	2.6	77
6	3000	2.7	80	1.6	97	1.3	99.9	4.7	2.6	78
7	3000	2.9	87	1.6	97	1.3	99	4.7	2.8	85
13	5000	0.4	86	0.2	98	0.16	99.9	5	0.3	86

greater than 3 are considered poor. Figure 5 illustrates an example of the coarse- and fine-size distribution for 900 rpm and $1.7 \text{ m}^3/\text{min}$. flow rate (60 cfm). These are compared to the inlet powder distribution as indicated by the dashed curve. Figure 6 is the resulting grade efficiency curve calculated by using Eq. (5) and shows the cut-size and sharpness index for this particular experiment to be $10.5 \text{ }\mu\text{m}$ and 1.6, respectively. Table 3 is a summary of the cut-size and sharpness indices.

DISCUSSION

The ideal powder separation would be 100% yield and 100% efficiency. To achieve this would be almost impossible because of the agglomeration tendencies of this B_4C powder. Agglomerates created by moisture or static electricity are major problems in the operation of most classifiers.

For the B_4C feed powder, the cut size-vs-operating speed characteristic curve is compared with the Donaldson calibration in Fig. 7.

The dominant effect on cut size attainable is the speed of the rotor. Secondary are the effects of flow rate shown by the short lines at 1.133 and $1.98 \text{ m}^3/\text{min}$. (40 and 77 cfm).

In the range 6 to $20 \text{ }\mu\text{m}$, comparison is good. However, below a cut size of $6 \text{ }\mu\text{m}$, dependency of cut size on revolutions per minute is not as pronounced for this B_4C powder as was expected. This is probably due to agglomeration

Table 3. Cut-size and sharpness indices for various operating conditions.

Run	Rotor speed, rpm	D_{50} cut-size, μm	Index of sharpness	Air Flow	
				cfm	m^3/min .
4	750	15	2.3	70	1.982
8	900	10.5	1.61	70	1.982
12	1200	7.5	2.5	70	1.982
9	1500	7.5	2	80	2.266
10	2000	6.1	2.25	90	2.549
11	2500	6	2.21	90	2.549
5	3000	6.5	1.8	80	2.266
13	5000	5	2.1	80	2.266

Fig. 5. Coarse and fine size distributions for 900 rpm and $1.7 \text{ m}^3/\text{min}$.

Fig. 6. Grade efficiency.

Fig. 7. Cut-size versus revolutions-per-minute results compared with expected calibrations.

tendencies of the powder. Such agglomeration can also explain the rather large sharpness indices of 1.6 to 4.0, when compared to those of 1.3 to 1.7 claimed by the manufacturer. Usually, these large sharpness indices arise from many fine particles being collected in the coarse powder fraction. This would occur if small particles formed agglomerates that could not be dispersed by the classifier. With installation of a filter on the air inlet line and replacement of house air with dry bottle gas, we expect to reduce the problem of agglomeration.

CONCLUSION

The coarse fraction contained more fines than is desirable; however, the fine fractions size distribution was very good. A major problem is the loss of fines into the coarse fraction.

We intend to run several other tests, including tests with

- (1) B_4C having a larger particle size.
- (2) A powder having a medium density ($\sim 8 \text{ Mg/m}^3$).
- (3) High density ($\sim 19 \text{ Mg/m}^3$).

Test (1) should eliminate most of the agglomerate problem, which would give us a very sharp cut size. Tests (2) and (3) are expected to give the operating conditions for powders of higher density not given in the manufacturer's guidelines.

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