BATCH CLASSIFICATION OF MIXTURES

PART I: CLASSIFICATION IN A CYLINDRICAL COLUMN

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PARENT et al. [6] and LEVA et al. [3] have reported segregation during their studies on fluidization of materials of wide size range. FLEMING [4], while fluidizing mixture of soda ash and tripoly phosphate of different particle size but almost identical densities, observed segregation. THOMAS et al. [7] fluidized a mixture of ballotini spheres of 60—295 micron size using air as fluidizing medium and observed concentration of fines near the surface of the bed and a lateral concentration gradient between the centre of the fluidized bed and the wall.

MASSIMILLA and BRACALE [5], using wire- mesh discs as baffles in a gas-solid fluidizing column observed smooth fluidization and improved performance. HALL and CRUMLEY [2] reported influence of baffles on segregation and higher percentage of fines at higher levels of the fluidized bed. GOPALKRISHNA and RAO [1] used streamline baffle in their experimental studies and the effect of baffles was to improve segregation.

Experimental setup

The experimental setup used for conducting studies on batch classification of coal and calcite is shown in Fig. 1. It consists of a pyrex glass column of 3.8 cm inside diameter. Holes of 1.2 cm diameter to serve as sample ports at 13.0, 24.5, 36.0 and 47.5 cm heights from the bottom are provided. The column is mounted on a flange which has a recess to hold 85 mesh screen reinforced by a punched brass plate to support the charge. An equalizing section 14 cm long, filled with 0.3 cm crushed quartz is provided. A bag filter at the top of the column is provided to collect fines, if any. Air-flow rate is measured by an orifice meter.

Investigation

The known amount of the charge of specific composition with respect to fines component was introduced into the column and the bag filter placed in position. Air was introduced and its flow regulated. Air flow was set at the

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desired rate. The charge was allowed to fluidize for some time to attain steady state conditions. Samples were drawn from appropriate sampling ports. Samples collected were subjected to sieve analysis and percentage of fines determined.

After the run was over, the material was blown off and collected in filter bag. The feed mixture was subjected to sieve analysis before and after classification, the attrition during classification was found to be insignificant.

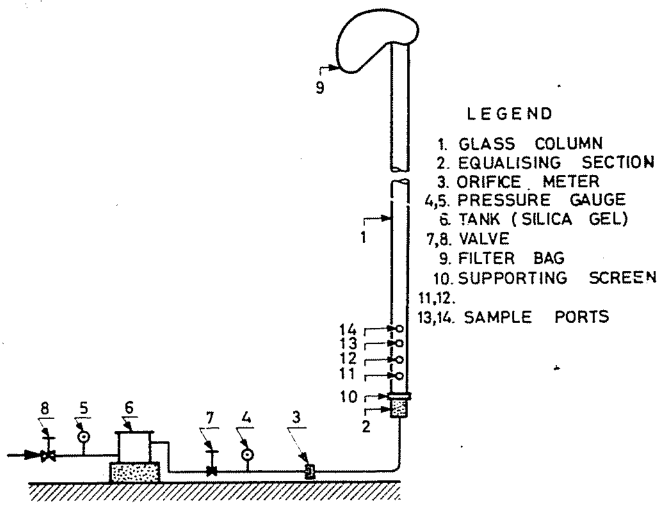

Fig. 1

For each mixture, the experiments were repeated with different heights of free board space to study its effect on classification of mixtures.

The materials used were coal and calcite. The sizes ranged between $-14+18$ and $-20+30$ mesh (BSS). The mixtures consisted of fines component viz. $-18+22$ and $-22+30$. $-14+18$ formed the coarse component. The fines percentage varied from 15.0 to 75.0%. The weight of the charge taken was 100 gm and 150 gm for coal mixture and calcite mixture, respectively. The data obtained are presented in Tables 1 to 3.

To predict the performance of the column, a 'separation factor' defined below is introduced.

$$SF = \frac{\text{Fines component fraction in the sample collected}}{\text{Fines component fraction in the initial charge}}$$

$$= \frac{X}{X_0}$$

The following qualitative observations are made on the behaviour of the system studied:

Table 1

Experimental data

Column diameter: 3.8 cm Height of column: 152.5 cm

Run No	Material	Size of components in charge	Fines in charge %	Air- flow rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
1	Coal	−14+18 & −18+22	15.0	269.3	47.5 13.0	27.2 13.4
2	Coal	−14+18 & −18+22	22.5	269.3	47.5 13.0	30.0 28.3
3	Coal	−14+18 & −18+22	30.0	269.3	47.5	33.5 31.3
4	Coal	−14+18 & −18+22	45.0	269.3	47.5 13.0	50.0 46.2
5	Coal	−14+18 & −18+22	60.0	269.3	47.5 13.0	63.1 53.5
6	Coal	−14+18 & −18+22	75.0	269.3	47.5 13.0	68.7 65.1
7	Coal	−14+18 & −18+22	15.0	253.6	47.5 13.0	24.8 22.1
8	Coal	−14+18 & −18+22	22.5	253.6	47.5 13.0	29.9 30.1
9	Coal	−14+18 & −18+22	30.0	253.6	47.5 13.0	30.4 29.7
10	Coal	−14+18 & −18+22	45.0	253.6	47.5 13.0	46.8 42.5
11	Coal	−14+18 & −18+22	60.0	253.6	47.5 13.0	60.4 53.7
12	Coal	−14+18 & −18+22	75.0	253.6	47.5 13.0	69.5 66.2
13	Coal	−14+18 & −18+22	15.0	232.6	36.0 13.0	20.0 19.0
14	Coal	−14+18 & −18+22	22.5	232.6	36.0 13.0	32.2 24.0
15	Coal	−14+18 & −18+22	30.0	232.6	36.0	36.5 28.7
16	Coal	−14+18 & −18+22	45.0	232.6	36.0 13.0	49.4 45.5
17	Coal	−14+18 & −18+22	60.0	232.6	36.0 13.0	60.7 58.3
18	Coal	−14+18 & −18+22	75.0	232.6	36.0 13.0	72.0 64.8

Table 1 (cont.)

Run No	Material	Size of components in charge	Fines in charge %	Air- flow rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
19	Calcite	−14+18 & −18+22	15.0	269.3	24.5 13.0	19.7 19.5
20	Calcite	−14+18 & −18+22	22.5	269.3	24.5 13.0	23.1 23.7
21	Calcite	−14+18 & −18+22	30.0	269.3	24.5 13.0	29.7 35.5
22	Calcite	−14+18 & −18+22	45.0	269.3	24.5 13.0	44.4 47.9
23	Calcite	−14+18 & −18+22	60.0	269.3	24.5 13.0	55.1 57.6
24	Calcite	−14+18 & −18+22	75.0	269.3	24.5 13.0	74.1 78.7
25	Calcite	−14+18 & −18+22	15.0	253.6	24.5 13.0	17.1 21.2
26	Calcite	−14+18 & −18+22	22.5	253.6	24.5 13.0	21.7 23.0
27	Calcite	−14+18 & −18+22	30.0	253.6	24.5 13.0	29.9 31.4
28	Calcite	−14+18 & −18+22	45.0	253.6	24.5 13.0	36.1 43.6
29	Calcite	−14+18 & −18+22	60.0	253.6	24.5 13.0	53.0 57.1
30	Calcite	−14+18 & −18+22	75.0	253.6	24.5 13.0	68.7 62.0
31	Coal	−14+18 & −22+30	15.0	253.6	47.5 13.0	22.6 20.4
32	Coal	−14+18 & −22+30	22.5	253.6	47.5 13.0	33.1 27.1
33	Coal	−14+18 & −22+30	30.0	253.6	47.5 13.0	44.9 34.4
34	Coal	−14+18 & −22+30	45.0	253.6	47.5 13.0	64.4 44.7
35	Coal	−14+18 & −22+30	60.0	253.6	47.5 13.0	73.4 59.4
36	Coal	−14+18 & −22+30	75.0	253.6	47.5 13.0	79.7 73.5
37	Coal	−14+18 & −22+30	15.0	232.6	36.0 13.0	25.3 22.1

Table 1 (cont.)

Run No	Material	Size of components in charge	Fines in charge %	Air-flow rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
38	Coal	−14+18 & −22+30	22.5	232.6	36.0 13.0	40.6 34.7
39	Coal	−14+18 & −22+30	30.0	232.6	36.0 13.0	44.9 41.9
40	Coal	−14+18 & −22+30	45.0	232.6	36.0 13.0	60.1 57.0
41	Coal	−14+18 & −22+30	60.0	232.6	36.0 13.0	77.9 62.8
42	Coal	−14+18 & −22+30	75.0	232.6	36.0 13.0	84.9 76.4
43	Calcite	−14+18 & −22+30	15.0	269.3	24.5 13.0	20.1 22.3
44	Calcite	−14+18 & −22+30	22.5	269.3	24.5 13.0	32.9 35.8
45	Calcite	−14+18 & −22+30	30.0	269.3	24.5 13.0	39.8 38.4
46	Calcite	−14+18 & −22+30	45.0	269.3	24.5 13.0	53.0 60.0
47	Calcite	−14+18 & −22+30	60.0	269.3	24.5 13.0	69.0 73.5
48	Calcite	−14+18 & −22+30	75.0	269.3	24.5 13.0	78.0 80.6
49	Calcite	−14+18 & −22+30	15.0	253.6	24.5 13.0	21.6 21.8
50	Calcite	−14+18 & −22+30	22.5	253.6	24.5 13.0	29.3 36.8
51	Calcite	−14+18 & −22+30	30.0	253.6	24.5 13.0	36.5 41.5
52	Calcite	−14+18 & −22+30	45.0	253.6	24.5 13.0	55.8 61.4
53	Calcite	−14+18 & −22+30	60.0	253.6	24.5 13.0	67.6 73.0
54	Calcite	−14+18 & −22+30	75.0	253.6	24.5 13.0	73.4 83.6

Table 2

Experimental data

Column diameter: 3.8 cm Height of column: 138.0 cm

Run No	Material	Size of components in charge	Fines in charge %	Air flow rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
55	Coal	−14+18 & −18+22	15.0	232.6	36.0 13.0	23.5 22.0
56	Coal	−14+18 & −18+22	22.5	232.6	36.0 13.0	31.3 32.4
57	Coal	−14+18 & −18+22	30.0	232.6	36.0 13.0	35.5 35.0
58	Coal	−14+18 & −18+22	45.0	232.6	36.0 13.0	46.0 47.4
59	Coal	−14+18 & −18+22	60.0	232.6	36.0 13.0	58.8 60.9
60	Coal	−14+18 & −18+22	75.0	232.6	36.0 13.0	68.5 68.7
61	Calcite	−14+18 & −18+22	15.0	269.3	24.5 13.0	15.7 19.6
62	Calcite	−14+18 & −18+22	22.5	269.3	24.5 13.0	24.8 30.9
63	Calcite	−14+18 & −18+22	30.0	269.3	24.5 13.0	29.6 36.8
64	Calcite	−13+18 & −18+22	45.0	269.3	24.5 13.0	44.3 45.2
65	Calcite	−14+18 & −18+22	60.0	269.3	24.5 13.0	55.6 58.5
66	Calcite	−14+18 & −18+22	75.0	269.3	24.5 13.0	70.6 70.8
67	Coal	−14+18 & −22+30	15.0	232.6	36.0 13.0	22.7 22.1
68	Coal	−14+18 & −22+30	22.5	232.6	36.0 13.0	34.2 30.4
69	Coal	−14+18 & −22+30	30.0	232.6	36.0 13.0	42.8 39.8
70	Coal	−14+18 & −22+30	45.0	232.6	36.0 13.0	54.4 64.8
71	Coal	−14+18 & −22+30	60.0	232.6	36.0 13.0	66.6 61.7
72	Coal	−14+18 & −22+30	75.0	232.6	36.0 13.0	79.4 76.6

Table 2 (cont.)

Run No	Material	Size of components in charge	Fines in charge %	Airf- low rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
73	Calcite	$-14+18$ & $-22+30$	15.0	269.3	24.5 13.0	19.9 23.9
74	Calcite	$-14+18$ & $-22+30$	22.5	269.3	24.5 13.0	29.3 30.0
75	Calcite	$-14+18$ & $-22+30$	30.0	269.3	24.5 13.0	44.6 40.9
76	Calcite	$-14+18$ & $-22+30$	45.0	269.3	24.5 13.0	51.0 56.9
77	Calcite	$-14+18$ & $-22+30$	60.0	269.3	24.5 13.0	69.4 59.4
78	Calcite	$-14+18$ & $-22+30$	75.0	269.3	24.5 13.0	75.8 76.0

a) The percentage of fines obtained at a sample port for a given mixture depends on the bed expansion (or its equivalent ratio of fluid velocity to minimum fluidization velocity).

b) The percentage of fines is higher at higher levels of the bed in case of coal; but in case of calcite the fines percentage is found to be higher at lower levels of the bed for the same air- flow rate.

c) The separation depends upon the ratio of the fines to coarse size. The percentage of fines increases as the ratio of fines to coarse size decreases for the same air-flow rate.

d) The percentage of fines at the top increases together with the percentage in the charge.

e) The separation factor decreases with the percentage of fines in the charge.

f) The separation factor decreases with decrease in air- flow rate for the same percentage of fines in the charge.

From the few runs undertaken with different heights of the column, it is noticed that the height above the bed acts as a 'reflux condenser' and helps improving the separation.

Table 3

Experimental Data

Column diameter: 3.8 cm **Height of column: 123.0 cm**

Run No	Material	Size of components in charge	Fines in charge %	Air- flow rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
79	Coal	−14+18 & −18+22	15.0	232.6	36.0 13.0	23.4 23.9
80	Coal	−14+18 & −18+22	22.5	232.6	36.0 13.0	30.6 32.3
81	Coal	−14+18 & −18+22	30.0	232.6	36.0 13.0	34.6 35.6
82	Coal	−14+18 & −18+22	45.0	232.6	36.0 13.0	46.5 47.9
83	Coal	−14+18 & −18+22	60.0	232.6	36.0 13.0	58.0 62.3
84	Coal	−14+18 & −18 +22	75.0	232.6	36.0 13.0	67.0 66.5
85	Calcite	−14+18 & −18+22	15.0	269.3	24.5 13.0	14.8 16.8
86	Calcite	−14+18 & −18+22	22.5	269.3	24.5 13.0	25.2 31.2
87	Calcite	−14+18 & −18+22	30.0	269.3	24.5 13.0	27.1 35.3
88	Calcite	−14+18 & −18+22	45.0	269.3	24.5 13.0	43.4 47.3
89	Calcite	−14+18 & −18+22	60.0	269.3	24.5 13.0	54.2 65.0
90	Calcite	−14+18 & −18+22	75.0	269.3	24.5 13.0	70.5 71.8
91	Coal	−14+18 & −22+30	15.0	232.6	36.0 13.0	21.4 21.6
92	Coal	−14+18 & −22+30	22.5	232.6	36.0 13.0	32.8 28.6
93	Coal	−14+18 & −22+30	30.0	232.6	36.0 13.0	39.8 34.4
94	Coal	−14+18 & −22+30	45.0	232.6	36.0 13.0	54.2 54.8
95	Coal	−14+18 & −22+30	60.0	232.6	36.0 13.0	65.7 59.4
96	Coal	−14+18 & −22+30	75.0	232.6	36.0 13.0	76.0 75.0

Table 3 (cont.)

Run No	Material	Size of components in charge	Fines in charge %	Air-flow rate cm/sec	Sampling position	Fines %
1	2	3	4	5	6	7
97	Calcite	−14+18 & −22+30	15.0	269.3	24.5 13.0	19.6 25.8
98	Calcite	−14+18 & −22+30	22.5	269.3	24.5 13.0	29.9 32.2
99	Calcite	−14+18 & −22+30	30.0	269.3	24.5 13.0	39.2 41.4
100	Calcite	−14+18 & −22+30	45.0	269.3	24.5 13.0	50.4 52.7
101	Calcite	−14+18 & −22+30	60.0	269.3	24.5 13.0	66.5 61.4
102	Calcite	−14+18 & −22+30	75.0	269.3	24.5 13.0	75.5 75.1

Quantitative observations

Based on experimental data, the following relationship is proposed for coal mixtures, for predicting the amount of fines or separation factor at any height in the fluid bed:

$$X = 0.12\left[\left(\frac{U}{U_{mf}}\right)^{0.7}\left(\frac{l_{f_1}}{l_{f_0}}\right)^{0.35}(x_0)^{0.6}\right]$$

$$SF = 0.12\left[\left(\frac{U}{U_{mf}}\right)^{0.7}\left(\frac{l_{f_1}}{l_{f_0}}\right)^{0.35}(x_0)^{-0.4}\right]$$

The separation factor calculated by the above relationship and the experimental values are presented in Table 4.

Denominations

l_{f_0} height of the bed, cm
l_{f_1} height of the sample port from bottom of the column, cm
U air- flow rate, cm/sec
U_{mf} minimum fluidization velocity, cm/sec
X fines component fraction in the sample collected
X_0 fines component fraction in the initial charge

Table 4

Calculated and experimental values of Separation Factor for coal

Run No	Calculated value of fines component in the fraction collected (X)	Calculated value of separation factor (SF)	Experimental value of separation factor (SF)	Run No	Calculated value of fines component in the fraction collected (X)	Calculated value of separation factor (SF)	Experimental value of separation factor (SF)
1	2	3	4	1	2	3	4
1	0.290 0.183	1.93 1.22	1.81 0.89	16	0.493 0.344	1.10 0.76	1.10 1.01
2	0.373 0.236	1.66 1.05	1.53 1.26	17	0.600 0.418	1.00 0.70	1.01 0.97
3	0.448 0.282	1.49 0.94	1.12 1.04	18	0.705 0.491	0.94 0.66	0.96 0.86
4	0.602 0.381	1.34 0.85	1.11 1.03	31	0.292 0.184	1.94 1.23	1.51 1.36
5	0.733 0.463	1.22 0.77	1.05 0.89	32	0.384 0.243	1.71 1.08	1.92 1.20
6	0.861 0.544	1.15 0.73	0.92 0.87	33	0.474 0.300	1.58 1.00	1.50 1.15
7	0.278 0.176	1.85 1.17	1.65 1.47	34	0.660 0.417	1.47 0.93	1.43 0.99
8	0.358 0.226	1.59 1.06	1.33 1.33	35	0.856 0.541	1.43 0.90	1.22 0.98
9	0.430 0.272	1.43 0.91	1.01 0.99	36	1.077 0.680	1.43 0.90	1.06 0.98
10	0.576 0.365	1.28 0.81	1.04 0.95	37	0.249 0.173	1.66 1.16	1.68 1.47
11	0.703 0.444	1.17 0.74	1.01 0.90	38	0.328 0.220	1.47 0.98	1.81 1.54
12	0.825 0.521	1.10 1.70	0.93 0.88	39	0.405 0.282	1.35 0.94	1.50 1.40
13	0.237 0.165	1.58 1.10	1.33 1.27	40	0.563 0.392	1.25 0.87	1.34 1.27
14	0.306 0.213	1.36 0.95	1.43 1.07	41	0.731 0.509	1.22 0.85	1.30 1.05
15	0.367 0.253	1.22 0.85	1.21 0.96	42	0.895 0.640	1.19 0.85	1.13 1.02

Summary

Systematic investigations on the effect of varying air- flow rate, free board space, fines percentage in the initial charge and cylindrical column versus tapered column on degree of classif icationin batch fluid beds, have received less attention. The available work indicates the degree of classification achieved in some limited ranges of operation; no specific correlations useful for design are reported. The experimental data obtained in the present work and the correlations developed are presented.

References

1. Gopalkrishna, N.—Rao, M. N.: Ind. Chem. Engr. Vol. V, 3. T45—58 (1963)
2. Hall, C. C.—Crumley, P.: J. Appl. Chem. (London) 2, Suppl. Issue, 1, 547—555 (1952)
3. Leva, M.—Weintraub, M.—Pollchik, M.—Storch, H. H.: U. S. Bur. Mines, Bull., 504 (1951)
4. Leva, M.: "Fluidization", McGraw-Hill Book Company Inc., New York, 107 (1959)
5. Massimilla, L.—Bracale, S.: Ricerea Sci., **26,** 487 (1956)
6. Parent, J. D.—Yagol, N.—Steiner, C. S.: Chem. Eng. Progr., **43,** 7, 429 (1947)
7. Thomas, W. J.—Grey, P. J.—Watkins, S. B.: British Chem. Eng., **6,** 3, 176 (1961)

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