

## REFERENCES

- Allen, T. Particle Size Measurement. *Powder Technology Series*. 3rd Edition, New York : Chapman and Hall, 1981 : 156-164.
- Graf, J.C. The importance of resolution limits to the interpretation of fractal descriptions of fine particles. *Powder Technology*. 67 (1991) : 83-85.
- Hasegawa, M., Honma, T. and Kanda, Y. Effect of Mill diameter on the Rate of Initial Grinding in Vibration Ball Mill. *Powder Technology*. 60 (1990) : 259-264.
- Kousaka, Y., Maki, N. and Yoshida, T. *Kokaku Kokaku*. 37 (1973) : 713-718.
- Leonard C.Y. Chan and Neil W. Page. Particle fractal and load effects on internal friction in powders. *Powder Technology*. 90 (1997) : 259-266.
- Mandelbrot, B.B. Fractal form, chance and dimension. W.H. Freeman and Company (1977).
- Oshima, T., Zhang, Y.L., Hirota, M., Suzuki, M. and Nakagawa, T. The effect of the types of mill on the flowability of ground powders. *Advanced Powder Technology*. 6 No.1 (1995) : 35-45.
- Otani, M., Minoshima, H., Uchiyama, T., Shinohara, K., Takayashiki, K. and Ura, T. The effect of particle shape on the mechanical properties of powder bed. *Journal of Society of Powder Technology., Japan*. 32 No.3 (1995) :151-157.
- Otani, M., Uchiyama, T., Arahari, K. and Shinohara, K. The preparation of differently shaped particles by grinding. *Journal of Society of Powder Technology., Japan*. 34 (1997) : 432-436.
- Paramanand, S. and Ramakrishnan, P. Powder Characterization by Particle Shape Assessment. *Kona*. 14 (1996) : 16-30
- P. Meechumna. Crushing and Grinding. *TPTC Training Course 01/1995* : 1-43
- Paramasiva, R. and Vedaraman, R. Effect of fatty acid additives on the material flow properties of dry grinding. *Powder Technology*. 77 (1993) : 69-78.
- Ralph L. Carr, JR. Evaluating flow properties of solids. *Chemical Engineering*. January 18 (1965) : 163-168.

- Ridgway, K. and Rupp, R. The effect of particle shape on powder properties. *Journal of Pharmacy Pharmaceutical*. 21 (1969) : 30S-39S.
- Riley, G.S. and Mann, G.R. Effects of particle shape on angles of repose and bulk densities of a granular solid. *Material Research Bulletin*. 7 (1972) : 163-170.
- Suzuki, M., Muguruma, Y., Hirota, M. and Oshima, T. Fractal dimensions of particle projected shapes. *Advanced Powder Technology*. 1 No.2 (1990) : 115-123.
- Walpole, R. *Introduction to Statistics*. 3rd Edition, New York : 385-395.
- Wen, S.B. and Chen, C.K. Size reduction of magnetite sand to nanometer powder in a laboratory vibration mill. *Powder Technology*. 55 (1988) : 11-17.
- Wills, B.A. Comminution. *Mineral Processing Technology*, 4th Edition, Pergamon Press (1988) : 133-141.

## **APPENDICES**

## APPENDIX A

### Specification of equipment

#### 1.1 Vibration Mill

##### Main Specification

Model	MB-1
Volume	3.4 l X 2 units
Pot standard size	180 X 220 H
Motor	0.75 kW X 6 P
Body weight without medium or pot	160 kg
Standard process volume per batch	0.8 l X 2 units

#### 1.2 Powder Characteristics Tester

##### Main Specification

Electric Supply	AC 100V 50/60 Hz
Accessories	With 26 parts
Electronic Balance	FA-2000
Weight	89 kg

## APPENDIX B

### Experimental data

#### B.1 Particle Size Distribution

##### 1. Grinding time = 15 minutes

Weight ratio between media and feldspar = 3:1

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	4.83	4.85	4.85
45-149	97.0	17.11	17.19	22.04
149-210	179.5	4.47	4.49	26.53
210-297	253.5	6.51	6.54	33.07
297-420	358.5	8.72	8.76	41.83
420-595	507.5	13.32	13.38	55.21
595-841	718.0	19.18	19.27	74.48
841-1190	1015.5	16.25	16.32	90.80
1190-2000	1595.0	9.16	9.20	100.00
Total		99.55	100.00	100.00

Average Size = 386.38 micron  $\sigma = 2.964$

##### 2. Grinding time = 20 minutes

Weight ratio between media and feldspar = 3:1

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	2.31	2.35	2.35
45-149	97.0	22.07	22.41	24.76
149-210	179.5	7.65	7.77	32.53
210-297	253.5	8.26	8.39	40.92
297-420	358.5	10.45	10.61	51.53
420-595	507.5	15.03	15.26	66.79
595-841	718.0	18.05	18.33	85.12
841-1190	1015.5	10.83	11.00	96.12
1190-2000	1595.0	3.82	3.88	100.00
Total		98.47	100.00	100.00

Average Size = 328.29 micron  $\sigma = 2.603$

### 3. Grinding time = 25 minutes

Weight ratio between media and feldspar = 3:1

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	4.95	5.05	5.05
45-149	97.0	25.86	26.36	31.41
149-210	179.5	10.19	10.39	41.80
210-297	253.5	9.26	9.44	51.24
297-420	358.5	11.14	11.36	62.60
420-595	507.5	14.63	14.91	77.51
595-841	718.0	14.94	15.23	92.74
841-1190	1015.5	5.86	5.97	98.71
1190-2000	1595.0	1.27	1.29	100.00
Total		98.10	100.00	100.00

Average Size = 252.64 micron  $\sigma = 2.665$

### 4. Grinding time = 30 minutes

Weight ratio between media and feldspar = 3:1

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	11.77	11.81	11.81
45-149	97.0	32.20	32.33	44.14
149-210	179.5	8.06	8.09	52.23
210-297	253.5	10.65	10.69	62.92
297-420	358.5	12.29	12.34	75.26
420-595	507.5	13.93	13.99	89.25
595-841	718.0	8.98	9.02	98.27
841-1190	1015.5	1.55	1.56	99.83
1190-2000	1595.0	0.17	0.17	100.00
Total		99.60	100.00	100.00

Average Size = 175.81 micron  $\sigma = 2.831$

**5. Grinding time = 20 minutes****Weight ratio between media and feldspar = 4:1**

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	5.80	5.80	5.8
45-149	97.0	35.96	35.97	41.77
149-210	179.5	11.90	11.91	53.68
210-297	253.5	10.69	10.70	64.38
297-420	358.5	12.42	12.43	76.81
420-595	507.5	13.05	13.06	89.87
595-841	718.0	8.17	8.17	98.04
841-1190	1015.5	1.63	1.63	99.67
1190-2000	1595.0	0.33	0.33	100.00
Total		99.95	100.00	100.00

Average Size = 191.66 micron  $\sigma = 2.469$ **6. Grinding time = 20 minutes****Weight ratio between media and feldspar = 5:1**

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	16.58	16.71	16.71
45-149	97.0	41.80	42.13	58.84
149-210	179.5	11.04	11.13	69.97
210-297	253.5	13.73	13.84	83.81
297-420	358.5	11.24	11.33	95.14
420-595	507.5	4.43	4.46	99.60
595-841	718.0	0.38	0.38	99.98
841-1190	1015.5	0.01	0.01	99.99
1190-2000	1595.0	0.01	0.01	100.00
Total		99.22	100.00	100.00

Average Size = 116.98 micron  $\sigma = 2.479$

### 7. Grinding time = 20 minutes

**Weight ratio between media and feldspar = 6:1**

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	19.67	19.75	19.75
45-149	97.0	54.47	54.69	74.44
149-210	179.5	15.26	15.32	89.76
210-297	253.5	8.58	8.61	98.37
297-420	358.5	1.57	1.58	99.95
420-595	507.5	0.05	0.05	100.00
595-841	718.0	0.00	0.00	100.00
841-1190	1015.5	0.00	0.00	100.00
1190-2000	1595.0	0.00	0.00	100.00
<b>Total</b>		99.60	100.00	100.00

Average Size = 88.64 micron  $\sigma = 2.141$

### 8. Grinding time = 15 minutes

**Weight ratio between media and feldspar = 5:1**

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	14.94	14.99	14.99
45-149	97.0	27.12	27.21	42.20
149-210	179.5	8.91	8.94	51.14
210-297	253.5	11.24	11.28	62.42
297-420	358.5	13.10	13.14	75.56
420-595	507.5	13.50	13.54	89.10
595-841	718.0	8.69	8.72	97.82
841-1190	1015.5	1.86	1.87	99.69
1190-2000	1595.0	0.31	0.31	100.00
<b>Total</b>		99.67	100.00	100.00

Average Size = 171.06 micron  $\sigma = 3.002$



**9. Grinding time = 25 minutes****Weight ratio between media and feldspar = 5:1**

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	40.21	40.31	40.31
45-149	97.0	28.62	28.69	69.00
149-210	179.5	22.52	22.58	91.58
210-297	253.5	7.69	7.71	99.29
297-420	358.5	0.70	0.70	100.00
420-595	507.5	0.00	0.00	100.00
595-841	718.0	0.00	0.00	100.00
841-1190	1015.5	0.00	0.00	100.00
1190-2000	1595.0	0.00	0.00	100.00
Total		99.74	100.00	100.00

Average Size = 67.18 micron  $\sigma = 2.575$ **10. Grinding time = 30 minutes****Weight ratio between media and feldspar = 5:1**

Size (micron)	Mean Size (micron)	Weight (g)	Percent Weight (%)	Cumulative Percent Weight (%)
<45	22.5	48.72	49.02	49.02
45-149	97.0	38.60	38.84	87.86
149-210	179.5	9.74	9.80	97.66
210-297	253.5	2.22	2.23	99.90
297-420	358.5	0.10	0.10	100.00
420-595	507.5	0.00	0.00	100.00
595-841	718.0	0.00	0.00	100.00
841-1190	1015.5	0.00	0.00	100.00
1190-2000	1595.0	0.00	0.00	100.00
Total		99.38	100.00	100.00

Average Size = 51.47 micron  $\sigma = 2.316$

## B.2 Effect of the grinding conditions on the powder characteristics

### Run No.:

1.1 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 3:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	48.4	47.3	46.2	47.3
2. Angle of Fall	degree	26.1	25.3	24.6	25.3
3. Angle of Difference	degree				22.0
4. Aerated Bulk Density	g/cu.cm	1.643	1.628	1.648	1.639
5. Packed Bulk Density	g/cu.cm	1.822	1.825	1.821	1.822
6. Compressibility	%				10.0
7. Cohesion	%	92.2	92.2	92.6	92.3
8. Angle of Spatula	degree	55.7	55.9	54.6	55.4
9. Dispersibility	%	8.9	10.5	10.1	9.8

Flow index = 50.50 Degree : Not Good

Flood index = 69.00 Degree : Fairly high

1.2 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	40.5	40.8	40.2	40.5
2. Angle of Fall	degree	19.8	22.3	19.2	20.4
3. Angle of Difference	degree				20.1
4. Aerated Bulk Density	g/cu.cm	1.169	1.162	1.160	1.163
5. Packed Bulk Density	g/cu.cm	1.434	1.429	1.429	1.430
6. Compressibility	%				18.7
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	43.5	44.4	44.1	44.0
9. Dispersibility	%	6.7	7.9	5.9	6.8

Flow index = 78.00 Degree : Good

Flood index = 71.75 Degree : Fairly high

1.3 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	38.3	37.8	37.6	37.9
2. Angle of Fall	degree	17.7	17.9	17.8	17.8
3. Angle of Difference	degree				20.1
4. Aerated Bulk Density	g/cu.cm	1.278	1.281	1.278	1.279
5. Packed Bulk Density	g/cu.cm	1.398	1.401	1.407	1.402
6. Compressibility	%				8.7
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	35.9	36.8	39.8	37.5
9. Dispersibility	%	9.3	10.6	9.5	9.8

Flow index = 86.00 Degree : Fairly high

Flood index = 77.00 Degree : Fairly high

1.4 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	42.4	42.2	40.7	41.7
2. Angle of Fall	degree	22.5	21.6	22.9	22.3
3. Angle of Difference	degree				19.4
4. Aerated Bulk Density	g/cu.cm	1.281	1.278	1.289	1.282
5. Packed Bulk Density	g/cu.cm	1.432	1.434	1.420	1.428
6. Compressibility	%				10.2
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	44.4	42.8	43.2	43.4
9. Dispersibility	%	4	5.6	7.3	5.6

Flow index = 81.50 Degree : Fairly Good

Flood index = 69.50 Degree : Fairly high

**Run No.2**

2.1 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 3:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	46.7	49.4	48.0	48.0
2. Angle of Fall	degree	25.2	25.5	25.7	25.4
3. Angle of Difference	degree				22.6
4. Aerated Bulk Density	g/cu.cm	1.646	1.630	1.643	1.639
5. Packed Bulk Density	g/cu.cm	1.858	1.847	1.856	1.853
6. Compressibility	%				11.5
7. Cohesion	%	92.3	90.5	91.9	91.3
8. Angle of Spatula	degree	54.1	58.5	57.6	56.7
9. Dispersibility	%	9.8	8.7	9.3	9.2

Flow index = 49.00 Degree : Not Good

Flood index = 69.00 Degree : Fairly high

2.2 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.1	40.1	40.0	40.4
2. Angle of Fall	degree	20.6	20.9	22.1	21.2
3. Angle of Difference	degree				19.2
4. Aerated Bulk Density	g/cu.cm	1.176	1.183	1.174	1.178
5. Packed Bulk Density	g/cu.cm	1.451	1.450	1.450	1.450
6. Compressibility	%				18.76
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	45.5	45.1	45.4	45.3
9. Dispersibility	%	6.1	7.2	6.1	6.4

Flow index = 78.00 Degree : Good

Flood index = 70.50 Degree : Fairly high

2.3 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	38.9	38.5	39.0	38.8
2. Angle of Fall	degree	18.8	18.5	17.0	18.1
3. Angle of Difference	degree				20.7
4. Aerated Bulk Density	g/cu.cm	1.288	1.286	1.290	1.288
5. Packed Bulk Density	g/cu.cm	1.420	1.422	1.418	1.420
6. Compressibility	%				9.2
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	39.6	41.7	39.9	40.4
9. Dispersibility	%	14.5	16.4	12.6	14.5

Flow index = 84.00 Degree : Fairly Good

Flood index = 79.00 Degree : Fairly high

2.4 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.7	41.7	42.0	41.8
2. Angle of Fall	degree	21.8	23.2	22.3	22.4
3. Angle of Difference	degree				19.4
4. Aerated Bulk Density	g/cu.cm	1.267	1.302	1.299	1.289
5. Packed Bulk Density	g/cu.cm	1.454	1.451	1.446	1.450
6. Compressibility	%				11.1
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	42.5	44.5	43.5	43.5
9. Dispersibility	%	5.1	5.6	6.9	5.8

Flow index = 81.00 Degree : Fairly Good

Flood index = 69.50 Degree : Fairly high

**Run No.3**

3.1 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 3:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	48.3	48.8	49.2	48.7
2. Angle of Fall	degree	26.0	26.6	26.2	26.2
3. Angle of Difference	degree				22.5
4. Aerated Bulk Density	g/cu.cm	1.612	1.638	1.651	1.633
5. Packed Bulk Density	g/cu.cm	1.881	1.873	1.871	1.875
6. Compressibility	%				12.9
7. Cohesion	%	87.5	89.7	88.6	88.6
8. Angle of Spatula	degree	56.3	58.7	59.2	58.0
9. Dispersibility	%	6.9	7.6	7.0	7.1

Flow index = 49.00 Degree : Good

Flood index = 65.25 Degree : Fairly high

3.2 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.6	40.0	41.0	40.8
2. Angle of Fall	degree	22.2	22.1	21.0	21.7
3. Angle of Difference	degree				19.1
4. Aerated Bulk Density	g/cu.cm	1.180	1.180	1.182	1.181
5. Packed Bulk Density	g/cu.cm	1.453	1.456	1.458	1.456
6. Compressibility	%				18.89
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	45.2	46.4	46.5	46.0
9. Dispersibility	%	6.5	6.1	5.8	6.1

Flow index = 77.00 Degree : Good

Flood index = 69.50 Degree : Fairly high

3.3 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	40.1	40.1	38.0	39.4
2. Angle of Fall	degree	20.2	19.6	19.0	19.6
3. Angle of Difference	degree				19.8
4. Aerated Bulk Density	g/cu.cm	1.297	1.288	1.297	1.294
5. Packed Bulk Density	g/cu.cm	1.456	1.452	1.457	1.455
6. Compressibility	%				11.0
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	41.6	41.8	40.5	41.3
9. Dispersibility	%	8.3	8.4	8.2	8.3

Flow index = 83.00 Degree : Fairly Good

Flood index = 77.00 Degree : Fairly high

3.4 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	42.7	41.5	41.6	41.9
2. Angle of Fall	degree	22.1	22.8	23.1	22.6
3. Angle of Difference	degree				19.3
4. Aerated Bulk Density	g/cu.cm	1.300	1.278	1.281	1.286
5. Packed Bulk Density	g/cu.cm	1.464	1.476	1.484	1.474
6. Compressibility	%				12.7
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	46.5	44.4	43.3	44.7
9. Dispersibility	%	6.2	5.6	6.0	5.9

Flow index = 79.50 Degree : Fairly Good

Flood index = 69.50 Degree : Fairly high

**Run No.4**

4.1 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 3:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	49.3	49.8	49.1	49.4
2. Angle of Fall	degree	27.6	26.5	26.9	27.0
3. Angle of Difference	degree				22.4
4. Aerated Bulk Density	g/cu.cm	1.547	1.596	1.589	1.577
5. Packed Bulk Density	g/cu.cm	1.867	1.878	1.88	1.875
6. Compressibility	%				15.8
7. Cohesion	%	88.3	92.2	93.5	91.3
8. Angle of Spatula	degree	60.8	59.6	58.5	59.6
9. Dispersibility	%	7.1	6.6	7.6	7.1

Flow index = 46.50 Degree : Not Good

Flood index = 60.25 Degree : Fairly high

4.2 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.2	41.5	41.5	41.4
2. Angle of Fall	degree	22.5	22.3	22.9	22.5
3. Angle of Difference	degree				18.9
4. Aerated Bulk Density	g/cu.cm	1.185	1.185	1.182	1.184
5. Packed Bulk Density	g/cu.cm	1.456	1.450	1.457	1.454
6. Compressibility	%				18.57
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	47.1	45.0	46.0	46.0
9. Dispersibility	%	5.3	5.2	5.0	5.1

Flow index = 77.00 Degree : Good

Flood index = 66.50 Degree : Fairly high



4.3 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	38.6	41.4	39.1	39.7
2. Angle of Fall	degree	18.9	20.8	20.3	20.0
3. Angle of Difference	degree				19.7
4. Aerated Bulk Density	g/cu.cm	1.297	1.291	1.294	1.294
5. Packed Bulk Density	g/cu.cm	1.440	1.448	1.444	1.444
6. Compressibility	%				10.3
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	41.6	42.2	40.4	41.4
9. Dispersibility	%	13.3	11.2	15.4	13.3

Flow index = 83.00 Degree : Fairly Good

Flood index = 77.50 Degree : Fairly high

4.4 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 3:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.4	42.4	42.1	41.9
2. Angle of Fall	degree	24.0	23.2	22.5	23.2
3. Angle of Difference	degree				18.7
4. Aerated Bulk Density	g/cu.cm	1.291	1.318	1.282	1.297
5. Packed Bulk Density	g/cu.cm	1.479	1.459	1.468	1.468
6. Compressibility	%				11.6
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	45.9	43.0	45.2	44.7
9. Dispersibility	%	6.0	5.9	5.6	5.8

Flow index = 79.50 Degree : Fairly Good

Flood index = 69.50 Degree : Fairly high

**Run No.5**

5.1 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 4:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	49.1	48.6	48.1	48.6
2. Angle of Fall	degree	27.2	26.2	25.3	26.2
3. Angle of Difference	degree				22.4
4. Aerated Bulk Density	g/cu.cm	1.607	1.592	1.593	1.597
5. Packed Bulk Density	g/cu.cm	1.886	1.883	1.891	1.886
6. Compressibility	%				15.3
7. Cohesion	%	90.7	90.6	91.0	90.7
8. Angle of Spatula	degree	58.5	60.2	58.5	59.0
9. Dispersibility	%	8.3	7.5	8.9	8.2

Flow index = 48.00 Degree : Not Good

Flood index = 65.00 Degree : Fairly high

5.2 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 4:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	39.1	39.0	38.9	39.0
2. Angle of Fall	degree	20.0	20.2	19.0	19.7
3. Angle of Difference	degree				19.3
4. Aerated Bulk Density	g/cu.cm	1.225	1.217	1.220	1.220
5. Packed Bulk Density	g/cu.cm	1.445	1.440	1.448	1.444
6. Compressibility	%				15.50
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	44.4	45.5	43.5	44.4
9. Dispersibility	%	5.9	7.3	8.3	7.1

Flow index = 80.50 Degree : Fairly Good

Flood index = 71.25 Degree : Fairly high

5.3 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 4:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	33.5	35.9	34.0	34.4
2. Angle of Fall	degree	17.6	19.2	18.8	18.5
3. Angle of Difference	degree				15.9
4. Aerated Bulk Density	g/cu.cm	1.302	1.306	1.301	1.303
5. Packed Bulk Density	g/cu.cm	1.423	1.429	1.424	1.425
6. Compressibility	%				8.5
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	39.9	41.0	39.5	40.1
9. Dispersibility	%	11.4	8.6	17.8	12.6

Flow index = 87.00 Degree : Fairly Good

Flood index = 77.00 Degree : Fairly high

5.4 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 4:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.1	40.1	41.0	40.7
2. Angle of Fall	degree	18.2	21.0	19.7	19.6
3. Angle of Difference	degree				21.1
4. Aerated Bulk Density	g/cu.cm	1.320	1.315	1.313	1.316
5. Packed Bulk Density	g/cu.cm	1.456	1.458	1.454	1.456
6. Compressibility	%				9.6
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	41.4	42.3	41.2	41.6
9. Dispersibility	%	7.5	7.0	6.2	6.9

Flow index = 82.50 Degree : Fairly Good

Flood index = 71.75 Degree : Fairly high

**Run No.6**

6.1 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 5:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	48.8	49.3	49.5	49.2
2. Angle of Fall	degree	27.1	25.3	26.3	26.2
3. Angle of Difference	degree				23.0
4. Aerated Bulk Density	g/cu.cm	1.421	1.431	1.428	1.426
5. Packed Bulk Density	g/cu.cm	1.821	1.825	1.816	1.820
6. Compressibility	%				21.6
7. Cohesion	%	93.3	86.7	79.4	86.4
8. Angle of Spatula	degree	63.0	62.3	64.5	63.2
9. Dispersibility	%	32.5	28.4	33.8	31.5

Flow index = 40.00 Degree : Not Good

Flood index = 73.00 Degree : Fairly high

6.2 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	39.5	39	40.2	39.5
2. Angle of Fall	degree	20.2	20.4	20.3	20.3
3. Angle of Difference	degree				19.2
4. Aerated Bulk Density	g/cu.cm	1.191	1.190	1.187	1.189
5. Packed Bulk Density	g/cu.cm	1.454	1.458	1.456	1.456
6. Compressibility	%				18.30
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	45.1	45.1	45.7	45.3
9. Dispersibility	%	6.8	6.9	6.8	6.8

Flow index = 78.00 Degree : Good

Flood index = 71.25 Degree : Fairly high

6.3 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	37.7	38.1	39.1	38.3
2. Angle of Fall	degree	18.5	18.8	19.3	18.8
3. Angle of Difference	degree				19.5
4. Aerated Bulk Density	g/cu.cm	1.289	1.295	1.290	1.291
5. Packed Bulk Density	g/cu.cm	1.445	1.438	1.444	1.442
6. Compressibility	%				10.4
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	40.5	40.8	41.9	41.0
9. Dispersibility	%	7.1	10.0	13.5	10.2

Flow index = 83.50 Degree : Fairly Good

Flood index = 77.00 Degree : Fairly high

6.4 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	41.6	39.8	40.7	40.7
2. Angle of Fall	degree	20.0	20.0	19.9	19.9
3. Angle of Difference	degree				20.8
4. Aerated Bulk Density	g/cu.cm	1.316	1.316	1.319	1.317
5. Packed Bulk Density	g/cu.cm	1.460	1.469	1.458	1.462
6. Compressibility	%				9.9
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	43.6	42.6	42.5	42.9
9. Dispersibility	%	7.3	7.0	7.2	7.1

Flow index = 82.50 Degree : Fairly Good

Flood index = 71.75 Degree : Fairly high

**Run No.7**

7.1 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 6:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	53.2	49.6	50.1	50.9
2. Angle of Fall	degree	27.9	25.5	25.2	26.2
3. Angle of Difference	degree				24.7
4. Aerated Bulk Density	g/cu.cm	1.319	1.318	1.346	1.327
5. Packed Bulk Density	g/cu.cm	1.741	1.735	1.735	1.737
6. Compressibility	%				23.6
7. Cohesion	%	68.2	69.0	66.7	67.9
8. Angle of Spatula	degree	66.1	65.6	65.4	65.7
9. Dispersibility	%	31.9	37.2	43.7	33.4

Flow index = 42.00 Degree : Not Good

Flood index = 74.50 Degree : Fairly high

7.2 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 6:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	40.2	41.9	40.8	40.9
2. Angle of Fall	degree	22.3	23.8	22.5	22.8
3. Angle of Difference	degree				18.1
4. Aerated Bulk Density	g/cu.cm	1.178	1.181	1.178	1.179
5. Packed Bulk Density	g/cu.cm	1.455	1.455	1.463	1.457
6. Compressibility	%				19.0
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	48.4	47.6	46.4	47.4
9. Dispersibility	%	6.5	5.3	5.9	5.9

Flow index = 76.00 Degree : Good

Flood index = 69.00 Degree : Fairly high

7.3 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 6:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	40.0	36.3	38.6	38.3
2. Angle of Fall	degree	19.1	17.1	17.9	18.9
3. Angle of Difference	degree				19.4
4. Aerated Bulk Density	g/cu.cm	1.290	1.275	1.278	1.281
5. Packed Bulk Density	g/cu.cm	1.462	1.462	1.463	1.462
6. Compressibility	%				12.3
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	45.2	44.6	43.7	44.5
9. Dispersibility	%	14.9	14.6	6.3	11.9

Flow index = 81.50 Degree : Fairly Good

Flood index = 78.50 Degree : Fairly high

7.4 Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 6:1

Size of feldspar = 297-420 micron (None)

**Run No.8**

8.1 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 5:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	49.3	48.8	47.7	48.6
2. Angle of Fall	degree	26.1	24.9	26.4	25.8
3. Angle of Difference	degree				22.8
4. Aerated Bulk Density	g/cu.cm	1.592	1.570	1.597	1.586
5. Packed Bulk Density	g/cu.cm	1.877	1.875	1.877	1.876
6. Compressibility	%				15.4
7. Cohesion	%	89.5	88.3	88.9	88.9
8. Angle of Spatula	degree	60.1	57.8	57.7	58.5
9. Dispersibility	%	13.3	8.5	10.8	10.8

Flow index = 48.00 Degree : Fairly Good

Flood index = 70.50 Degree : Fairly high

8.2 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	38.2	37.8	38.8	38.2
2. Angle of Fall	degree	16.8	17.2	16.5	16.8
3. Angle of Difference	degree				21.4
4. Aerated Bulk Density	g/cu.cm	1.276	1.266	1.272	1.271
5. Packed Bulk Density	g/cu.cm	1.439	1.430	1.440	1.436
6. Compressibility	%				11.4
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	43.0	42.4	42.6	42.6
9. Dispersibility	%	11.0	11.3	11.9	11.4

Flow index = 83.00 Degree : Fairly Good

Flood index = 79.00 Degree : Fairly high



8.3 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	37.6	37.0	36.7	37.1
2. Angle of Fall	degree	15.9	15.5	15.0	15.4
3. Angle of Difference	degree				21.7
4. Aerated Bulk Density	g/cu.cm	1.392	1.371	1.377	1.380
5. Packed Bulk Density	g/cu.cm	1.437	1.433	1.430	1.433
6. Compressibility	%				3.6
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	40.6	39.3	39.4	39.7
9. Dispersibility	%	12.0	11.3	11.2	11.5

Flow index = 86.00 Degree : Fairly Good

Flood index = 79.00 Degree : Fairly high

8.4 Condition : Grinding time = 15 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 297-420 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	40.5	39.4	40.7	40.2
2. Angle of Fall	degree	18.4	18.6	18.7	18.5
3. Angle of Difference	degree				21.7
4. Aerated Bulk Density	g/cu.cm	1.312	1.305	1.313	1.310
5. Packed Bulk Density	g/cu.cm	1.457	1.456	1.46	1.457
6. Compressibility	%				10.0
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	41.4	41.3	40.9	41.2
9. Dispersibility	%	7.9	8.6	8.4	8.3

Flow index = 83.00 Degree : Fairly Good

Flood index = 75.00 Degree : Fairly high

**Run No.9**

9.1 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 5:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	50.9	50.3	51.0	50.7
2. Angle of Fall	degree	25.6	27.0	25.8	26.1
3. Angle of Difference	degree				24.6
4. Aerated Bulk Density	g/cu.cm	1.319	1.324	1.324	1.322
5. Packed Bulk Density	g/cu.cm	1.751	1.747	1.747	1.748
6. Compressibility	%				24.3
7. Cohesion	%	69.2	72.2	70.2	70.5
8. Angle of Spatula	degree	63.6	65.9	67.0	65.5
9. Dispersibility	%	51.5	53.1	41.3	48.6

Flow index = 42.00 Degree : Not Good

Flood index = 80.50 Degree : Very high

9.2 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	39.0	38.1	38.4	38.5
2. Angle of Fall	degree	17.6	18.0	17.8	17.8
3. Angle of Difference	degree				20.7
4. Aerated Bulk Density	g/cu.cm	1.271	1.266	1.275	1.270
5. Packed Bulk Density	g/cu.cm	1.461	1.468	1.467	1.465
6. Compressibility	%				13.3
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	44.0	42.8	43.4	43.4
9. Dispersibility	%	8.0	9.1	8.7	8.6

Flow index = 82.00 Degree : Fairly Good

Flood index = 76.50 Degree : Fairly high

9.3 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 210-297 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	37.8	37.3	36.7	37.2
2. Angle of Fall	degree	16.5	16.3	16.3	16.3
3. Angle of Difference	degree				20.9
4. Aerated Bulk Density	g/cu.cm	1.381	1.382	1.380	1.381
5. Packed Bulk Density	g/cu.cm	1.438	1.443	1.448	1.443
6. Compressibility	%				4.2
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	39.1	40.4	40.7	40.0
9. Dispersibility	%	11.0	9.8	10.7	10.5

Flow index = 86.00 Degree : Fairly Good

Flood index = 79.00 Degree : Fairly high

9.4 Condition : Grinding time = 25 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 297-420 micron (None)

**Run No.10**

10.1 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 5:1

Overall product

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	51.3	50.7	53.4	51.8
2. Angle of Fall	degree	27.1	26.4	26.0	26.5
3. Angle of Difference	degree				25.3
4. Aerated Bulk Density	g/cu.cm	1.211	1.237	1.240	1.229
5. Packed Bulk Density	g/cu.cm	1.690	1.696	1.696	1.694
6. Compressibility	%				27.4
7. Cohesion	%	65.0	66.4	66.1	65.8
8. Angle of Spatula	degree	66.4	64.9	67.3	66.2
9. Dispersibility	%	59.8	46.0	51.2	52.3

Flow index = 38.00 Degree : Bad

Flood index = 78.50 Degree : Fairly high

10.2 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 149-210 micron

Powder Characteristics	Unit	1	2	3	Average
1. Angle of Repose	degree	39.3	38.7	39.1	39.0
2. Angle of Fall	degree	19.1	18.6	18.3	18.6
3. Angle of Difference	degree				20.4
4. Aerated Bulk Density	g/cu.cm	1.272	1.272	1.267	1.270
5. Packed Bulk Density	g/cu.cm	1.466	1.465	1.482	1.471
6. Compressibility	%				13.6
7. Uniformity	-	1	1	1	1
8. Angle of Spatula	degree	45.3	42.7	44.2	44.0
9. Dispersibility	%	7.0	7.4	8.7	7.7

Flow index = 82.00 Degree : Fairly Good

Flood index = 75.00 Degree : Fairly high

10.3 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 210-297 micron (None)

10.4 Condition : Grinding time = 30 min

Weight ratio between media and feldspar = 5:1

Size of feldspar = 297-420 micron (None)

### B.3 Effect of the grinding conditions on the particle shape

**Run No.1** : Grinding time = 15 min, Weight ratio between media and feldspar =3:1

#### 1.1 Size 149-210 micron

No.	Fractal dimension (D)
1	1.077
2	1.064
3	1.070
4	1.067
5	1.050
6	1.048
7	1.079
8	1.045
9	1.057
10	1.088

No.	Fractal dimension (D)
11	1.037
12	1.040
13	1.031
14	1.015
15	1.066
16	1.094
17	1.076
18	1.075
19	1.102
20	1.068

#### 1.2 Size 210-297 micron

No.	Fractal dimension (D)
1	1.061
2	1.079
3	1.086
4	1.058
5	1.085
6	1.060
7	1.045
8	1.078
9	1.072
10	1.089

No.	Fractal dimension (D)
11	1.053
12	1.027
13	1.063
14	1.049
15	1.072
16	1.069
17	1.044
18	1.054
19	1.041
20	1.092

### 1.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.026
2	1.036
3	1.014
4	1.041
5	1.022
6	1.025
7	1.067
8	1.039
9	1.041
10	1.046

No.	Fractal dimension (D)
11	1.027
12	1.021
13	1.066
14	1.049
15	1.063
16	1.078
17	1.059
18	1.060
19	1.071
20	1.037

**Run No.2 : Grinding time = 20 min, Weight ratio between media and feldspar =3:1**

### 2.1 Size 149-210 micron

No.	Fractal dimension (D)
1	1.042
2	1.070
3	1.074
4	1.057
5	1.061
6	1.030
7	1.027
8	1.043
9	1.034
10	1.010

No.	Fractal dimension (D)
11	1.061
12	1.069
13	1.044
14	1.051
15	1.077
16	1.036
17	1.059
18	1.094
19	1.051
20	1.080

### 2.2 Size 210-297 micron

No.	Fractal dimension (D)
1	1.075
2	1.062
3	1.084
4	1.073
5	1.052
6	1.057
7	1.061
8	1.059
9	1.080
10	1.063

No.	Fractal dimension (D)
11	1.093
12	1.075
13	1.068
14	1.067
15	1.069
16	1.070
17	1.068
18	1.066
19	1.075
20	1.062

### 2.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.042
2	1.049
3	1.039
4	1.057
5	1.029
6	1.063
7	1.039
8	1.030
9	1.053
10	1.044

No.	Fractal dimension (D)
11	1.026
12	1.030
13	1.021
14	1.041
15	1.036
16	1.061
17	1.045
18	1.083
19	1.032
20	1.052



**Run No.3 : Grinding time = 25 min, Weight ratio between media and feldspar =3:1**

**3.1 Size 149-210 micron**

No.	Fractal dimension (D)
1	1.050
2	1.021
3	1.040
4	1.037
5	1.080
6	1.052
7	1.029
8	1.055
9	1.074
10	1.049

No.	Fractal dimension (D)
11	1.057
12	1.058
13	1.045
14	1.031
15	1.060
16	1.078
17	1.054
18	1.086
19	1.071
20	1.067

**3.2 Size 210-297 micron**

No.	Fractal dimension (D)
1	1.056
2	1.053
3	1.054
4	1.049
5	1.069
6	1.086
7	1.061
8	1.080
9	1.103
10	1.072

No.	Fractal dimension (D)
11	1.073
12	1.068
13	1.066
14	1.077
15	1.076
16	1.081
17	1.073
18	1.073
19	1.070
20	1.084

### 3.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.050
2	1.075
3	1.021
4	1.073
5	1.042
6	1.032
7	1.074
8	1.048
9	1.046
10	1.060

No.	Fractal dimension (D)
11	1.049
12	1.040
13	1.061
14	1.046
15	1.035
16	1.043
17	1.073
18	1.060
19	1.029
20	1.039

**Run No.4 : Grinding time = 30 min, Weight ratio between media and feldspar =3:1**

### 4.1 Size 149-210 micron

No.	Fractal dimension (D)
1	1.082
2	1.074
3	1.053
4	1.017
5	1.047
6	1.109
7	1.034
8	1.052
9	1.070
10	1.041

No.	Fractal dimension (D)
11	1.056
12	1.045
13	1.085
14	1.040
15	1.070
16	1.067
17	1.075
18	1.096
19	1.080
20	1.091

#### 4.2 Size 210-297 micron

No.	Fractal dimension (D)
1	1.068
2	1.076
3	1.051
4	1.064
5	1.081
6	1.081
7	1.055
8	1.085
9	1.087
10	1.073

No.	Fractal dimension (D)
11	1.065
12	1.066
13	1.047
14	1.100
15	1.088
16	1.071
17	1.083
18	1.085
19	1.108
20	1.090

#### 4.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.054
2	1.047
3	1.050
4	1.039
5	1.050
6	1.033
7	1.043
8	1.062
9	1.037
10	1.054

No.	Fractal dimension (D)
11	1.059
12	1.045
13	1.046
14	1.016
15	1.072
16	1.061
17	1.080
18	1.063
19	1.065
20	1.050

**Run No.5 : Grinding time = 20 min, Weight ratio between media and feldspar =4:1**

**5.1 Size 149-210 micron**

No.	Fractal dimension (D)
1	1.053
2	1.052
3	1.038
4	1.047
5	1.042
6	1.042
7	1.035
8	1.052
9	1.084
10	1.060

No.	Fractal dimension (D)
11	1.024
12	1.041
13	1.064
14	1.030
15	1.041
16	1.037
17	1.059
18	1.068
19	1.061
20	1.060

**5.2 Size 210-297 micron**

No.	Fractal dimension (D)
1	1.076
2	1.073
3	1.066
4	1.071
5	1.025
6	1.047
7	1.026
8	1.060
9	1.016
10	1.071

No.	Fractal dimension (D)
11	1.045
12	1.057
13	1.053
14	1.069
15	1.048
16	1.065
17	1.046
18	1.047
19	1.029
20	1.040

### 5.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.019
2	1.062
3	1.052
4	1.029
5	1.053
6	1.036
7	1.028
8	1.051
9	1.025
10	1.011

No.	Fractal dimension (D)
11	1.032
12	1.036
13	1.016
14	1.012
15	1.063
16	1.025
17	1.044
18	1.029
19	1.057
20	1.054

**Run No.6 : Grinding time = 20 min, Weight ratio between media and feldspar =5:1**

### 6.1 Size 149-210 micron

No.	Fractal dimension (D)
1	1.065
2	1.034
3	1.025
4	1.052
5	1.065
6	1.017
7	1.048
8	1.042
9	1.071
10	1.071

No.	Fractal dimension (D)
11	1.071
12	1.056
13	1.072
14	1.040
15	1.050
16	1.064
17	1.053
18	1.030
19	1.024
20	1.044

### 6.2 Size 210-297 micron

No.	Fractal dimension (D)
1	1.0487
2	1.046
3	1.0727
4	1.0814
5	1.0449
6	1.044
7	1.0472
8	1.0145
9	1.0257
10	1.0484

No.	Fractal dimension (D)
11	1.033
12	1.061
13	1.049
14	1.054
15	1.047
16	1.036
17	1.047
18	1.036
19	1.054
20	1.064

### 6.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.065
2	1.038
3	1.046
4	1.077
5	1.023
6	1.019
7	1.049
8	1.060
9	1.059
10	1.042

No.	Fractal dimension (D)
11	1.025
12	1.025
13	1.043
14	1.052
15	1.037
16	1.044
17	1.039
18	1.038
19	1.046
20	1.023

**Run No.7 : Grinding time = 20 min, Weight ratio between media and feldspar =6:1**

**7.1 Size 149-210 micron**

No.	Fractal dimension (D)
1	1.044
2	1.061
3	1.050
4	1.001
5	1.057
6	1.055
7	1.065
8	1.075
9	1.046
10	1.046

No.	Fractal dimension (D)
11	1.029
12	1.062
13	1.071
14	1.053
15	1.051
16	1.087
17	1.083
18	1.025
19	1.049
20	1.070

**7.2 Size 210-297 micron**

No.	Fractal dimension (D)
1	1.066
2	1.051
3	1.030
4	1.074
5	1.055
6	1.056
7	1.048
8	1.073
9	1.041
10	1.047

No.	Fractal dimension (D)
11	1.049
12	1.037
13	1.029
14	1.045
15	1.048
16	1.045
17	1.044
18	1.077
19	1.070
20	1.058

### 7.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.053
2	1.031
3	1.052
4	1.073
5	1.070
6	1.072
7	1.025
8	1.082
9	1.036
10	1.054

No.	Fractal dimension (D)
11	1.030
12	1.049
13	1.055
14	1.040
15	1.047
16	1.069
17	1.042
18	1.071
19	1.054
20	1.066

**Run No.8** : Grinding time = 15 min, Weight ratio between media and feldspar =5:1

### 8.1 Size 149-210 micron

No.	Fractal dimension (D)
1	1.031
2	1.066
3	1.034
4	1.048
5	1.057
6	1.039
7	1.037
8	1.066
9	1.047
10	1.042

No.	Fractal dimension (D)
11	1.060
12	1.050
13	1.047
14	1.061
15	1.030
16	1.056
17	1.054
18	1.051
19	1.041
20	1.027



### 8.2 Size 210-297 micron

No.	Fractal dimension (D)
1	1.045
2	1.043
3	1.049
4	1.050
5	1.053
6	1.045
7	1.056
8	1.044
9	1.046
10	1.049

No.	Fractal dimension (D)
11	1.058
12	1.048
13	1.040
14	1.074
15	1.029
16	1.051
17	1.056
18	1.038
19	1.068
20	1.071

### 8.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.022
2	1.052
3	1.036
4	1.024
5	1.039
6	1.057
7	1.048
8	1.043
9	1.043
10	1.052

No.	Fractal dimension (D)
11	1.036
12	1.027
13	1.004
14	1.027
15	1.017
16	1.026
17	1.033
18	1.048
19	1.027
20	1.039

**Run No.9 : Grinding time = 25 min,Weight ratio between media and feldspar =5:1**

**9.1 Size 149-210 micron**

No.	Fractal dimension (D)
1	1.055
2	1.056
3	1.050
4	1.050
5	1.076
6	1.083
7	1.063
8	1.037
9	1.049
10	1.068

No.	Fractal dimension (D)
11	1.049
12	1.025
13	1.076
14	1.043
15	1.025
16	1.036
17	1.026
18	1.071
19	1.058
20	1.086

**9.2 Size 210-297 micron**

No.	Fractal dimension (D)
1	1.058
2	1.034
3	1.054
4	1.023
5	1.024
6	1.070
7	1.046
8	1.076
9	1.042
10	1.039

No.	Fractal dimension (D)
11	1.035
12	1.056
13	1.023
14	1.041
15	1.066
16	1.050
17	1.046
18	1.074
19	1.079
20	1.076

### 9.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.042
2	1.053
3	1.074
4	1.058
5	1.034
6	1.079
7	1.046
8	1.055
9	1.050
10	1.044

No.	Fractal dimension (D)
11	1.062
12	1.064
13	1.054
14	1.061
15	1.060
16	1.061
17	1.047
18	1.069
19	1.031
20	1.046

**Run No.10 : Grinding time = 30 min,Weight ratio between media and feldspar =5:1**

### 10.1 Size 149-210 micron

No.	Fractal dimension (D)
1	1.040
2	1.043
3	1.039
4	1.039
5	1.062
6	1.047
7	1.053
8	1.050
9	1.041
10	1.030

No.	Fractal dimension (D)
11	1.043
12	1.022
13	1.025
14	1.047
15	1.044
16	1.039
17	1.050
18	1.031
19	1.053
20	1.044

### 10.2 Size 210-297 micron

No.	Fractal dimension (D)
1	1.048
2	1.062
3	1.045
4	1.039
5	1.042
6	1.048
7	1.053
8	1.045
9	1.073
10	1.042

No.	Fractal dimension (D)
11	1.053
12	1.059
13	1.057
14	1.054
15	1.047
16	1.055
17	1.032
18	1.064
19	1.038
20	1.061

### 10.3 Size 297-420 micron

No.	Fractal dimension (D)
1	1.023
2	1.023
3	1.047
4	1.056
5	1.058
6	1.056
7	1.057
8	1.055
9	1.054
10	1.041

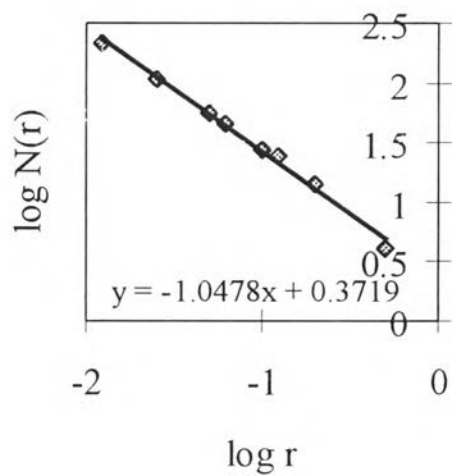
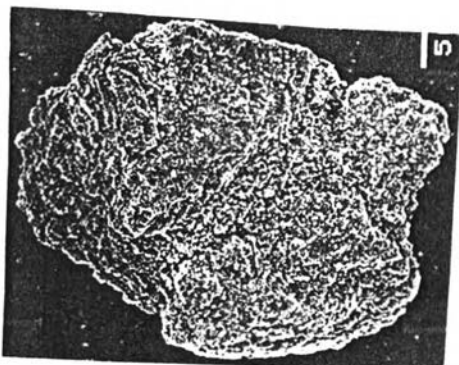
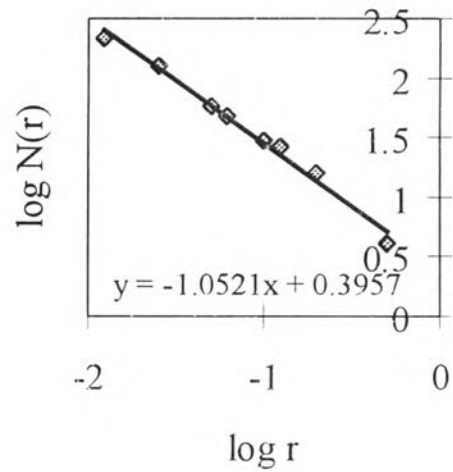
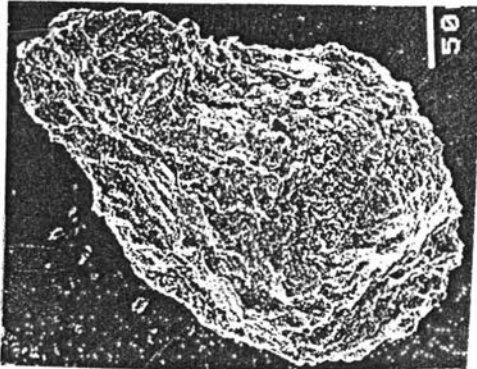
No.	Fractal dimension (D)
11	1.043
12	1.036
13	1.065
14	1.026
15	1.020
16	1.072
17	1.014
18	1.048
19	1.028
20	1.052

### Example of Particle shape

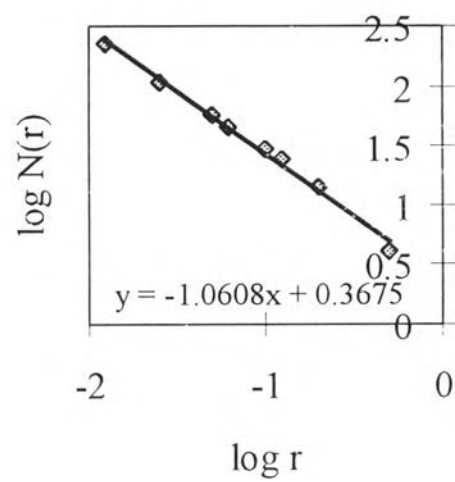
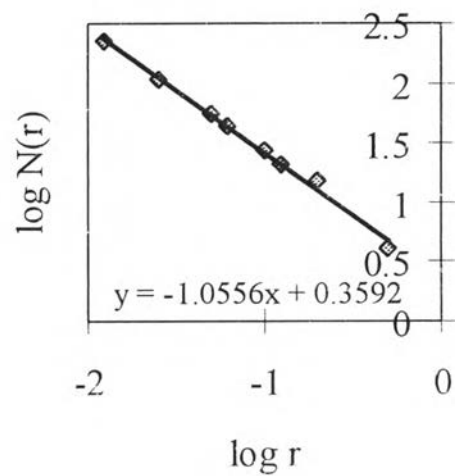
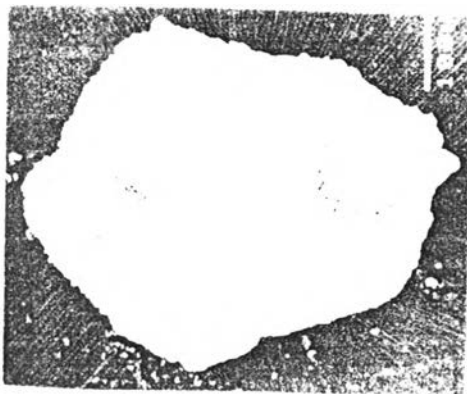
Condition : Grinding time = 20 min

Weight ratio between media and feldspar = 5:1

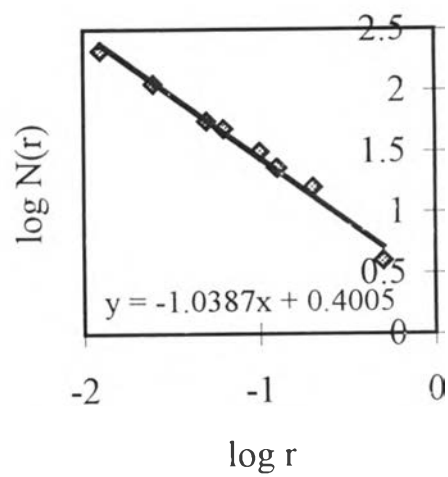
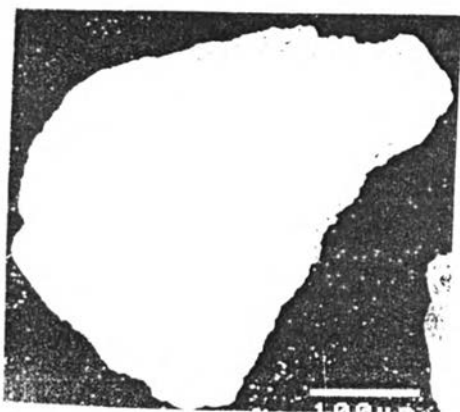
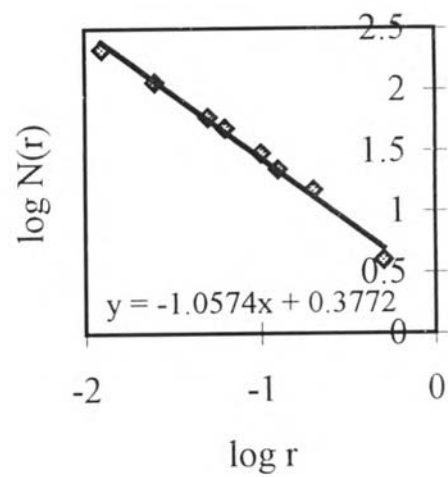
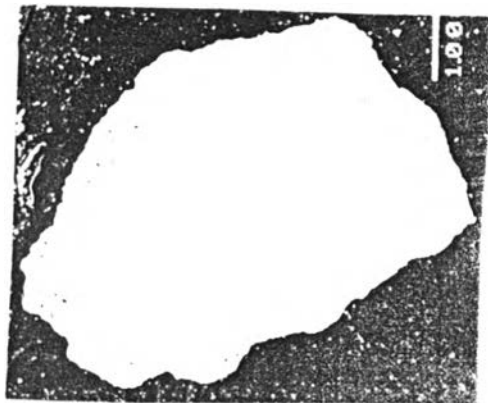
Size of ground feldspar = 149-210 micron



Condition : Grinding time = 25 min  
 Weight ratio between media and feldspar = 3:1  
 Size of ground feldspar = 210-297 micron



Condition : Grinding time = 20 min  
 Weight ratio between media and feldspar = 3:1  
 Size of ground feldspar = 297-420 micron



## APPENDIX C

### Example of the analysis of variance of particle shape

**Example 1.** Analysis of variance of data between two population of fractal dimension obtained from two different milling conditions is employed to test the hypothesis whether both population have different average fractal dimension value at the 0.1 level of significance.

Case 1. Grinding time = 20 minutes, weight ratio between media and feldspar = 3:1

Fractal dimension of ground product in sizes range 297-420 micron are shown in this table

1.042	1.049	1.039	1.057	1.029	1.063	1.039	1.030	1.053	1.044
1.026	1.030	1.021	1.041	1.036	1.061	1.045	1.083	1.032	1.052

Case 2. Grinding time = 25 minutes, weight ratio between media and feldspar = 5:1

Fractal dimension of ground product in sizes range 297-420 micron are shown in this table

1.042	1.053	1.074	1.058	1.034	1.079	1.046	1.055	1.050	1.044
1.062	1.064	1.054	1.061	1.060	1.061	1.047	1.069	1.031	1.046

Hypothesis 0 :  $D_1 = D_2$

Hypothesis 1 :  $D_1 \neq D_2$

Critical region :  $F [ \alpha = 0.1, 38 ] > 2.848$

$n_1 = 20$  ,  $n_2 = 20$

$$SST = \sum_i \sum_j X_{ij}^2 - \frac{T^2}{\sum_i n_i}$$



$$\begin{aligned}
&= \frac{[(1.042)^2 + (1.049)^2 + \dots + (1.031)^2 + (1.046)] - (1.042 + 1.049 + \dots + 1.031 + 1.046)^2}{40} \\
&= 44.028 - 44.020 \\
&= 0.008
\end{aligned}$$

and

$$\begin{aligned}
SSC &= \sum_i \frac{T_i^2}{n_i} - \frac{T^2}{\sum_i n_i} \\
&= \frac{(20.872)^2}{20} + \frac{(21.090)^2}{20} - 44.020 \\
&= 0.001
\end{aligned}$$

Therefore

$$\begin{aligned}
SSE &= SST - SSC \\
&= 0.008 - 0.001 \\
&= 0.007
\end{aligned}$$

Taking the result put in a table for analysis of variance

Source of variance	Sum of square	Degrees of Freedom	Mean Square	Computed F
Column means	0.001	1	0.0012	6.292
Error	0.007	38	0.0002	
Total	0.008	39		

According to calculating results shown in the above table, we must reject the first hypothesis (Hypothesis 0) and conclude that the mean of fractal dimension of ground product from these conditions is not the same.

**Example 2.** Analysis of variance of data between two population of fractal dimension obtained from two different milling conditions is employed to test the hypothesis whether both population have different average fractal dimension value at the 0.1 level

Case 1. Grinding time = 15 minutes, weight ratio between media and feldspar = 3:1

Fractal dimension of ground product in sizes range 210-297 micron are shown in this table

1.061	1.079	1.086	1.058	1.085	1.060	1.045	1.078	1.072	1.089
1.053	1.027	1.063	1.049	1.072	1.069	1.044	1.054	1.041	1.092

Case 2. Grinding time = 25 minutes, weight ratio between media and feldspar = 3:1

Fractal dimension of ground product in sizes range 210-297 micron are shown in this table

1.056	1.053	1.054	1.049	1.069	1.086	1.061	1.080	1.103	1.072
1.073	1.068	1.066	1.077	1.076	1.081	1.073	1.073	1.070	1.084

Hypothesis 0 :  $D_1 = D_2$

Hypothesis 1 :  $D_1 \neq D_2$

Critical region :  $F [ \alpha = 0.1, 38 ] > 2.848$

$n_1 = 20, n_2 = 20$

$$\begin{aligned}
 SST &= \sum_i \sum_j x_{ij}^2 - \frac{T^2}{\sum_i n_i} \\
 &= [(1.061)^2 + (1.079)^2 + \dots + (1.070)^2 + (1.084)^2] - \\
 &\quad \frac{(1.061 + 1.079 + \dots + 1.070 + 1.084)^2}{40} \\
 &= 45.594 - 45.584 \\
 &= 0.010
 \end{aligned}$$

$$\begin{aligned}
 \text{and} \quad \text{SSC} &= \sum_i \frac{T_i^2}{n_i} - \frac{T^2}{\sum_i n_i} \\
 &= \frac{(22.636)^2}{20} + \frac{(22.949)^2}{20} - 45.584 \\
 &= 0.001
 \end{aligned}$$

$$\begin{aligned}
 \text{Therefore} \quad \text{SSE} &= \text{SST} - \text{SSC} \\
 &= 0.010 - 0.001 \\
 &= 0.009
 \end{aligned}$$

Taking the result put in a table for analysis of variance

Source of variance	Sum of square	Degrees of Freedom	Mean Square	Computed F
Column means	0.001	1	0.0005	2.229
Error	0.009	38	0.0002	
Total	0.010	39		

According to calculating results shown in the above table, we must reject the second hypothesis (Hypothesis 1) and conclude that the mean of fractal dimension of ground product from these conditions is the same.

**APPENDIX D****Grinding Conditions**

- D(1) : Fractal diemson of ground feldpar in the case of grinding time = 15 minutes,  
Weight ratio between media and feldspar = 3:1
- D(2) : Fractal diemson of ground feldpar in the case of grinding time = 20 minutes,  
Weight ratio between media and feldspar = 3:1
- D(3) : Fractal diemson of ground feldpar in the case of grinding time = 25 minutes,  
Weight ratio between media and feldspar = 3:1
- D(4) : Fractal diemson of ground feldpar in the case of grinding time = 30 minutes,  
Weight ratio between media and feldspar = 3:1
- D(5) : Fractal diemson of ground feldpar in the case of grinding time = 20 minutes,  
Weight ratio between media and feldspar = 4:1
- D(6) : Fractal diemson of ground feldpar in the case of grinding time = 20 minutes,  
Weight ratio between media and feldspar = 5:1
- D(7) : Fractal diemson of ground feldpar in the case of grinding time = 20 minutes,  
Weight ratio between media and feldspar = 6:1
- D(8) : Fractal diemson of ground feldpar in the case of grinding time = 15 minutes,  
Weight ratio between media and feldspar = 5:1
- D(9) : Fractal diemson of ground feldpar in the case of grinding time = 25 minutes,  
Weight ratio between media and feldspar = 5:1
- D(10) : Fractal diemson of ground feldpar in the case of grinding time = 30 minutes,  
Weight ratio between media and feldspar = 5:1

## VITA

Mr. Supakij Samuthpongthorn was born on September 22,1971, in Bangkok, Thailand. He has graduated from Watsuthiwararam School in 1990. He received his Bachelor Degree of Science from Department of Chemical Technology, Faculty of Science, Chulalongkorn University in 1994. After that he worked at Union Carbide (Thailand) Company Limited for 1 year. Then he was studying for Master Degree of Engineering at Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University since 1995.

