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Experiment Number (4)

Mixing of Powders

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Abstract

In this experiment the effect of mixing time and the particle size distribution of ingredients on the state of mixing were investigated. The double-cone mixer is used to simulate the mixing process in this study, on a mixture of granules of silica sand and potassium chloride salt. A constant tumbling speed was performed on the process. The equilibrium standard deviation for complete mixing over standard deviation was founded along the variation of time applied in three different locations in each period (top, middle, bottom), analyzed by titration method. As expected, the increase of mixing time leads to an incremental of degree of mixing up to optimum level. However, uncertainty in proceeding the experiment and other sources leads to multi optimum homogeneity at t =5 min, t=30. also, at t = 60.

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Table (1): Parameters of salt and sand.

Particle size of KCl salt	(µm)	350-500
Particle size of silica sand	(µm)	850-1400
Average size of silica sand	(µm)	1125
Average size of salt	(µm)	425
Weight of sand	(g)	271.69
Weight of KCl salt	(g)	248.8
Density of KCl	(g/cm³)	1.984
Density of sand	(g/cm³)	1.602
Volume of KCl salt	(cm³)	4.019E-05
Volume of sand	(cm³)	7.455E-04
Mass of salt particle	(g)	7.975E-05
Mass of sand particle	(g)	1.976E-03
Total Number of sand particle		1.375E+05
Total Number of salt particle		3.120E+06
overall fraction of sand		4.222E-02
overall fraction of salt		9.578E-01

Table (2): Results at time=5 minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.1	6.6	6.60E-04	0.0492	0.0508	0.4920	0.5080	0.5974	0.0080
Middle	0.25	9	9.00E-04	0.0671	0.1829	0.2684	0.7316		0.0180
Bottom	0.1	6	6.00E-04	0.0447	0.0553	0.4473	0.5527		0.0020

Table (3): Results at time=10 minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.11	4.3	4.30E-04	0.0321	0.0779	0.2914	0.7086	0.8277	0.0142
Middle	0.11	0.3	3.00E-05	0.0022	0.1078	0.0203	0.9797		0.0231
Bottom	0.12	3.3	3.30E-04	0.0246	0.0954	0.2050	0.7950		0.0011

Table (4): Results at time=15 minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.1	3.3	3.30E-04	0.0246	0.0754	0.2460	0.7540	0.7729	0.0004
Middle	0.12	5.9	5.90E-04	0.0440	0.0760	0.3665	0.6335		0.0194
Bottom	0.13	1.2	1.20E-04	0.0089	0.1211	0.0688	0.9312		0.0251

Table (5): Results at time=20 minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.11	6.4	6.40E-04	0.0477	0.0623	0.4337	0.5663	0.6645	0.0096
Middle	0.15	7.9	7.90E-04	0.0589	0.0911	0.3926	0.6074		0.0033
Bottom	0.12	2.9	2.90E-04	0.0216	0.0984	0.1802	0.8198		0.0241

Table (6): Results at time=30 minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.11	1.7	1.70E-04	0.0127	0.0973	0.1152	0.8848	0.7980	0.0075
Middle	0.11	4.6	4.60E-04	0.0343	0.0757	0.3118	0.6882		0.0121
Bottom	0.1	2.4	2.40E-04	0.0179	0.0821	0.1789	0.8211		0.0005

Table (7): Results at time=45minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.1	0.4	4.00E-05	0.0030	0.0970	0.0298	0.9702	0.8100	0.0257
Middle	0.1	2.7	2.70E-04	0.0201	0.0799	0.2013	0.7987		0.0001
Bottom	0.11	5	5.00E-04	0.0373	0.0727	0.3389	0.6611		0.0222

Table (8): Results at time=60 minutes.

Location of spot	Sample weight (g)	Volume of $AgNO_3$ (ml)	Moles of $AgNO_3$	Salt mass (g)	Sand mass (g)	X_{salt}	X_{sand}	ΣX_{sand}	$(x-x_{avg})^2$
Top	0.12	4.4	4.40E-04	0.0328	0.0872	0.2734	0.7267	0.5949	0.0173
Middle	0.12	7.6	7.60E-04	0.0567	0.0633	0.4722	0.5279		0.0045
Bottom	0.1	6.3	6.30E-04	0.0470	0.0530	0.4697	0.5303		0.0042

Table (9): Results of mixing index during mixing.

At t=		5 min	10 min	15 min	20 min	30 min	45 min	60 min
Number of sand particle during mixing	Top	42.5323	65.2621	63.1312	52.1538	81.4915	81.2332	73.0109
	Middle	153.1464	90.2304	63.6478	76.2827	63.3895	66.8764	53.0363
	Bottom	46.2776	79.8772	101.3586	82.3740	68.7491	60.8927	44.4050
Number of salt particle during mixing	Top	616.9991	401.9842	308.4995	598.3021	158.9240	37.3939	411.3327
	Middle	841.3624	28.0454	551.5598	738.5292	430.0296	252.4087	710.4838
	Bottom	560.9082	308.4995	112.1816	271.1056	224.3633	467.4235	588.9536
index		0.1367	0.1185	0.1113	0.1274	0.1717	0.1124	0.1690

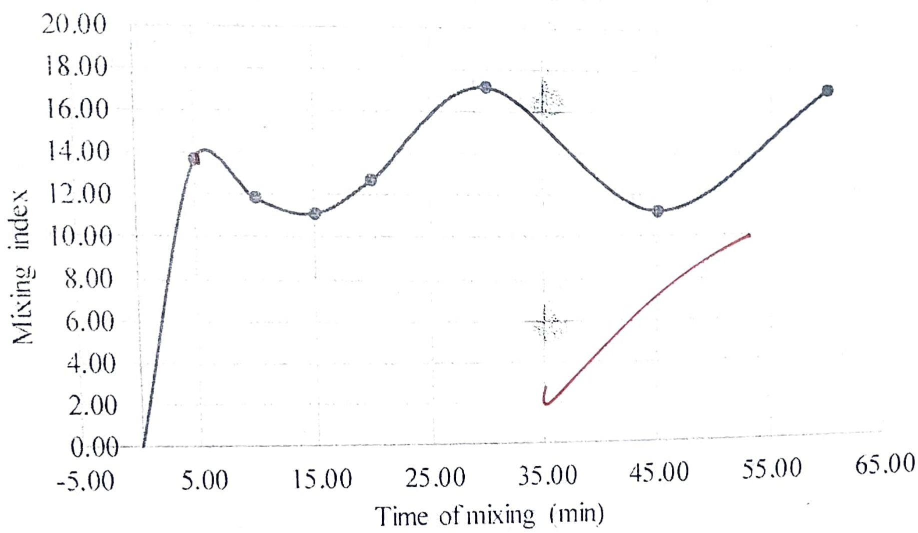

Figure (1): Response of mixing index due to successive step changes in the time of mixing under constant speed.

Discussion

Generally, it is difficult to accurately quantify the particle mixing behavior under the experimental condition. However, when dealing with solid particles, the statistical variation in composition among samples withdrawn at any time from a mixture is commonly used as a measure of the degree of mixing. The index should be related to the properties of the required mixture. Mixing index is a measure of the degree to which fluid flow will promote the dispersion of dissolved solutes or suspended materials in the fluid, leading to homogeneity. It is an indicator of the quality of the mixing process. A collection of representative samples is a crucial step for determining the degree of mixing. For any material it cannot attain the perfect mixing, and the best that can be obtained is a degree of randomness in which two similar particles may well be side by side.

The double-cone mixer is used to simulate the mixing process in this study. Three different samples were taken from different spots along each time interval, titrating them with $AgNO_3$ and $K_2Cr_2O_7$ indicator with different volumes (referring to Table 2,3, 4,…,8) leads to the determination of fractional composition of KCl and sand in each sample.

As shown at Fig. (1), the effect of mixing time with mixing index, it is clear that several optimum mixings are obtained at t =5 min, t=30. Also, at t = 60 min optimum mixing can be considered.as seen, initially mixing tends to reach homogeneous mixture after reaching the equilibrium the mixture tends to segregate. Segregation or demixing occurs when the motion of individual particles is biased according to their characteristics – size, shape, composition etc.

Variations in individual particle mobility with size typically lead to segregation in a bed of particles subjected to vibration or flow. In the absence of such bias, individual motion invariably leads to homogenization of the mixture. By referring to Table (1) it shows the variety of the component sizes (Particle size of KCl salt (µm)= 350-500 and Particle size of silica sand (µm)= 850-1400).

The electrostatic forces occurring in dry granular solids mixing avert the mixture from reaching efficient mixing. In addition to that, if any moisture interferes the process, the particle will have the tendency to stick together due for humidity transfers creating bonds between those solids.

As our results nearly reached the expectations, uncertainty could be taken due to the personal errors, errors in calibration of titration tools, and error in our calculation.

Conclusion

The mixing index is an indicator of the performance of an industrial mixer judged by time required to get the desired homogeneity, the powder load, and the properties of the product.

The rate of mixing as measured by the rate of change of Is with time, varies greatly with kind of mixers and the properties of mixed material, such as particles size, solids of different particle sizes have the tendency to separate again after certain time of mixing, with the small particles in one area and the big ones in another area.

Solid particles could also be segregated depending on density and shape, if particles have complex shapes leading to interlocking between each other, and therefore to a bad flowability, they will be difficult to mix. But once mixed, the interlocking effect will reduce the segregation, and that segregation will naturally limit the homogeneity that can be reached in a given mixer.

The electrostatic forces that accrue in dry granular solids mixing also plays a role in preventing the mixture from being completely mixed. If there is moisture, the particle will have the tendency to stick together due to some humidity transfers creating bonds between those solids.

As the time of mixing and mixing index could have more than one peak with almost similar index value the time of the second peak might be considered to be the best optimum mixing time since it gives the highest homogeneity with the least possible cost.

If the optimum time obtained from the curve is not reasonable for the process it can be reduced by changing one or more of the following factors:

1. mixer type.

2. mixing speed: A higher mixing speed usually gives a shorter mixing time, up to a certain speed at least although some problems like powder breakage should be considered.

3. mixing volume: A higher mixing volume will lead to higher mixing time.

4.loading of material.

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Appendix

A. Sample of calculation

$$I_s = \frac{\sigma_e}{S} = \sqrt{\frac{\mu_P * (1 - \mu_P) * (N - 1)}{n \sum_{i=1}^{N} (x_i - \bar{x})^2}}$$

From table (1), taking the second column:

1. **Average particle size of sand and salt:**

$$d_{\text{sand}} = \frac{850 + 1400}{2} = 1125 \ \mu m$$

$$d_{\text{salt}} = \frac{350 + 500}{2} = 425 \ \mu m$$

2. **Volume of sand and salt particles:**

$$V_{\text{sand}} = \frac{\pi \, d_{\text{sand}}^3}{6} = \frac{\pi * 1125^3}{6} = 7.455 * 10^{-4} \ cm^3$$

$$V_{\text{salt}} = \frac{\pi \, d_{\text{salt}}^3}{6} = \frac{\pi * 425^3}{6} = 4.019 * 10^{-5} \ cm^3$$

3. **Mass of sand and salt particles:**

$$m_{\text{sand}} = \rho_{\text{sand}} * V_{\text{sand}} = 1.602 * 7.455 * 10^{-4} = 1.194 * 10^{-3} \ g$$

$$m_{\text{salt}} = \rho_{\text{salt}} * V_{\text{salt}} = 1.984 * 4.019 * 10^{-5} = 7.975 * 10^{-4} \ g$$

4. **Total number of particles of sand and salt in the sample:**

$$\text{for sand: } n = \frac{\text{weight of sand}}{\text{mass of sand particle}} = \frac{271.69}{1.194 * 10^{-3}} = 2.275 * 10^5$$

$$\text{for salt: } n = \frac{\text{weight of salt}}{\text{mass of salt particle}} = \frac{248.8}{7.975 * 10^{-5}} = 3.120 * 10^6$$

5. **μ_p of sand and salt**

$$\text{for sand: } \mu_{p(sand)} = \frac{\text{Number of sand particles}}{\text{Total number of Particles}} = \frac{2.275 * 10^5}{2.275 * 10^5 + 3.120 * 10^6} = 6.796 * 10^{-2}$$

$$\text{for salt: } \mu_{p(salt)} = 1 - \mu_{p(sand)} = 1 - 0.06796 = 0.93204$$

From table (2), and table (9), taking the first rows:

1. **Number of spot samples:**

   N = 3 spots (middle, top, bottom).

2. **Volume of $AgNO_3$ in the top spot:**

V= 22.6-16 = 6.6 $\pm$0.07 (uncertainty of the burette due to the difference of volume reading) = $\sqrt{0.05^2 + 0.05^2} = \pm 0.07$).

3. **Moles of $AgNO_3$:**

Concentration $AgNO_3$=0.1 M.

$\text{moles of } AgNO_3 = \text{concentration} \times \text{volume}$

$\text{moles of } AgNO_3 = 0.1 \times (6.6 \times 10^{-3}) = 6.6 * 10^{-4}$ mole.

4. **Moles of KCl salt:**

$\text{moles of KCl} = \text{moles of } AgNO_3 = 6.6 * 10^{-4}$ mole.

5. **Mass of KCl salt:**

KCl molar mass =74.55 g/mol.

$\text{mass of KCl} = \text{number of moles} * \text{moleculer weight} = 6.60 * 10^{-4} * 74.55 = 0.0492$ g.

6. **Mass of silica sand:**

$\text{mass of sand} = \text{sample weight} - \text{mass of KCl} = 0.1 - 0.0492 = 0.0508$ g.

7. **Mass fraction of silica sand and salt (X_{salt}, X_{sand}):**

$$\text{mass fraction of X} = \frac{\text{mass of sand}}{\text{total mass}}$$

For sand: $X_{sand} = \frac{0.0508}{0.1} = 0.5080$

For salt: $X_{salt} = \frac{0.0492}{0.1} = 0.4920$

mass fraction of sand for other two spots are: 0.7316 , 0.5527

8. **The average of mass fraction of sand:**

$$X_{avg} = \frac{0.5080+0.7316+0.5527}{3} = 0.5974$$

*from table (a)

1. **Number of sand and salt particles during mixing:**

$$\text{for sand: } n = \frac{\text{weight of sand}}{\text{mass of sand particle}} = \frac{0.0508}{1.194*10^{-3}} = 42.5323$$

$$\text{for salt: } n = \frac{\text{weight of salt}}{\text{mass of salt particle}} = \frac{0.0492}{7.975*10^{-5}} = 616.9991$$

n for sand in the two other spots: 153.1464, 46.2776

The sum of sand particles in the sample = 42.5323 + 153.1464 + 46.2776 = 241.9564

2. **The Index of mixing in each interval of time according to this equation:**

$$I_s = \sqrt{\frac{\mu_p \cdot (1-\mu_p) \cdot (N-1)}{n \sum_{i=1}^{N} (x_i - x_{ave})^2}}$$

$\sum(X - X_{ave})^2 = (0.5080 - 0.5974)^2 + (0.7316 - 0.5974)^2 + (0.5527 - 0.5974)^2 =$
$0.0080 + 0.0180 + 0.0020 = 0.0280$

$$I_s = \sqrt{\frac{0.06796 * 0.9320 * (3-1)}{(241.9564) * 0.0280}} = 0.1367$$

Mixing of Powder Data Sheet

Weight of salt: 248.8

Particle size of salt: 350 – 500 µm

Weight of sand: 271.869

Particle size of sand: 1.4 mm – 850 µm

Time	Sample Location	Sample wt(g)	Vol. of $AgNO_3$ (ml)
5 min	Top	0.1028 g	16 – 22.6
	Bottom	0.1 g	10 – 16
	Right	0.25 middle g	1 – 10
	Left		
10 min	Top	0.14 g	22.6 – 26.9
	Bottom	0.12 g	26.9 – 30.2
	Right	middle 0.11 g	30.2 – 30.5
	Left		
15 min	Top	0.1 g	30.7 – 34
	Bottom	0.13 g	34 – 36.2
	Right	midd 0.12 g	36.2 – 42.1
	Left		
20 min	Top	0.11 g	11.7 → 18.1
	Bottom	0.12 g	26 → 28.9
	Right	middle 0.15	18.1 → 26
	Left		
30 min	Top	0.11 g	36.2 – 37.9
	Bottom	0.10	33.8 – 36.2
	Right	middle 0.1	middle 29 – 33.8
	Left	—	
45 min	Top	0.1	37.9 – 38.3
	Bottom	0.1	18.7 – 23.7
	Right	middle 0.1	middle 16 – 18.7
	Left		
60 min	Top	0.12	23.7 – 28.1
	Bottom	0.1	35.7 – 42
	Right	middle 0.12	middle 28.1 – 35.7
	Left		

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