B.M.S. COLLEGE OF ENGINEERING, BENGALURU-19

Autonomous Institute, Affiliated to VTU

Department of Chemical Engineering

Tutorial Sheets

Course: Mechanical Operation **Course Code: 19CH3DCMOP**

Faculty: Dr. Shivakumar. R

Unit 1: Particle Technology

Problem Statements

1. A quartz mixture having the screen analysis shown in Table 1 is screened through a standard 10-mesh screen. The cumulative screen analysis of overflow and underflow are given in Table 1. Calculate the mass ratios of the overflow and underflow to feed and the overall effectiveness of the screen.

Table 1: Screen analyses Data

		Cumulative fraction smaller than D_p		
Mesh	D_p, mm	Feed	Overflow	Underflow
4	4.699	0	0	
6	3.327	0.025	0.071	
8	2.362	0.15	0.43	0
10	1.651	0.47	0.85	0.195
14	1.168	0.73	0.97	0.58
20	0.833	0.885	0.99	0.83
28	0.589	0.94	1.00	0.91
35	0.417	0.96		0.94
65	0.208	0.98		0.975
Pan		1.00		1.00

2. A Sand Mixture was screened through a standard 12 mesh screen. The mass fraction of the oversize material in feed, overflow, and underflow were found to be 0.4, 0.8, and 0.2 respectively. Calculate the screen effectiveness based on the oversize materials.

3. A Sponge-iron industry uses a screen of 5mm aperture to separate the oversize from undersize fines which is then recycled to the furnace. The screen analysis of the furnace output was found to contain 25% fines. The screen effectiveness was 50%. The underflow from the screen contains around 95% fines. If the furnace production rate is 100 tons/h. Find the product rate and number of fines present in the products.

4. Table salt is being fed to a vibrating screen at the rate of 150 kg/h. The desired product is -30 + 20 mesh fraction. Estimate the effectiveness of the screen. The mass fraction screen analysis for oversize 30 mesh and oversize & undersize of 20 mesh is as under. It is observed that oversize is mesh 30, oversize from mesh 20 and undersize from mesh 20 are in the ratio 2:1.5:1.

Mesh	-85+60	-60+40	-40+30	-30+20	-20+15	-15+10
Feed	0.097	0.186	0.258	0.281	0.091	0.087
Over size 30 mesh	0.197	0.389	0.337	0.066	0.005	0.006
Oversize 20 mesh	0.026	0.039	0.322	0.526	0.061	0.026
Undersize 20 mesh	0.0005	0.0009	0.0036	0.3490	0.2990	0.3470

5. The screen analysis in the following table applies to a sample of crushed quartz. The density of the particles is 2650 kg/m^3 and shape factors are a = 2 and Φs = 0.571. For the material between 4 mesh and 200 mesh in particle size calculate, (a) The number of particles per gram (b) volume mean diameter.

Mesh	Screen opening, D_p mm	Mass Fraction
4	4.699	0.000
6	3.327	0.0251
8	2.362	0.125
10	1.651	0.3207
14	1.168	0.257
20	0.833	0.159
28	0.589	0.0538
35	0.417	0.021
48	0.295	0.0102
65	0.208	0.0077
100	0.147	0.0058
150	0.104	0.0041
200	0.074	0.0031
Pan	....	0.0075

6.

Dolomite mixture having the following screen analysis is screened through a standard 100 mesh screen. Calculate the effectiveness of the screen and the mass rations of overflow and underflow to feed. Screen analysis data:

Mesh No.	Weight %.		
	Feed	Oversize	Undersize
35	7.07	13.67	0.00
48	16.60	32.09	0.00
65	14.02	27.12	0.00
100	11.82	20.70	2.32
150	9.07	4.35	14.32
200	7.62	2.07	13.34
-200	33.80	0.00	70.02

7. The screen analysis shown in the following table applies to a sample of crushed galena (Density = 7650kg/m^3), of sphericity (Φs) 0.62. For the material between 4-mesh and 65-mesh in particle size, calculate Aw, in square millimeters per gram by differential and cumulative analysis method.

Mesh Number	4	8	10	20	35	48	65	pan
Screen opening D_{pi} (mm)	4699	2362	1651	833	417	295	208	-
Mass fraction	0	0.25	0.31	0.15	0.2	0.01	0.05	0.03

B.M.S. COLLEGE OF ENGINEERING, BENGALURU-19

Autonomous Institute, Affiliated to VTU

Department of Chemical Engineering

Unit 2: Size Reduction

Problem Statements

1. A certain crusher accepts a feed material having a volume-surface mean diameter of 19 mm and gives a product of volume-surface mean diameter of 5 mm. The power required to crush 15 tonnes per hour is 7.5 kW. What will be the power consumption if the capacity is reduced to 12 tonnes per hour?

2. What will be the power required to crush 150 tonnes per hour of limestone if 80 percent of the feed passes 50 mm screen and 80 percent of the product a 3.125 mm screen?

3. What is the power required to crush 100 ton/h of limestone if 80 percent of the feed passes a 2-in. screen and 80 percent of the product ai-in. screen?

Particles of the average feed size of 50×10^{-4} m are crushed to an average product size of 10×10^{-4} m at the rate of 20 tonnes per hour. At this rate, the crusher consumes 40 kW of power of which 5 kW are required for running the mill empty. Calculate the power consumption if 12 tonnes/h of this product is further crushed to 5×10^{-4} m size in the same mill? Assume that Rittinger's law is applicable.

Find the power required for crushing 5 tonne/h of limestone (Rittinger's number = 0.0765 m^2/J) if the specific surface areas of the feed and the product are 100 and 200 m^2/kg respectively. If the machine consumes a power of 4 hp, calculate its efficiency.

A sample of materials is crushed in a Blake jaw crusher such that the average size of the particles is reduced from 50 mm to 10 mm with the energy consumption of 13 kW/(kg/s). Determine the consumption of energy to crush the same material of 75-mm average size to an average size of 25 mm using Rittinger's and Kick's laws.

A crusher and a grinder are connected to the same power drive. 2700 kg/h of limestone first passes through the crusher and then through the grinder in succession. Screen analysis of feed, product from the crusher, and product from the grinder indicated surface areas of 2.9, 103, and 865 m^2/kg respectively. Calculate the power required by the drive to run the crusher–grinder assembly, if the efficiency of the crusher is 20 %and that of the grinder is 25 % Rittinger's number for limestone is 77.4 m^2/kJ.

270 kW of power is required to crush 150 tonnes/h of a material. If 80% of the feed passes through a 50-mm screen and 80% of the product passes through a 3-mm screen, calculate the work index of the material.

And what will be the power required for the same feed at 150 tonnes/h to be crushed to a product such that 80 % is to pass through a 1.5-mm screen?

Unit 3: Flow of Fluid past Immersed Bodies

Problem Statements

1. Air flows through a packed bed column. The column is packed with a powdery material of 1cm depth. The superficial velocity of air is 1cm/s. The pressure drop of 1cm of water across the bed was measured using a manometer. Porosity of the bed was around 0.4. Assuming Kozeny Carman equation is valid for the study. Estimate the particle size of powder in terms of equivalent diameter.

2. A packed bed reactor is 2m in diameter. The reactor is packed with cylindrical catalyst pellets of diameter equal to 1mm and length of 3mm. The height of packing in the reactor is 5m. The density of the catalyst materials is 2250 kg/m^3. The reactor processes a gas stream with viscosity $2.5 \times 10^{-5} \frac{kg}{ms}$ and density 2 kg/m^3. The mass flow rate of gas through the reactor is around 6 kg/s. The gas flows downwards into the packed bed reactor and bed voidage is 0.45. Calculate the pressure drop over the bed.

3. Calculate the pressure drop in terms of cm of water in a packed bed column. The column is packed with particles of diameter 0.05 cm, density 2000 kg/m^3. The height of the bed is 60 cm, and the bed porosity is 0.5.

4. Water tickles by gravity over a bed of solid particles. The diameter of the particles are 6 cm and height of solid bed is 2 m. The water is fed into the bed from a reservoir whose diameter is larger than the solid bed. The water is tickled at a height of 0.1 m above the top of the bed. The porosity of the bed is 0.3%. Calculate the volumetric flow rate of water required. The viscosity of the water is 1 cP.

5. Laboratory filtrations conducted at constant pressure drop on a slurry of $CaCO_3$ in H_2O gave the data shown below. The filter area was 440 m^2, the mass of solid per unit volume of filtrate was 23.5 kg/m^3, and the temperature was 25°C. Evaluate the quantities α and $R_{m.}$ Pressure drop is 112 kPa and viscosity of the water is 0.886 cP.

Filtrate volume, m^3	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Time, sec	6.8	19.0	34.6	53.4	76.0	102.0	131.2	163.0

6. Constant-pressure filtration of a slurry of $CaCO_3$ in H_2O. The filter was a 6-inch and the filter press with an area of 1.0 ft^2. The mass fraction of solids in the feed to the press was 0.139. Calculate the values of α, R_m and cake thickness. Pressure drop is 35 kPa and viscosity of the water is 0.886 cP. Mass ratio of wet cake to dry cake is 1.59. density of solids 1018 kg/m^3.

Filtrate volume, L	0	0.91	1.81	2.72	3.63	4.535	5.44	6.35
Time, sec	0	24	71	146	244	372	524	690

7. For a sludge filtered in a washing plate and frame the filtration equation $V^2= Kt$ holds good, where V is the volume of the filtrate obtained in time t. When the pressure is constant, 30 m^3 of filtrate is obtained in 10 h.

i. Calculate the washing time if 3 m^3 of wash water is forced to the cake at the end of filtration.
ii. If the filtering area/surface is doubled keeping all other things constant, how long would it take to obtain 30 m^3 of filtrate?

B.M.S. COLLEGE OF ENGINEERING, BENGALURU-19
Autonomous Institute, Affiliated to VTU
Department of Chemical Engineering

Unit 4: Motion of Particles Through Fluids

Problem Statements

Find the terminal settling velocity for particles of 40-micron size having a specific gravity of 2.6 falling through still water if the settling zone is laminar. All particles may be assumed to be spherical and the wall effect may be neglected. Viscosity of water may be taken as 1 cP.

A sample of bauxite ore is to be cleaned using water in a classifier. The ore particles have a size range of 10 to 500 microns. The mixture is being separated into three parts: pure bauxite (specific gravity 2.2), pure silica (specific gravity 2.8), and the third fraction is the middling which is recycled. Assuming the flow to be laminar and neglecting any wall effect, estimate the size range of the three fractions.

An ore sample having a specific gravity of 2.1 is to be separated from rock associated with it using a hydraulic classifier. The ore consists of 1 mm spherical particles. The rock particles have an average specific gravity of 5.4 and the screen analysis gives the following:

Particle si e mm	*Mass fraction*
+ 2 – 5	0.43
+ 0.5 – 2	0.47
< 0.5	0.10

The ore–rock mixture contains 30% rock particles. Estimate the % purity of the dressed ore. Assume settling to be laminar.

A mixture of galena (having a density of 7500 kg/m^3) and quartz (having a density of 2650 kg/m^3) contains particles in the size range of 0.0004 to 0.001 cm. This is separated in a hydraulic classifier using water under free and laminar settling conditions, into three fractions: one of pure galena, one of pure quartz, and the third one containing both particles. Find the size ranges of the two materials in these fractions.

Reference

1. McCabe, Warren, L., Smith, Julian, C. and Harriott, Peter, Unit operations of chemical engineering, 5th edition, McGraw-Hill, Singapore, 2000.

2. Anup Kumar Swain, Hemalata Patra, and Gopendra Kishore Roy, Mechanical Operations, 1st edition, Tata McGraw Hill Education Private Limited, NEW DELHI.