Tentamen TA 3390

Minor Mining & Resource Engineering: Physical Processing
Cursusjaar 2008-2009
Datum: 13 Januari 2009
Tijd: 9.00 - 12.00 uur
Examinator: Dr.Ir. Rénard Chaigneau

1. Defecten zijn inherent aan kristallen en hebben een grote invloed op de mechanische eigenschappen van vaste stoffen
    a. Waarom bestaat een perfect kristal niet?
    b. Waarom zijn ionogene stoffen in het algemeen brosser dan metalen.
    c. Breken en malen zijn zeer energie intensieve bewerkingen. Leg uit op welke drie manieren deze energie ´verdwijnt´ in de korrels en geef een indicatie voor de verhouding/verdeling (ga uit van 100% energietoevoer)
    d. Het steeds fijner malen van korrels kost steeds meer energie. Leg uit waarom, in relatie tot alle drie de manieren uit antwoord c.

2. De Bond Workindex geeft de specifieke maalenergie om een mineraal te malen.
    a. Waarom is een proef met een open maalcircuit, waarin de korrelgrootte als functie van de tijd wordt gemeten, onbetrouwbaar om een industrieel circuit op te zetten met als doel mineralen vrij te maken voor een concentratiestap?
    b. De Workindex van hematiet is bepaald met de Bond methode door een laborant. In de evenwichtssituatie blijkt de maalbaarheid G_{bp} bij een zeefgroote van 75µm op 0.9 g/rev te liggen. Op de Rosin Rammler grafiek zijn de gemeten deeltjesgrootte verdeling van voeding (feed) en product geplot (figuur 1).
    Bepaal de Wi voor deze hematiet.
    c. Als de kogelmolen een doorzet heeft van 400 t/hr en een beschikbaarheid van 93%, hoeveel ton kan er dan jaarlijks extra worden geproduceerd als de Wi 10% kleiner blijkt te zijn en het opgenomen vermogen hetzelfde blijft? (het bedrijf betaalt 0.14 €/kWh).

3. Erts heeft een dichtheid van 2.2 t/m^3. Het moet op 3 mm afgezeefd worden met een doorzet van 200t/hr. 10% van het materiaal bevindt zich in de moeilijke zeefklasse van 1.5-4.5 mm.
    a. Hoe groot is het zeefoppervlak?
    b. Ontwerp met het antwoord van a en de kopieën van Weiss (blz 3E-10) de correcte lengte en breedte en bepaal het aantal zeven.
    c. Weiss (blz 3E-11) geeft in Chart A een alternatieve manier om de zeefcapaciteit te bepalen van verschillende materialen. Beargumenteer waarom er verschil is tussen die vier materialen en beargumenteer waarom de lijnen lineair zijn bij grote openingen en gekromd weglopen naar het nulpunt toe (dus beargumenteer de vorm van de curve).
    d. Teken in een grafiek het verloop van de zeefcapaciteit als functie van vocht percentage (x-as vocht% 0-15%; y-as zeefcapaciteit, indicatief kwantitatief)

e. Als je weet dat het materiaal ´s winters tot 8% vochtig kan zijn, welke maatregelen (minimaal 3) kun je nemen om de capaciteit te garanderen.

f. Kan deze scheiding ook plaatsvinden met een hydrocycloon? Betrek bij je kwalitatieve antwoord hierbij ook 3 belangrijke verschillen tussen beide scheidingsprincipes.

4. Om de hematiet in een ertslichaam vrij te maken, moet het erts zeer fijn gemalen worden. De tailings van de concentrator moeten ingedikt worden van 5 kg water per kg solids naar 1.5 kg water/kg solids in een indikker. De gevraagde productiecapaciteit is 7.2 **t/hr** solids.
   In het laboratorium is bij verschillende suspensie niveaus de sedimentatiesnelheid bepaald:

Suspensie D (**kg water/kg solid**)	5.0	4.2	3.7	3.1	2.5
Sedimentatie snelheid (**mm/sec**)	0.20	0.12	0.094	0.070	0.050

a. Wat is de benodigde oppervlakte A van de indikker (let op een correct gebruik van alle eenheden!)?

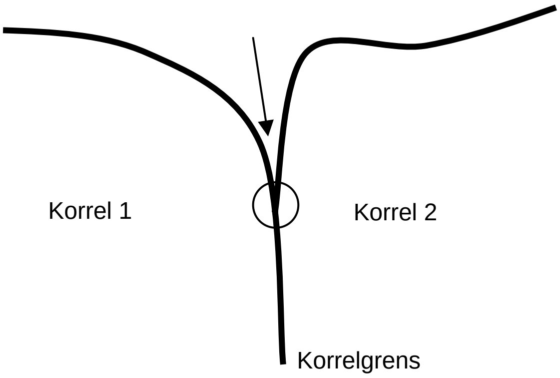
b. Bewijs dat een deeltje hematiet van 0.1 mm nog laminair bezinkt.

c. Waarom verschilt de berekende stationaire valsnelheid uit b) van de sedimentatiesnelheid zoals hierboven in de tabel is aangegeven (minimaal 2 redenen).

Algemene materiaalconstanten

Medium	Dichtheid ρ	Dynamische viscositeit η
	kg/m^3	Pa·s = N·s/m^2
Lucht	1.29	$18 * 10^{-6}$
Water	998	$1*10^{-3}$
Kwarts	2200	-
Hematiet	5200	-

5. Onderstaande figuur geeft schematisch twee korrels weer, welke aan elkaar sinteren.



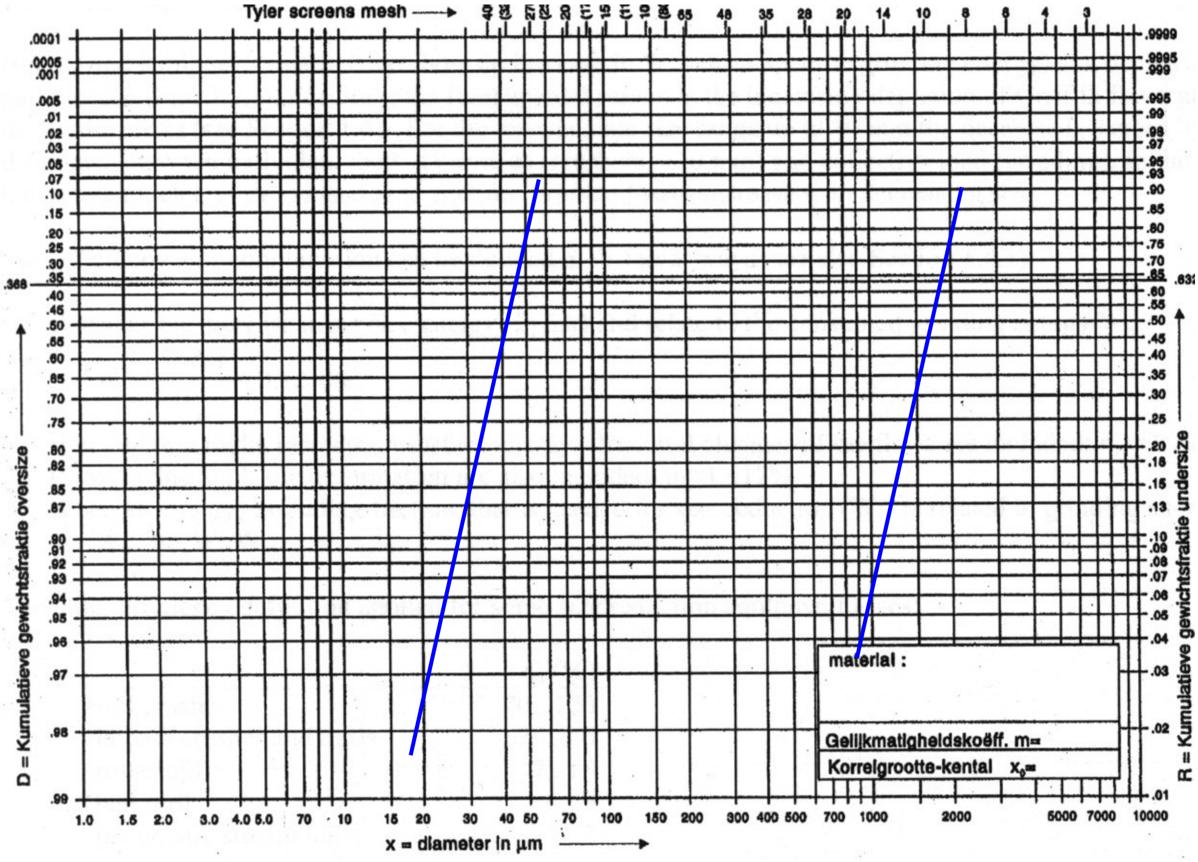
a. Teken de verschillende transportroutes naar de nek, aangegeven met de cirkel.

b. Wat is de drijvende kracht achter sinteren?

c. In het eindstadium van sinteren groeien de korrels. Er zal echter nooit een één kristal ontstaan. Leg uit waarom niet en neem in je antwoord onzuiverheden en porositeit mee.

Appendices met algemene en bruikbare data en formules

Figuur 1 Gemeten korrelgrootte verdeling voor en na malen in een Bond kogelmolen, behorende bij vraag 2



Bond

$$W_i = \frac{44.5}{X^{0.23} G_{bp}^{0.82} \left(\frac{10}{\sqrt{P_{80}}} - \frac{10}{\sqrt{F_{80}}} \right)}$$

P= Product, F= Feed

1 short ton = 907.2 kg

Screen capacity in t/m²·hr $C = 1.4 \frac{\rho}{\gamma} D^{0.6}$ **(not in SI units!)**

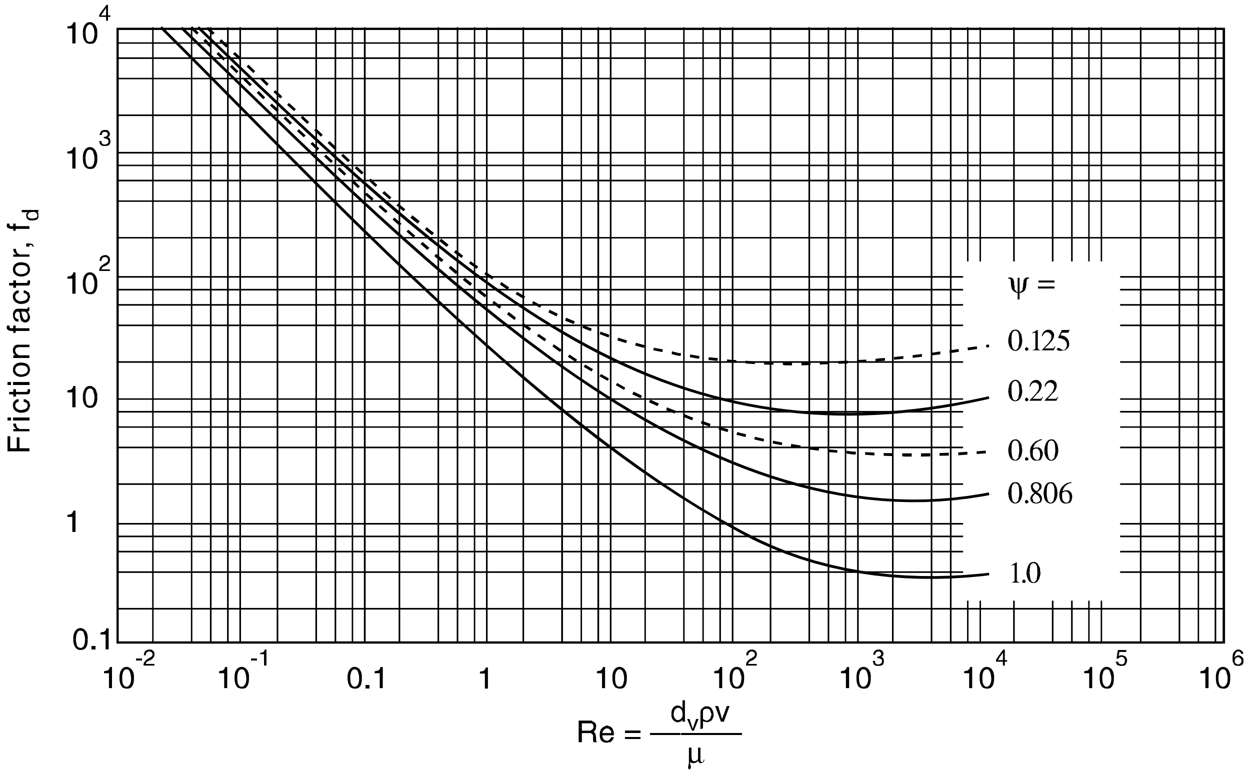
1 foot = 12 inch = 0.3048 m

Coe and Clevenger

$$A = \frac{D - D_u}{\rho \nu (D)} Q C \rho_s$$

D = (initial) dilution, mass of water per mass of solids
D_u= final dilution
ν = settling rate at dilution D
Q = volumetric capacity of the tank [m³/s]
C = volume fraction solid in the feed [m³/m³]

Reynolds as function of C_w (= friction factor f_d)



Free settling velocity (all in SI units!)

$$v_s = \sqrt{\frac{4}{3} g \frac{d(\rho_s - \rho_l)}{C_{w(\mathrm{Re})} \rho_l}}$$

Laminair: $C_w = \frac{24}{\mathrm{Re}}$

Turbulent: $C_w = 0.43$

Reynolds: $\mathrm{Re} = \frac{v_r d_p \rho_l}{\eta}$ met

v_r is a relative velocity
d_p particle diameter
ρ_l liquid density
η dynamic viscosity

contains such small amounts of surface moisture as not to impede screening.

10) Combination—In many cases, the operation may involve two or more of the preceding. If so, attention should be given to each to determine the controlling factors.

The screen manufacturer and his technical representative should be prepared to provide specific data on the types of screening operations for which their units are best suited. They must also provide some indication of the range of product sizes and capacities for which any given unit may be considered. With this preliminary data at hand, the field of available choices is narrowed down considerably.

The next step, then, is to make a screen sizing calculation based on a rational method. Such a calculation, however, should not be regarded as providing an exact solution, since the many constants have been determined empirically and have somewhat limited ranges of applicability.

It should be noted that there are, in current use, three basic methods for capacity calculation: (1) overflow method, (2) through-flow method, (3) total feed method. As their names imply, these methods differ in the flow of material that is used as a basis of calculation; tons per hour passing over, through, or into the feed box of the screen.

Each method has its proponents, and each proponent has his favorite set of empirical factors and variations in procedure. The procedure presented here is a through-flow method.

Screen Selection Calculations

The basic relationship on which screen sizing calculations are based may be expressed as follows: The area of screen surface required is equal to the through-flow tonnage or capacity divided by the corrected unit capacity for the material being handled. In mathematical terms, this may be expressed as follows:

$$A = C_t/C_u \times F$$

where A is area of screen surface in square feet; C_t is through-flow capacity, or tonnage of undersize in the feed to the screen; C_u is unit capacity or basic tons per hour per square foot through the screen, for the size separation and material being handled; F is the product of the various corrective factors.

Table 5 presents a summary and description of these various factors, and provides an index to the tables in which their numerical values may be found.

The typical problem requires entering chart A with the size of separation desired and type of material handled. Moving horizontally across the graph, read out the unit capacity.

For example, assuming sand and gravel at a 2-in. separation, a unit capacity of 4.85 tph per sq ft is obtained. This value of C_u must now be corrected for the various conditions represented by the factors.

Previously, the many variables that affect screening performance were discussed briefly and their interrelatedness noted.

Now, having described the use of a rational screen sizing procedure by which the required screen area may be approximated, it seems appropriate to return to these many variables and illustrate their influence on the final selection of a screen.

It should be noted that for a multi-product screen, it is necessary to calculate the area of each deck separately for the size of separation desired.

Having determined the approximate area that must be provided, the determination of the proper length to width ratio must be resolved. As a general rule, the largest ratio that should be considered is about 2:1. However, 1.5:1 provides a somewhat better ratio.

Within limits, the wider screen delivers a greater capacity at a higher efficiency. It follows then, that the widest units practical should be used for greatest efficiency.

S. A. Stone, vice president-engineering, Deister Concentrator Co., speaking for the clay products industry, recommends a maximum length of 7 to 8 ft for the fine mesh screening encountered there. A corresponding maximum of 5 ft is recommended for the width of such units. It is suggested that a battery of smaller screens be considered as a more effective alternative than the larger screen. There are, of course, other advantages to the use of a battery of screens in parallel, and these will be discussed in detail later.

One down-to-earth guide for proper screen width says that it should be possible to see the screen deck through the bed within 1 to 2 ft of the discharge end.

Assume that the area required was approximately 32 sq ft. Applying a ratio of 2:1, a 4 x 8-ft screen would be indicated; whereas, for a ratio of 1.5:1, a 5 x 8-ft screen is the better choice.

One method of arriving at a rational selection of width involves determining the theoretical depth of bed. The importance of bed depth and its effect on stratification has been discussed previously. The formula $C = 3\ d\ W/20$, in which C = tons per hour per inch of depth, provides a simple means for calculating bed depth or tonnage

Table 5. Screening Sizing Calculations—Through-Flow Method

Factor	Data required	Refer to chart	Comments
C_u screen capacity per sq. ft.	Name, description and weight of material	A	
F_f, fines factor	% half-size	B	Provides comparison of the difficulty of separation
F_o, oversize factor	% oversize	B	Allows for stratification. May use 0.80-in. range 70 to 95% if screen is wide enough
F_e, efficiency	% efficiency desired	B	Scalping efficiency usually taken as 85%. Separation range 80 to 95%
F_d, decks	Number of separations	C	Allows for area lost on lower decks
F_w, wet screening	Size of opening	D	When water/feed ratio is 3 to 5 gpm per cycle per hr, use F_w. If not certain of water use adjusted factor, F_{wa}
F_{oa}, open area	% open area of medium to be used	E	Assume capacity varies directly with the change in open area
F_s, slotted opening	Shape of opening and length/width ratio	F	Assumes long dimension of opening is parallel to material flow and in line with screen motion
40% rule: area equals $\dfrac{\text{Tph (feed)} \times 0.40}{C_u \times F_w \times F_{oa} \times F_s}$	% of feed less than opening size		Use when 40% or less of feed is smaller than openings, or for rescreening where little or nothing is screened out

Adapted from Hewitt-Robins, Inc.

Chart A—Screen capacity per square foot

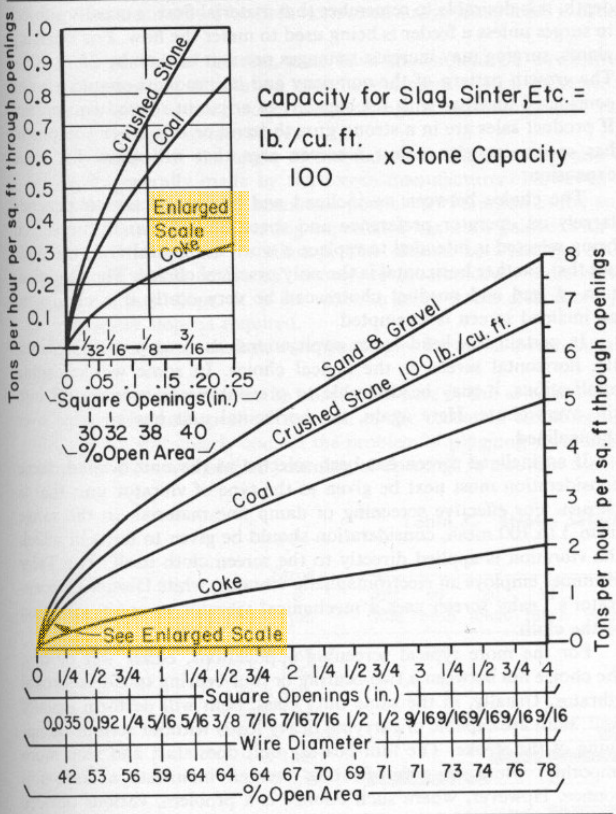


Chart B

%	Factor Fines, F_f	Oversize, F_o	Efficiency, F_e
0	0.44		
10	0.55	1.05	
20	0.70	1.01	
30	0.80	0.98	
40	1.00	0.95	
50	1.20	0.90	
60	1.40	0.86	
70	1.80	0.80	
80	2.20	0.70	1.75
85	2.50	0.64	1.50
90	3.00	0.55	1.25
95	3.75	0.40	1.00

Chart C

Decks	Deck factor, F_d
Top	1.00
2nd	0.90
3rd	0.75

Chart D

Opening size (square), in.	Wet screening factors Limiting moisture*	F_w	F_{wa}†
1/32 or less	0%	1.25	1.10
1/16	1%	3.00	2.00
1/8	1%	3.50	2.50
3/16	2%	3.50	2.50
5/16	4%	3.00	2.00
3/8	4%	2.50	1.50
1/2	6%	1.75	1.30
3/4	6%	1.35	1.20
1 to 2	6%	1.25	1.10
1-1/2	No limit	1.25	1.10
+2	No limit	1.0	1.0

* When screening dry: If moisture exceeds this limit, must consider special aperture constructions

† Use F_{wa} when uncertain about maximum spray water being available, or being used efficiently

Chart E

Open area factor – % Open area = P
For the more common apertures

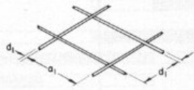
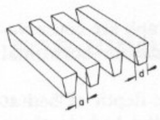
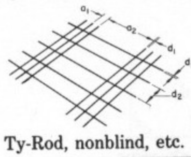
Type of aperture	Formula for % open area, P
Rectangular opening 	P = % Open area d = diam of wire, or horizontal width of bar (for plate) a = clear opening dimension $P = \frac{\text{Open area} \times 100}{\text{Total area}} = \frac{100\,(a_1)\,(a_2)}{(a_1 + d_1)\,(a_2 + d_2)}$
Square openings Specified by opening size.	$P = \frac{100\,a^2}{(a + d)^2} = 100\left(\frac{a}{a + d}\right)^2$ $a_1 = a_2 = a$ $d_1 = d_2 = d$
Square openings Specified in mesh (m).	$P = 100\,a^2\,m^2$ $m = \frac{1}{a + d}$
Parallel rod decks 	$P = \frac{100\,a}{(a + d)}$
Special weaves  Ty-Rod, nonblind, etc.	Assuming $a_3 = a_1$ $P = 100\left[\frac{a_1\,(a_3 + 2a_1)}{(a_2 + 2a_1 + 3d_2)\,(a_1 + d_1)}\right]$

Chart F—Slotted opening factor

Typical screen media	Length/width ratio [(a_2/a_1), Chart E]	Slotted opening factor, F_s
Square and slightly rectangular openings	less than 2	1.0
Rectangular openings, Ton-Cap	Equal to or greater than 2, but less than 4	1.1
Slotted openings, Ty-Rod, nonblind	Equal to or greater than 4, but less than 25	1.2
Parallel rod decks	Equal to or greater than 25	1.4