Mineral Processing

MU 05/06

"Sizing and Metallurgical Testing"

Philip Stewart

- Size is crucial to virtually all mineral processing
- A size range in a standard series is generally identified by the bottom size in the range
- A single size parameter is not enough to define a size distribution
- Narrow size ranges are generally best for following separation processes
- Sizes are usually arranged in a ratio series
  - Ratios of 2, √2, ^{4}√2 are the norm
- This gives systematic coverage of a wide range of particles sizes and is convenient in many ways.
- Also relates better to the effect of size on the behaviour of the particles in many separations.

Size Distribution

- Size distributions are generally tabulated if they are to be used in further calculations
- May be plotted in many ways – useful visualisation
- Cumulative log-log has many advantages
  - Disadvantage is compression of coarse sizes
  - Compensate by expanding Y-scale
- Differential plots rely on consistency in size intervals

Size Distribution Functions

- Many functions for describing size distribution mathematically
  - none universal
  - none with valid theoretical basis
- Gaudin-Schumann the most useful to fit the fine sizes

  $Y = 100 \times (d/D)^n$

  Where 'Y' is the % passing size, d

  'D' corresponds to the 100% passing size

  - extrapolate back

  'n' is a constant corresponding to the slope

Size Distribution Expressions

- Straight line part of the narrow distribution is expressed by:

  $Y = 100 \times (d/111)^{1.65}$
- That for the wide distribution by:

  $Y = 100 \times (d/104)^{0.75}$
- Note the wider distribution has the smaller index.
- This relationship is a straight line on a log-log plot
- Over the same size range (where the relationship applies) the differential plot will also be a straight line plot
- It will be parallel to the cumulative plot
- A good differential plot depends on accurate ratios in the size intervals

Typical Size Distributions						
Size* (microns)	% in size range			% passing size		
	Narrow	Intermediate	Wide	Narrow	Intermediate	Wide
1000			1.2	100.0	100.0	98.9
707		0.4	1.5	100.0	99.7	97.4
500		0.7	2.0	100.0	99.0	95.4
354	0.1	1.4	2.5	99.9	97.6	92.9
250	1.1	3.0	3.2	98.8	94.7	89.7
177	5.8	5.6	4.2	93.0	89.1	85.5
125	13.0	9.4	5.5	80.0	79.7	80.0
88	20.0	13.5	7.1	60.0	66.2	72.9
63	21.5	15.6	9.1	38.5	50.6	63.8
44	16.7	14.4	11.4	21.8	36.2	52.4
31	9.5	11.5	12.0	12.3	24.7	40.4
22	5.4	7.8	9.2	6.9	16.9	31.2
16	3.0	5.4	7.1	3.9	11.5	24.0
11	1.7	3.7	5.5	2.2	7.9	18.5
8	1.0	2.5	4.2	1.2	5.4	14.3
6	0.5	1.7	3.3	0.7	3.7	11.0
4	0.3	1.2	2.5	0.4	2.5	8.5
3	0.2	0.8	1.9	0.2	1.7	6.6
< 3	0.2	1.7	6.6			
TOTAL	100.0	100.0	100.0	820.0	886.7	983.2

$$Y = 100 \times \left(\frac{d}{D}\right)^n$$

or $$\log(Y) = n \times \log\left(\frac{d}{D}\right) + 2$$

- Where y is the % passing size d, D corresponds to 100% passing and n is a constant corresponding to the slope of the log-log plot

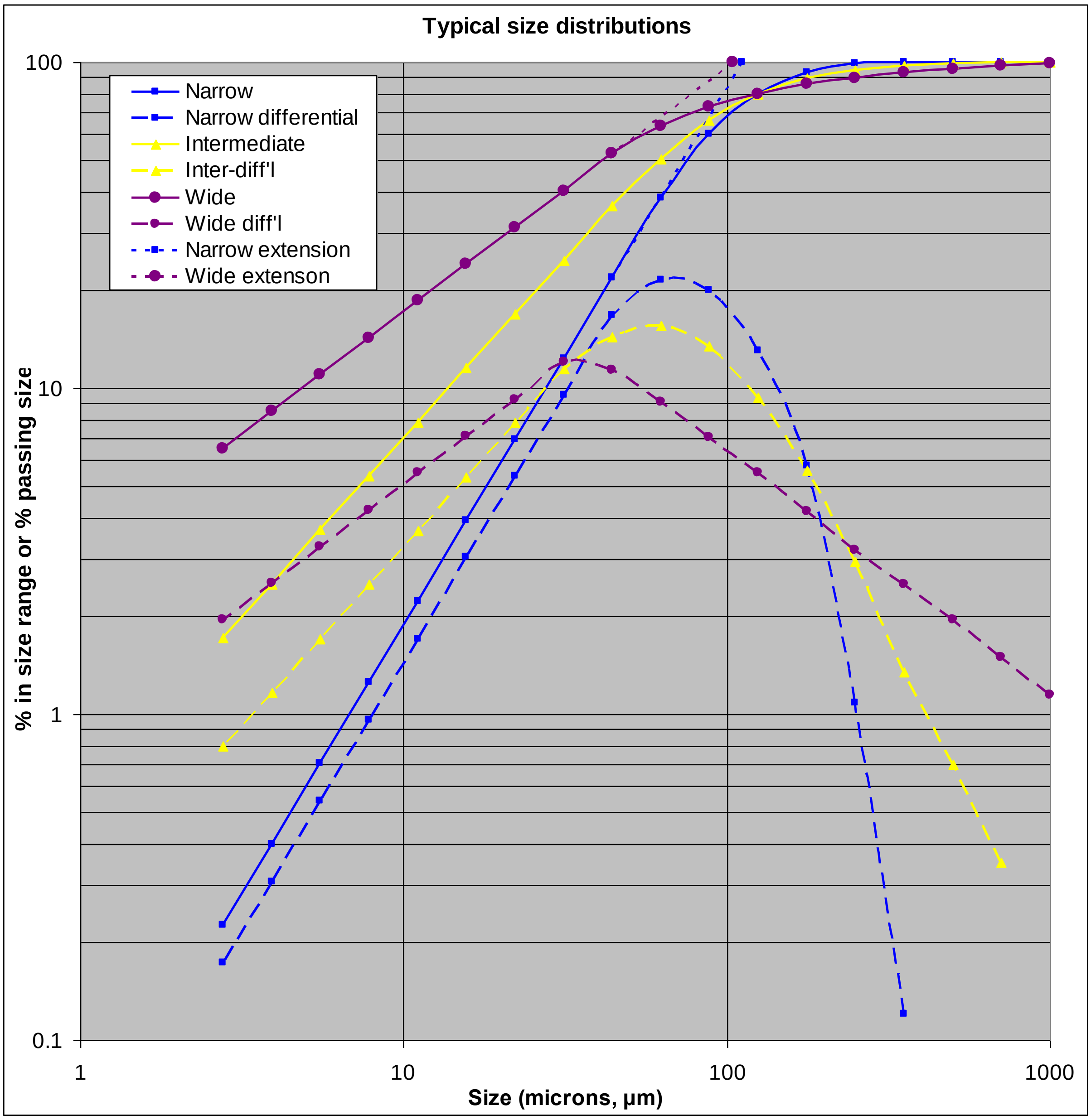
The straight line portion of the narrow size distribution in the fine sizes is thus expressed by:

$$Y = 100 \times \left(\frac{d}{111}\right)^{1.65}$$

and of the wide distribution is expressed by:

$$Y = 100 \times \left(\frac{d}{104}\right)^{0.75}$$

- Note that the wider distribution has a smaller index than the narrow distribution.
- This is a straight line on a log-log plot and over the same range the differential plot will also be a straight line on log-log (see graph)
- Straight line in fine sizes on log-log plot very common from typical grinding circuit
- Parallel line for differential plot goes with this (straight forward maths)
- Narrow size distributions have a higher peak on a differential plot than wide size distributions reflecting the greater concentration of material at or close to the peak value
- On a cumulative plot the slope is greater for narrow size distributions



Note although 80% passing size is the same for all distributions the rest of the distributions are very different, e.g. compare wide and narrow distributions at 3µm – narrow 0.25% passing, wide 7% passing.

Measuring Size

- Many methods using:
  - Screens
  - Settling rate
  - Light scattering
  - Laser diffraction
  - Capacitance (Coulter counter), etc.
- Desirable to get sized material in hand
  - Can analyse
  - Do mineralogical study
  - Specialised tests
- Screens are best for +38µm
- Cyclosizer best for sub-screen sizing

Screening

- Cut out accurate sample from product
- Wet screen on fine screen (38 or 43µm)
  - may need to add dispersant
  - removes clay,
  - and fines which tend to adhere to coarse particles
  - settle
  - dry if nothing finer to be done
- Dry oversize – not too hot (depends on mineral)
  - e.g. pyrrhotite very reactive
- Screen on appropriate stack (Ro-Tap)
- Combine minus 38µm
- Decant minus 2-5µm, settle and dry
- Cyclosize

Cyclosizing

- Cyclone principle with repeated cycling of the underflow
- Variation in dimensions of overflow tube and entry size permits progressively finer cuts
- Does not adhere to strict √2 sequence
  - 44, 33, 23, 15, 11 µm cutpoints (quartz)
  - commercial reasons!
- Uses a lot of water (can dissolve metal from very fine particles
  - temperature control for consistent sizes
- Sized fine particles available for assay

Enhanced Fine Sizing Procedure

- Advantage if we could recover all solids
- Remove finest solids by beaker decantation
  - chose conditions for cutpoint of about 5 µm (quartz)
- May now all collect solids from Cyclosizer effluent in suitable centrifuge to complete a size-mass balance on the sample
  - account for all mass
  - account for all metals
- If finest solids left in cyclosizer feed the centrifuge collection would be inefficient

Sizing by Cyclosizer

For the full procedure refer to the paper on the CD by Stewart and Restarick – *Improved Cyclosizing Technique,* Proc AusIMM, No.251, September, 1974, pp 9-10.

- Size fractions available for analysis
- Cut sizes affected by:
  - particle shape
  - particle SG
  - water viscosity
  - water density

$$d^2 \propto \frac{\mu_W}{(\rho_S - \rho_W)}$$

- Best run at set temperature (constant sizing)
- Calibrate to give continuity with screens (graphical method on log-log best)

Basis of Size Correction

- Difference from nominal calibration mainly due to differences in SG of particles
  - primary calibration is for quartz
- Secondary differences due to particle shape
- Correction best done empirically on graph
- A further reason for temperature control is ρ_w
- Temperature control to maintain constant water density and viscosity

$$d^2 \propto \frac{(\rho_{S1} - \rho_W)}{(\rho_{S2} - \rho_W)}$$

Other Particle Properties

- Bulk properties
  - **size**
  - shape
  - **SG**
  - resistance to fracture
  - **magnetic response**
  - mineral content
  - metal content
  - cracking
- Surface properties
  - surface area
  - mineral exposure
  - **appearance, fluorescence**
  - **electrostatic conductivity**
  - **surface hydrophobicity (flotation)**
- **Chemical solubility**
  - by component

Bold blue for most important properties for separations

Other Metallurgical Testing

- Liberation testing
  - heavy liquids
  - super-panner
  - Jones tube
  - QEM*SEM
- Crushing
  - Manufacturers tests
  - SAG & AG drop test
- Grinding
  - Bond grindability
  - Work index
- Flotation
  - Denver cell
  - 'Bottle reaching'
  - locked cycle
- Magnetic/electrostatic/gravity
  - specialised equipment available
  - generally consult supplier e.g. Gekko, Kelsey, …
- Leaching (CIL)
  - big range of tests
  - consider separately