TECHNICAL NOTES 4

VIBRATING SCREENS

SIZE CLASSIFICATION

It is always necessary to control the size characteristics of particulate material that is fed to process equipment that separates the mineralogical components. It is not possible within the production environment to exercise precise control over the size of all particles in a population and, in most cases, size classification equipment is designed to split a feed of particulate material into a coarse and a fine product. Occasionally one or two product streams of intermediate size may be produced such as by a double or triple deck screen. Probably the most common application of size classification is its use to prevent oversize material leaving a comminution circuit. Oversize material is recycled to a comminution stage for further size reduction before passing to subsequent stages of processing.

The most significant consideration when evaluating classification equipment is the lack of a clean cut at a particular size. Even the most efficient industrial size classifiers will pass a proportion of oversize material and will retain a portion of undersize material.

Size classification equipment is also subject to capacity limitations and these must be considered when evaluating the performance of new or existing classification equipment. In fact older methods of performance evaluation concentrate entirely on the capacity limitations. However, more modern procedures recognize that the efficiency of separation must also be considered if the performance of a size classifier in a plant circuit is to be accurately evaluated. The procedures that follow take this into account.

There are essentially two types of classifier available for process operation: screens and classifiers that rely on the variation of terminal settling velocities of particles of varying size when these are immersed in a viscous fluid. In general the former are used for the classification of drier material at coarser sizes.

4.1 Classification Based on Sieving - Vibrating screens

The basic method of operation of a screen is very simple. The screen presents a barrier to the passage of oversize material while it readily passes undersize material. It is only necessary to ensure that each particle has an opportunity to reach the screen. In practice each particle is given several opportunities to pass through the screen. Screens can be stationary or the screen can vibrate which increases the rate of presentation of each particle and assists in moving oversize material over and away from the screening surface.

4.1.1 Models based on screen capacity

The traditional method of evaluation of screen performance is the use of a capacity measure. This represents the ability of the screen to accept and handle the feed tonnage of material. The most important assumption in this approach is that the capacity of a screen is directly proportional to its surface area so that the basic capacity is specified at tons of feed per hour per square meter of screen. This quantity is represented by I_u. The basic capacity of any screen is determined under standard operating conditions using a predefined standard feed material. As the nature of the feed material changes and as the operating conditions change so the actual capacity of the screen changes - it will increase for conditions less arduous than the standard and decrease for conditions more arduous than the standard. These modifications are represented by capacity factors which multiply the standard unit screen capacity to get the actual screen capacity under conditions that the screen will actually meet in its position in the operating plant

$$\begin{aligned}\text{Rated screen feed capacity} &= I_u K_1 K_2 \ldots\ldots \\ &= I_u \prod_i K_i \quad \text{tons/hr m}^2\end{aligned} \tag{4-1}$$

where the separate K_i are the capacity factors for deviations from the standard conditions with respect to a number of individual conditions.

The basic unit capacity varies primarily with the size of the screen opening - screens with larger openings being able to handle large quantities of feed material. A typical relationship between I_u and mesh size is

$$I_u = 0.783h + 37 \qquad \text{for } h \geq 25\,\text{mm} \tag{4-2}$$

$$= 20.0\,h^{0.33} - 1.28 \qquad \text{for } h < 25 \text{ mm} \tag{4-3}$$

where I_u is in tons/hr m^2 and h is the mesh size in mms. Each screen manufacturer has its own basic capacity-size relationships for its range of screens. The above expressions are only meant to define a typical trend.

The individual capacity factors are provided by screen manufacturers in tabular or graphical form although the availability of computers is encouraging the presentation of these factors in algebraic form. The following factors are typical for woven wire mesh screens.

The open area factor K_1

The standard condition is usually 50% open area and the capacity is proportional to the open area available.

$$K_1 = \frac{\%\ \text{open area}}{50} \tag{4-4}$$

For material having a bulk density less than 800 kg/m^3 the standard open area is 60% rather than 50% and equation (4.4) should be modified accordingly.

The half-size factor K_2

Feed that contains a large proportion of material that is considerably smaller than the screen mesh size will be handled more easily by a screen. The standard condition is defined as feed material having 40% smaller than one half of the mesh size. If the feed has more than 40% smaller than one half of the screen mesh size, the half-size factor will exceed unity and vice versa.

$$K_2 = 2P^F(0.5h) + 0.2 \tag{4-5}$$

The oversize factor K_3

A screen can handle a greater tonnage of feed material that contains large quantities of oversize material because this material passes directly over the screen and need not be transmitted through the mesh. This is accounted for by the oversize factor K_3 which has a value of unity for a standard feed containing 25% oversize material. This factor increases very quickly as the fraction of oversize increases and is given by

$$K_3 = 0.914 \ \exp \ \exp(4.22\,\bar{P}^F(h) - 3.50) \tag{4-6}$$

In equation (4.6) $\bar{P}^F(h)$ is the fraction of material in the feed that has size greater than the screen mesh size h. It is related to the cumulative size distribution function by

$$\bar{P}^F(h) = 1 - P^F(h) \tag{4-8}$$

The bulk density factor K_4

Denser materials will be transmitted more easily than lighter materials. A factor K_4 accounts for this effect when bulk density differs from the standard of 1600 kg/m^3

$$K_4 = \frac{\rho_B}{1600} \tag{4-9}$$

The deck position factor K_5

Screens that are lower down in the deck receive undersize from the screen above and can handle less material than a screen that takes fresh feed. The capacity decreases with position according to capacity factor K_5

$$K_5 = 1.1 - 0.1S \tag{4-10}$$

where S represents the deck position; 1 for top deck, 2 for 2nd deck and so on.

The screen angle factor K_6

The standard inclined screen has an angle of inclination of 15°. Lower angles of inclination increase the projected area of the screen aperture in the horizontal plane and the screen can handle a greater load. This is accounted for by capacity factor K_6

$$K_6 = 1.0 - 0.01(\alpha - 15) \tag{4-11}$$

where α is the angle of inclination in degrees.

The wet screen factor K_7

Screening at finer mesh sizes can be improved by spraying the screen load with water. The factor K_7 accounts for this effect

$$K_7 = 1.0 + 2.4\times10^{-4}(25-h)^{2.5} \quad \text{for } h \le 25\,\text{mm}$$
$$= 1.0 \quad \text{for } h > 25\,\text{mm} \tag{4-12}$$

The aperture shape factor K_8

The standard screen has square openings and other shapes influence the capacity as shown in the table.

Table 2.1 Screen capacity factor for different apertures

Shape of screen opening	K_8
Round	0.8
Square	1.0
2 to 1 rectangular slot	1.15
3 to 1 rectangular slot	1.2
4 to 1 rectangular slot	1.25

Particle shape factor K_9

Slabby and elongated particles are more difficult to screen than particles that are essentially isometric. If the feed contains about 15% of slabby or elongated particles K_9 should be set at 0.9. Larger amounts of this type of material would give significant problems and would need to be investigated specially.

The surface moisture factor K_{10}

Surface moisture tends to make the particles adhere and screen capacity is reduced. Factor K_{10} accounts for this and can be evaluated from the table below.

Table 2.2 Surface moisture capacity factor for screens.

Condition of feed	K_{10}
Wet, muddy or sticky material.	0.75
Wet surface quarried and material from surface stockpiles with up to 14% moisture by volume.	0.85
Dry crushed material.	1.0
Naturally or artificially dried material.	1.25

4.1.2 Screen transmission efficiency

Ideally the screen should be able to transmit all of the undersize material in the feed. In practice, however, not all of the undersize material passes through the screen and the fraction of the feed undersize that does pass through is referred to as the screen efficiency. The efficiency is determined primarily by the actual feed loading on the screen relative to the rated feed capacity as calculated by equation (4.1). The efficiency of transmission decreases if the screen must handle feed in excess of 80% of the rated tonnage because the access of individual particles to the screen surface is hindered to a greater or lesser degree. The efficiency also decreases as the actual feed tonnage falls below 80% of rated capacity because particles tend to bounce on the lightly loaded screen and make fewer contacts with the screen surface.

If W^F represents the actual feed tonnage, then the rating ratio is given by

$$RR = \frac{W^F}{I_u \prod_i K_i \times \text{screen area}} \tag{4-13}$$

and the efficiency of transmission is given by

$$\begin{aligned} e &= 0.95 - 0.25(RR - 0.8) - 0.05(RR - 0.8)^2 \quad &\text{for } RR \geq 0.8 \\ &= 0.95 - 1.67(0.8 - RR)^2 \quad &\text{for } RR < 0.8 \end{aligned} \tag{4-14}$$

The actual tonnage passed to the undersize stream is

$$W^U = eP^F(h)W^F \tag{4-15}$$

Each size class smaller than the mesh size is subject to the same efficiency factor e so that the particle size distribution in the underflow stream is calculated in discrete form as

$$\begin{aligned} p_i^U &= \frac{ep_i^F W^F}{eP^F(h)W^F} = \frac{p_i^F}{P^F(h)} \quad &\text{for } d_{pi} < h \\ &= 0 \quad &\text{for } d_{pi} \geq h \end{aligned} \tag{4-16}$$

where p_i^U is the fraction of the underflow stream in the size class i and p_i^F that fraction in the feed stream.

The actual tonnage passed to the overflow stream is

$$\begin{aligned} W^O &= (1 - P^F(h))W^F + (1 - e)P^F(h)W^F \\ &= W^F(1 - eP^F(h)) \end{aligned} \tag{4-17}$$

and the discrete size distribution in the overflow stream is given by

$$p_i^O = \frac{(1-e)p_i^F}{(1-eP^F(h))} \quad \text{for } d_p < h \tag{4-18}$$

$$= \frac{p_i^F}{1-eP^F(h)} \quad \text{for } d_p \geq h \tag{4-19}$$

The simple capacity model permits the calculation of the total screen area that is required for a specific duty. The aspect ratio of the screen (length/width ratio) must be determined by considering the depth of the bed of particles on the screen. An approximate guide is the restriction of the bed depth at the discharge end to no more than 4 times the mesh size. The thickness of the bed is determined by the total flowrate over the screen surface, the width of the screen, b, and the velocity of travel of the material along the screen.

$$t_b = \frac{W^O}{b u \rho_b} \tag{4-20}$$

where t_b is the bed thickness, W_d the mass flowrate across the discharge end, b the screen width, u the velocity of travel across the screen surface and ρ_b the bulk density. The velocity of travel depends primarily on the angle of inclination and the amplitude and mode of vibration.

4.2 The Classification Function

A more realistic description of the performance of a classification device is provided by the classification function. This function defines the probability that an individual particle will enter the oversize stream that leaves the classifier. This function is also known as the partition function and when shown graphically as the partition curve. It is a complicated function of the particle properties and the classifying action of the particular device under consideration. The classification function $c(d_{pi})$ is defined as the mass fraction of material in size interval i in the feed which finally leaves in the oversize stream.

Once the partition function is known, the size distribution in both overflow and underflow can be calculated by a simple mass balance over the solids in size class i.

$$W^U p_i^U = (1 - c(d_{pi}))\, W^F p_i^F \tag{4-21}$$

$$W^O p_i^O = c(d_{pi}) W^F p_i^F \tag{4-22}$$

where the superscripts O, U and F refer to oversize, undersize and feed respectively.

The total flowrates of solid in the oversize and the undersize are given by

$$W^U = \sum_i W^U p_i^U = \sum_i (1 - c(d_{pi})) W^F p_i^F \tag{4-23}$$

$$W^O = \sum_i W^O p_i^O = \sum_i c(d_{pi}) W^F p_i^F \tag{4-24}$$

$$p_i^U = [1 - c(d_{pi})] \frac{W^F}{W^U} p_i^F = \frac{[1 - c(d_{pi})] p_i^F}{\sum_i [1 - c(d_{pi})] p_i^F} \tag{4-25}$$

$$p_i^O = c(d_{pi}) \frac{W^F}{W^O} p_i^F = \frac{c(d_{pi}) p_i^F}{\sum_i c(d_{pi}) p_i^F} \tag{4-26}$$

These formulas are often written in terms of the total yield of solids to the overflow

$$Y_s = \frac{W^O}{W^F} \tag{4-27}$$

$$p_i^{\,U} = \frac{(1 - c(d_{pi}))p_i^{\,F}}{1 - Y_s} \tag{4-28}$$

$$p_i^{\,O} = \frac{c(d_{pi})p_i^{\,F}}{Y_s} \tag{4-29}$$

$$Y_s = \sum_i c(d_{pi})p_i^{\,F} \tag{4-30}$$

4.2.1 The Karra model

The approach described in the previous section is the traditional method used for sizing screens. Its chief limitation is that the screen must be sized according to the amount of feed that is presented to the screen. A more logical approach is based on the amount of material that must be actually transmitted by the screen to the underflow stream. This approach has been developed by V.K. Karra (CIM Bulletin, April 1979 pp. 168-171) into an effective description of how a screen may be expected to perform during plant operation.

The approach is similar to the traditional approach but is based on the capacity of the screen to transmit undersize material proportional to the screen area. As in the traditional method this basic capacity is modified by a number of factors that allow for variations of the feed material and the screen from the standard test conditions.

Let *A* represent the basic capacity which is defined as the tonnage of undersize that a particular screen can transmit per unit of screen surface area. The basic capacity is increased or decreased depending on the nature of the feed and conditions on the screen. A number of capacity factors allow for the amount of oversize in the feed (factor *B*), the amount of half size in the feed (factor *C*), the location of the deck (factor *D*), factor for wet screening (factor *E*) and for material bulk density (factor *F*). These factors all have a value of unity at the nominal standard operating condition and move down or up as the screening duty becomes more or less arduous. Karra has also recognized that the amount of near-size material has a significant effect on the ability of the screen to transmit undersize material and he has introduced a near-size capacity factor G_c.

The theoretical amount of undersize that can be transmitted by the screen is given by

$$Th = A.B.C.D.E.F.G_c \times \text{screen area} \tag{4-31}$$

A screen will be well designed to handle its duty in the circuit if *Th* is approximately equal to the quantity of undersize in the feed. Each of the capacity factors is related to the quality of the feed and to the type of screen.

Karra bases the screen performance on the effective throughfall aperture of the screen defined by

$$h_T = (h + d_w)\cos\theta - d_w \tag{4-32}$$

where d_W is the diameter of the wire and θ is the angle of inclination of the deck. Equation (4.32) gives the effective aperture area projected onto the horizontal plane which is appropriate for particles that must pass through the screen under gravity.

The basic capacity *A*.
The basic capacity is primarily determined by the mesh size of the screen with the effective throughfall aperture being used as the appropriate measure of screen mesh size.

$$A = 12.13 h_T^{0.32} - 10.3 \quad \text{for } h_T < 51 \text{ mm} \tag{4-33}$$

$$A = 0.34\ h_T + 14.41 \quad \text{for } h_T \geq 51 \text{ mm} \tag{4-34}$$

with h_T in mm and *A* is in metric tons/hr m^2.

The basic capacity will also depend on the open area of the screen used. The basic capacity calculated from equation (4.33) and (4.34) are applicable to standard industrial light-medium woven wire mesh. For other screen cloths and surfaces, *A* must be adjusted in proportion to the open area. The percent open area for light-medium wire mesh is related to the mesh size *h* by

$$OA = 21.5\ \log_{10} h + 37 \tag{4-35}$$

with *h* in millimeters.

Thus capacity *A* must be adjusted to

$$\frac{A \times \text{actual \% open area}}{OA} \tag{4-36}$$

The oversize factor *B*

$$\begin{aligned} B &= 1.6 - 1.2\bar{P}^F(h_T) && \text{for } \bar{P}^F(h_T) \leq 0.87 \\ B &= 4.275 - 4.25\bar{P}^F(h_T) && \text{for } \bar{P}^F(h_T) > 0.87 \end{aligned} \tag{4-37}$$

The half-size factor *C*

$$
\begin{aligned}
C &= 0.7 + 1.2\ P^F(0.5h_T) \quad \text{for } P^F(0.5h_T) \le 0.3 \\
C &= 2.053\ P^F(0.5h_T)^{0.564} \quad \text{for } 0.3 < P^F(0.5h_T) \le 0.55 \\
C &= 3.35\ P^F(0.5h_T)^{1.37} \quad \text{for } 0.55 < P^F(0.5h_T) \le 0.8 \\
C &= 5.0\ P^F(0.5h_T) - 1.5 \quad \text{for } P^F(0.5h_T) > 0.8
\end{aligned} \tag{4-38}
$$

The deck location factor D

$$D = 1.1 - 0.1\ S \tag{4-39}$$

where S = 1 for top deck, S = 2 for 2nd deck and so on

The wet screening factor E
Let $T = 1.26\ h_T$ (h_T in mm)

$E = 1.0$	for $T < 1$
$E = T$	for $1 \le T < 2$
$E = 1.5 + 0.25T$	for $2 \le T < 4$
$E = 2.5$	for $4 \le T < 6$
$E = 3.25 - 0.125T$	for $6 \le T < 10$
$E = 4.5 - 0.25T$	for $10 \le T < 12$
$E = 2.1 - 0.05T$	for $12 \le T < 16$
$E = 1.5 - 0.0125T$	for $16 \le T < 24$
$E = 1.35 - 0.00625T$	for $24 \le T < 32$
$E = 1.15$	for $T > 32$

whenever the material is sprayed with water.

The bulk density factor F

$$F = \frac{\rho_B}{1600} \tag{4-40}$$

The near-size capacity factor G_c
The capacity of the screen is also affected by the presence of near-size material in the feed. The near-size material in the feed is in the size range from $0.75h_T$ to $1.25h_T$. Considerable quantities of near-size material will inhibit the passage of undersize material through the screen. The near-size capacity factor can be evaluated from

$$
\begin{aligned}
G_c &= 0.975(1 - \text{near-size fraction in feed})^{0.511} \\
G_c &= 0.975\left(1 - P^F(1.25h_T) + P^F(0.75h_T)\right)^{0.511}
\end{aligned} \tag{4-41}
$$

4.2.2 The screen classification function

In practice, not all of the undersize is transmitted because of various physical factors that impair the efficiency of the screen. This effect is described by the screen partition function. Several standard functional forms are available to describe this effect, and Karra uses the function

$$c(d_p) = 1 - \exp[-0.693(d_p/d_{50})^{5.9}] \tag{4-42}$$

which gives the efficiency of transfer of particles of size d_p to oversize.

The parameter that will determine the screening efficiency is d_{50}. Values of d_{50} greater than the mesh size give high efficiencies and *vice-versa.*

The actual d_{50} achieved will depend primarily on the effective throughfall aperture of the wire mesh used on the screen, on a loading coefficient K defined by

$$\begin{aligned} K &= \frac{\text{tons of undersize in the feed / unit of screen area}}{ABCDEF} \\ &= \frac{W^F P(h_T)/\text{screen area}}{ABCDEF} \end{aligned} \tag{4-43}$$

and on the near-size factor G_c.

Karra has found that experimental screening data are well represented by

$$\frac{d_{50}}{h_T} = \frac{G_c}{K^{0.148}} \tag{4-44}$$

d_{50} can be substituted in equations (4.42) and (4.21 - 4.26) to calculate the size distributions in the two product streams.

$$p_i^U = \frac{[1 - c(d_{pi})]p_i^F}{\sum_i [1 - c(d_{pi})]p_i^F} \tag{4-45}$$

$$p_i^O = \frac{c(d_{pi})p_i^F}{\sum_i c(d_{pi})p_i^F} \tag{4-46}$$

The model provides a simulation of the actual performance of the screen in the circuit. This performance can be compared with the design capacity of the screen and the screen performance evaluated. In particular, the actual operating efficiency can be calculated from

$$\text{simulated efficiency} = \frac{\text{tonnage transmitted to undersize}}{\text{tonnage of undersize in feed}} \tag{4-47}$$

$$= \frac{\sum_i [1 - c(d_{pi})] p_i^F}{P^F(h)} \tag{4-48}$$

The effective utilization of the screen area can be calculated from

$$\begin{aligned} AUF &= \text{area utilization factor} \\ &= \frac{\text{tonnage transmitted to undersize}}{\text{theoretical ability of the screen to pass undersize}} \\ &= \frac{W^F P^F(h) \times \text{simulated efficiency}}{A.B.C.D.E.F.G_c \times \text{screen area}} \end{aligned} \tag{4-49}$$

An *AUF* equal to unity indicates that the screen capacity is exactly balanced to the required duty. $AUF > 1$ indicates that the screen is overloaded while $AUF < 1$ indicates that the screen is underloaded

A particular advantage of the Karra screen model is that no free parameters are required to be estimated from operating data.

4.3 A Simple Kinetic Model for Screening

Screening can be considered to be a kinetic process because the rate at which solid particulate material is transmitted through a screen is dependent on the nature of the screen, on the load that the screen is carrying and on the nature and size of particles. Obviously larger particles are transmitted more slowly than small particles and so on. The rate of transmission of particles through the screen will vary from point to point on an actual screen because the load that the screen carries varies in the direction of the material flow. In general the rate of transmission depends primarily on the particle size relative to the screen mesh size.

Observation of operating screens shows clearly that the screen action varies according to the load on the screen. Near the feed end, industrial screens are almost invariably heavily loaded so that the particulate material forms a multilayer of particles on the surface. As the particles move down the screen surface, the smaller material falls through and the load on the screen surface decreases steadily until only a monolayer of particles remain. These two conditions are referred to as the crowded and separated regimes respectively.

In the crowded condition, the undersize material must percolate through the upper layers of coarse material before it has a chance to contact the screen and thus fall through. Thus the rate of transmission of material is a function of the size distribution in the particle layer immediately above the screen surface. On the crowded feed end of the screen, the screen, this layer is replenished by downward percolation of undersize material through the upper layers of the bed. The net rate at which particles of a particular size are transmitted through the screen is a function of the percolation process as well as the screen transmission process

This model of the screening operation is illustrated in Figure 4.1

Let $w_i(l)$ = mass flowrate per unit width of screen of material in size interval i down the screen at distance l from the feed end (kg/ms). $w_i(l)$ is related to the discrete size distribution density function

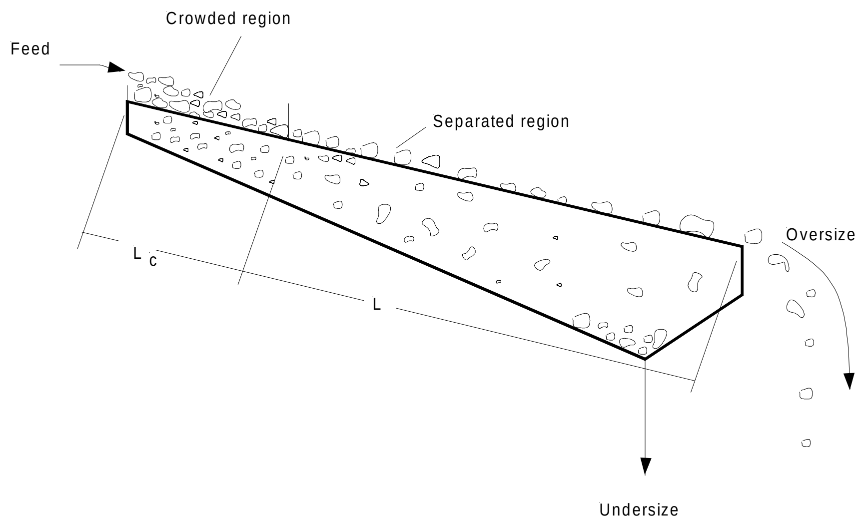

Figure 4.1 *Varying rate of transmission of particles through a wire mesh screen.*

by $w_i(l) = W(l)p_i(l)$ where $W(l)$ is the total flow of material down the screen per unit width at position l and the dependence of these functions on position is shown explicitly by the argument l.

If the rate of transmission of particles in size interval i is represented by $r(d_{pi})$ kg/m^2 s, a differential mass balance gives

$$\frac{dw_i(l)}{dl} = -\, r(d_{pi}) \tag{4-50}$$

This equation can be integrated if a model for the rate of transmission can be developed.

The rate of transmission will be modeled differently under the crowded and separated conditions. Accurate models for the crowded condition are complex since they must take into account both the stratification process and the transmission process. A more realistic model is developed in the next section. We assume here that the rate of transmission does not vary along the screen under crowded conditions and that

$$r(d_{pi}) = k(d_{pi})M_o p_i^F \tag{4-51}$$

where M_o is the load on the screen in kg/m^2 at the feed end. There is some experimental evidence that confirms the constant rate of transmission under crowded conditions. Soldinger M., Interrelation of Stratification and passage in the screening process. Minerals Engineering 12, pp 497 -516, 1999.

The simplest model for the variation of $k(d_{pi})$ with particle size is

$$\frac{k(d_{pi})}{u} = \frac{k_0}{u}\left(1 - \frac{d_{pi}}{u}\right) \qquad \text{for } d_{pi} < h$$

$$= 0 \qquad \text{for } d_{pi} \geq h$$

where k_0/u is the operating parameter. k_0/u will depend on the mesh size and the fraction open area and on other operating parameters such as vibration amplitude and frequency.

Equation (4.50) can be integrated immediately to give

$$w_i(l) = w_i(0) - r(d_{pi})l \tag{4-53}$$

At the transition between the crowded regime and the separated regime $l = L_c$

$$w_i(L_c) = w_i(0) - r(d_{pi})L_c \tag{4-54}$$

$$= \frac{W^F}{b}p_i^F - k(d_{pi})M_o p_i^F L_c \tag{4-55}$$

Let $M(l)$ = total load per unit area of screen surface at a distance l from the feed end in kg/m^2. The flowrate down the screen $W(l)$ is related to the load on the screen by

$$W(l) = M(l)u \tag{4-56}$$

where u is the velocity at which material travels down the screen.

$$\begin{aligned} w_i(L_c) &= M_o u\, p_i^F - k(d_{pi})M_o p_i^F L_c \\ &= M_o p_i^F\left(u - k(d_{pi})L_c\right) \\ &= W^F p_i^F\left(1 - \frac{k(d_{pi})}{u}L_c\right) \end{aligned} \tag{4-57}$$

$$= M_o p_i^F\left(u - k(d_{pi})L_c\right) \tag{4-58}$$

L_c can be defined as the position on the screen at which particles in the smallest size class just become depleted

$$L_c = \frac{u}{k(d_{pN})} \tag{4-59}$$

Under separated conditions, the rate of transmission of particles if size d_p is assumed to be proportional to the amount of that material per unit area of screen surface

$$\frac{dw_i(l)}{dl} = -s(d_{pi})M(l)p_i(l) \tag{4-60}$$

where

$p_i(l)$ = the discrete particle size density function of the material on the screen at distance l from the feed end.

$s(d_{pi})$ = the specific rate of transmission for particles of size d_{pi} (sec^{-1})

$w_i(l)$ is related to $M(l)$ by

$$w_i(l) = p_i(l)M(l)u \tag{4-61}$$

where u is the velocity at which the material travels down the screen surface

$$\frac{dw_i(l)}{dl} = -\frac{s(d_{pi})}{u}w_i(l) \tag{4-62}$$

This is easy to integrate and match the individual mass flowrates for each size interval at the boundary between the crowded and separated regions

$$w_i(l) = w_i(L_c)\exp\left(-\frac{s(d_{pi})}{u}(l-L_c)\right) \tag{4-63}$$

$$= \left[w_i(0) - r(d_{pi})L_c\right]\exp\left(-\frac{s(d_{pi})}{u}(l-L_c)\right) \tag{4-64}$$

The partition factor can be evaluated from equation (4.64)

$$\begin{aligned} c(d_{pi}) &= \frac{w_i(L)}{w_i(0)} \\ &= \left[1-\frac{r(d_{pi})L_c}{w_i(0)}\right]\exp\left(-\frac{s(d_{pi})}{u}(L-L_c)\right) \end{aligned} \tag{4-65}$$

Ferrara et. al. (G. Ferrara, U. Preti and G.D. Schena. International Journal of Mineral Processing 22 (1988) 193-222) have determined the specific rate constant $s(d_{pi})/u$ in terms of the probability of passage of a particle during a single contact with the screen. This is usually computed as the ratio of the area of the effective aperture to the total area of the screen. In order to pass cleanly through a square mesh opening a spherical particle must pass with its center within a square of side h-d_p in the center of the mesh opening. Thus the probability of passage is given by

$$P_r = \frac{(h-d_p)^2}{(h+d_w)^2} = \frac{h^2}{(h+d_w)^2}\left(1-\frac{d_p}{h}\right)^2$$
$$= f_0\left(1-\frac{d_p}{h}\right)^2 \tag{4-66}$$

where f_0 is the fraction open area of the screen. This is illustrated in Figure 4.2.

Ferrara et. al. suggest an empirical functional form

$$\frac{s(d_{pi})}{u} = n f_0^{\sigma/2}\left(1-\frac{d_{pi}}{h}\right)^{\sigma} \tag{4-67}$$

where σ is a constant that should be close to 2. n is the number of presentations per unit length of bed. Equation (4.67) can be written

$$\frac{s(d_{pi})}{u} = s_{50}2^{\sigma}\left(1-\frac{d_{pi}}{h}\right)^{\sigma} \tag{4-68}$$

where s_{50} is the value of $s(d_{pi})/u$ when the particle size is one half the mesh size.

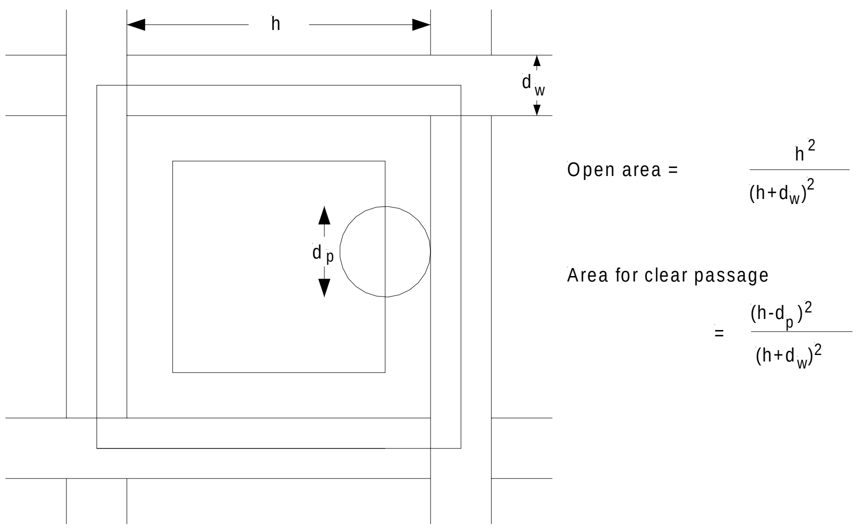

Figure 4.2 *Geometrical restrictions on the passage of a particle through square-mesh screen*

Unfortunately there is very little data available on the value of the transmission rate for crowded conditions, $r(d_p)$, and its variation with particle size and with conditions on the screen. It is also dependent on the size distribution in the feed.