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Performance Investigation of Indigenously Designed Multideck Screen (MDS)

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Abstract

Multideck screen (MDS) has found wide applications in mineral processing, chemical and pharmaceutical industries and their performance can be evaluated on the basis of various parameters. The MDS was indigenously designed with three decks of various replaceable screens. The efficiency of MDS was evaluated at different parameters through efficiency equation and partition/Tromp curves which are normally used for screens, classifiers and separation devises. The imperfection factor and cut size was also determined. Material feed rate of 1 kg/min, 2 kg/min and 3 kg/min; screen angle of 7°, 10° and 13°; aperture size of 2 mm, 1mm and 0.3 mm in the three decks were taken into account. The results showed that the efficiency of MDS improves with increasing screen angle and aperture size whereas it reduces with increasing feed rate. The cut size value improves with increasing screen angle and aperture size whereas it reduces with increasing feed rate. The imperfect factor value reaches zero with increasing screen angle and aperture size while value of imperfect factor increases with increasing feed rate. The maximum efficiency was found approx. 95% at screen angle of 13°, feed rate of 1 kg/min and aperture size of 2 mm.

Keywords: Multideck screen, Partition curve, Imperfect factor, Cut size , Mineral Processing

1. Introduction:

Screening is a process of classifying of particles into two or more products based on size of particles [1]. Screening operation is used in many industries like pharmaceutical, food, cement, chemical, mineral, mining, and metallurgical industries [2, 3]. Screens are most often employed in industries for classifying particles between 300 mm to 40 μm. Dry screening is used to classify particles having size fractions of more than 5 mm whereas wet screening can be used to classify particles up to 250 μm in size. The reduction in screen aperture size drastically put a bad impact on screening performance [4]. Sieves could be alternative to screens for laboratory investigations [5]

In the gravel production and for the extraction of gold from the placer sand, usually MDS screens have been used which save a lot of useful space and are environment friendly. These can classify various materials simultaneously. In addition of producing 3 - 4 products, the MDS is also applied to stone powder and removes fines for secondary and/or tertiary crushing stages. The MDS available in the market are costly and have fixed mesh sizes. Indigenously designed and fabricated MDS are cheaper, easily maintainable and serviceable after installation. In the current research work, the performance of indigenously designed MDS was investigated for various screen factors and the results were analyzed using particle size distriubtion (PSD), cut size and imperfection.

Screens Performance Parameters:

During screening operations, the materials

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stratification takes place [6, 7] and the rate of stratification is influenced by various factors like feed rate, amount of undersize particles in the feed, angle of screen deck and mode of vibration at which screening operation is being conducted [6, 8]. Vibration at predetermined frequency and amplitude helps to provide continued stratification of particles on the screen by raising the particles over and to avoid choking of the screen surfaces.

Setting the screen surface at a specific angle provides movement to the particles being presented on the screen for classification [9]. The likelihood of particles passing via screen aperture determines the passage of particles through screen aperture [10].

There are a number of variables that influence the rate of screening and they are classified into two categories. Operating variables like feed rate, particle size distribution, particle shape, moisture content of the feed, near mesh particles and presence of clay particles in the feed. Machine parameters are screen aperture size, screen aperture shape, open area, size of surface of the screen, angle of screen deck, amplitude and frequency with which screen is operated [1, 11].

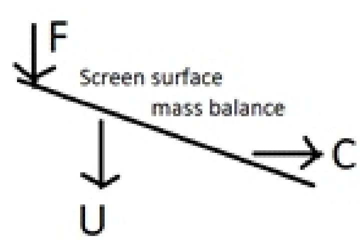
The material flow rate is related to the length of particle residence and the thickness of the screen bed. With a high flow rate, the thickness of the bed increases subsequently followed by reduction in time of residence, thereby decreasing screen performance consequently [9]. A thick bed of material is supplied to the screen at high feed rate due to which some fine particles do not get the opportunity to reach to the bottom of bed before they get passed through the screen aperture. The net result is that overall screening performance is reduced [4]. Rogers and Brame (1985) have conducted various experiments on screen aperture sizes ranging from 292 microns to 111 microns in their research. The results obtained by their experiments revealed that increasing flow rate has very little effect on screening performance given that the capacity of the screen has not been exceeded [12]. The screen angle affects the performance of the screen and how the particles come in contact with the surface of the screen. This phenomenon is used by certain screens to produce separations that are much finer than the screen aperture.

Screening performance could be increased by increasing the angle of screen deck until the maximum value after which further increment in value of angle results in reduced performance of screen. The angle of inclination of the the screen deck angle also influences the speed of particles at which they move along the surface of the screen. Screens placed at steeper slope makes the particles to flow quickly along the screen towards the discharge end due to which the retention time of particles on the screen is reduced and the opportunities for particles to come in contact with the screen surface also reduces, thereby reducing efficiency of screen to classify particles [4, 13].

Screening efficiency can be influenced by its mesh size. Small aperture size of screen results in low efficiency as the chances of the particles to pass through the screen decreases and large amounts of fine particles misplaced and report to the overflow. The large aperture size of the screen results in misplacement of coarse particles in underflow, thereby reducing screen performance [13]. Very fine screen aperture size reduces the open area available for particles to pass through the screen and decreases the efficiency of screen and increases energy consumption [4, 10].

Screens Efficiency Determination:

The most common method of investigating screen efficiency is a thorough efficiency equation obtained from the mass balancing of a system and partition curve and then estimating the parameters of imperfect factor and cut size. A simple mass balance as defined by Wills, 2015 [4] has been given in the following line diagram.



Here F is feed; C is coarser fraction and U is the finer fraction. F, C and U could be in t/h for continuous operations and tons or kg or even in grams for batch operations. The mass balance obtained is:

$$F = C + U \quad (1)$$

Now if f, c and u denote the proportion of material in feed, overflow and underflow that is larger than aperture size as measured on the 100% efficient laboratory screen of the same aperture size as that of the screen whose performance is to be determined then the mass balance of the oversize fraction should be

$$Ff = Cc + Uu \quad (2)$$

And the mass balance of the undersize fraction should be

$$F(1 - f) = C(1 - c) + U(1 - u) \quad (3)$$

Then the recovery of the oversize fraction in the screen oversize will be calculated as

$$R_c = \frac{Cc}{Ff} = \frac{c(f-u)}{f(c-u)} \quad (4)$$

and the undersize fraction in the undersize as:

$$R_u = \frac{U(1-u)}{F(1-f)} = \frac{(c-f)(1-u)}{(c-u)(1-f)} \quad (5)$$

The overall efficiency of the screen operations can be calculated by multiplying the equations (4) and (5) which is denoted with E, [4, 11].

$$E = \frac{c(f-u)(1-u)(c-f)}{f(1-f)(c-u)^2} \quad (6)$$

Tromp, in 1937, invented a universally accepted graphical method which is used to evaluate the efficiency of separation. It is termed as partition curve or Tromp curve. The partition curve has been used to determine the percentage of each size fraction in the feed to the coarse product. The parameters of partition curve are cut size or d_{50} and imperfection factor, I. Cut size or d_{50} is defined as size fraction in the feed at which all the particles will have 50% probability either to report to oversize product or undersize product. Value of cut size is taken corresponding to the 50% partition in partition curve [4, 11]. Imperfect factor or imperfection, I graphically show the deviation of actual curve from ideal curve. The slope of the central segment of the partition curve between partition of 0.75 (75%) and 0.25 (25%) determines the sharpness of cut. The closer the slope to vertical, the higher is the efficiency [14]. Mathematically, the imperfection I is estimated by:

$$I = \frac{d_{75} - d_{25}}{2d_{50}} \quad (7)$$

In equation (7), the terms d_{75}, d_{25} and d_{50} are the particle sizes corresponding to 75%, 25% and 50% partitions on a partition curve respectively. The value of imperfection stays in between 0 and 1 where the value closer to the zero indicates good performance [11, 15]. Ahmad et al [16-17] has developed empirical models for the of washing of bauxite ore. The clay impurities can be removed from the bauxite using the MDS.

2. Experimental Work:

Around 20 kg sand sample was mixed with 20 kg fine crush sample thoroughly. Coning and quartering was carried out on a blended 40 kg sand and crush sample and four representative sets was created, each 10 kg by weight as shown in fig. 1.

Figure 1: Conning and quartering of sample.

Three sets were selected randomly and size analysis of all the three sets were conducted individually. The results show that particle size distribution of all the three sets are almost same and consistent to each other as shown in Fig 2. All the four sets were then packed and saved for subsequent use in experiments.

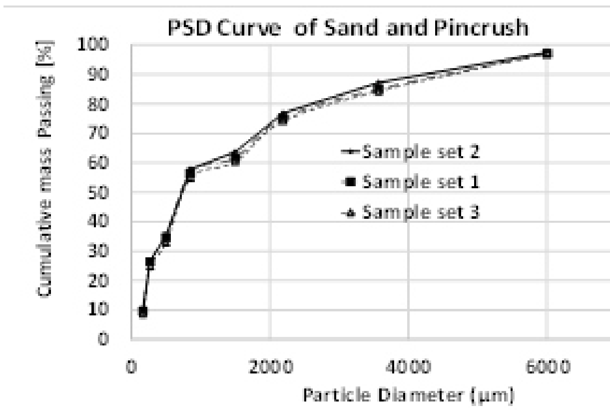


Figure 2: Particle size distribution of feed material.

The different performance affecting factors which were taken into account for investigation of efficiency were feed rate, screen angle and aperture size. Rest of the parameters were fixed. The experimental design for tests on MDS is shown in table 1. The MDS, as shown in fig. 3, was operated five times to collect data for various combinations.

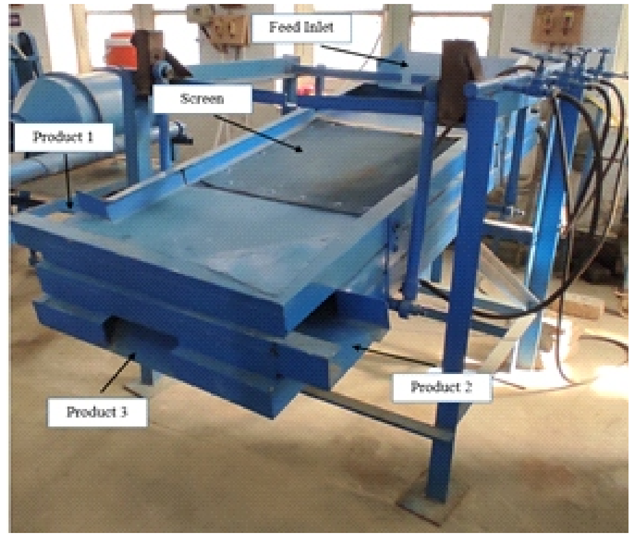


Figure 3: MDS containing 3-Decks

Table 1: Experimental matrix

Exp. #	Feed rate (Kg/min)	Angle (°)	Aperture size (mm)
1	1	7	2
2			1
3			0.3
4		10	2
5			1
6			0.3
7		13	2
8			1
9			0.3
10	2		2
11			1
12			0.3
13	3		2
14			1
15			0.3

Each set of pre-packed sample was used individually for each run. The oversize particles retained on screen surface of each screen deck and moved toward discharge end where they were collected. The undersize particles passed through screen's apertures of each screen deck. On each run of MDS, different products were obtained due to having three different screens mounted on the top of other. The PSD analysis were conducted with the aim to find the values for f, c and u. for each product through sieve analysis and experimental data was collected to investigate the influence of various factors on the MDS efficiency.

3. Results and Discussions:

3.1 Efficiency of MDS:

Using equation (6), efficiency of each deck of MDS screen was evaluated at various factors. The experiments were performed for three different screen angles at same feed rate of 1 kg/min. The result shows that on increasing the screen angle from 7° to 13°(experiments no. 1 to 9), the efficiency of multi-deck screen was found to be increasing at each screen's aperture size as shown in fig 4.

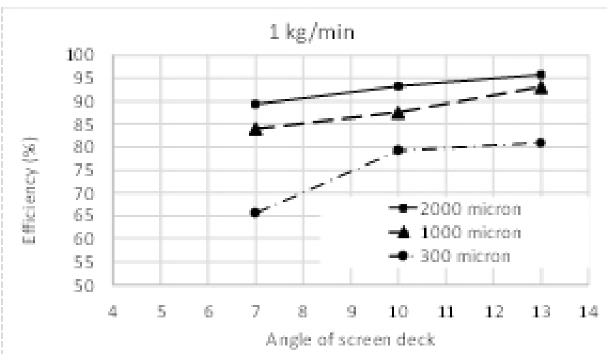


Figure 4: Influence of screen angle on efficiency of multi-deck screen.

Similarly, the experiments were performed for the feed rate of 1, 2 and 3 kg/min three different feed rates at the same screen angle of 13° (experiments no. 7 to 15). The results obtained reveals that on increasing the feed rate from 1 kg/min to 3 kg/min, the efficiency of multi-deck screen was found to be decreasing at each screen's aperture size as shown in fig. 5.

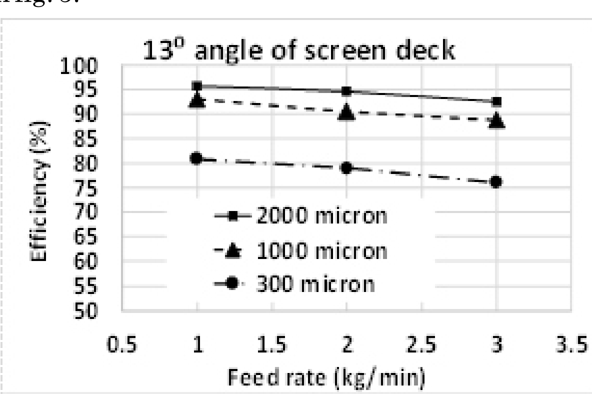


Figure 5: Influence of feed rate on efficiency of MDS

At the same screen angle of 13°, the curves are plotted between MDS efficiency and screen's aperture size at different feed rates. The obtained results show that on increasing the aperture size resulted in increase in efficiency of multi-deck screen as shown in fig. 6.

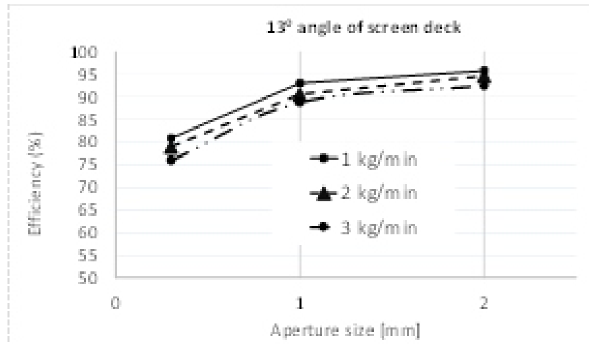


Figure 6: Influence of aperture size on efficiency of MDS

3.2 Cut size:

Using partition curve, cut size values are determined at various factors and compared to get the final results. In fig. 7, it can be seen that on increasing the screen angle from 7□ to 13□, the cut size value was found to be increasing correspondingly at 2 mm and 1 mm screen's aperture size but at 0.3 mm screen's aperture size, the cut size value initially decreased and then increased on increasing the screen angle.

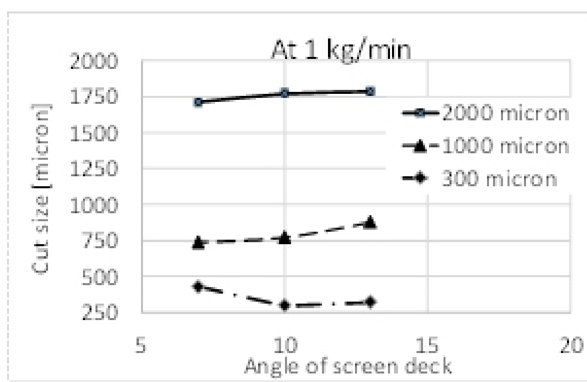


Figure 7: Influence of cut size on screen angle.

The influence of feed rate on cut size value is plotted at different aperture sizes. The obtained results show that on increasing the feed rate from 1 kg/min to 3 kg/min, the cut size value was found to be decreasing at each aperture size as shown in fig. 8.

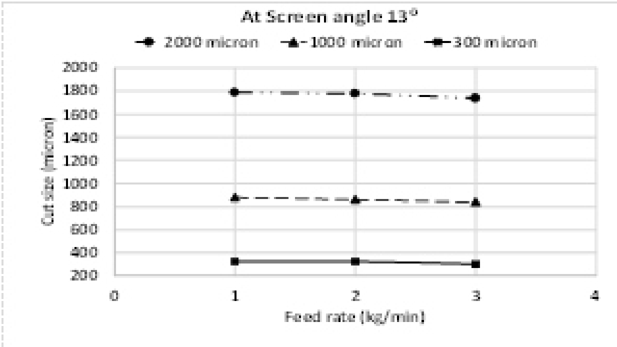


Figure 8: Influence of cut size on feed rate.

In the fig. 9, it can be seen that at different feed rates, increment in screen's aperture size from 0.3 mm to 2 mm, the cut size value was found to be increasing correspondingly.

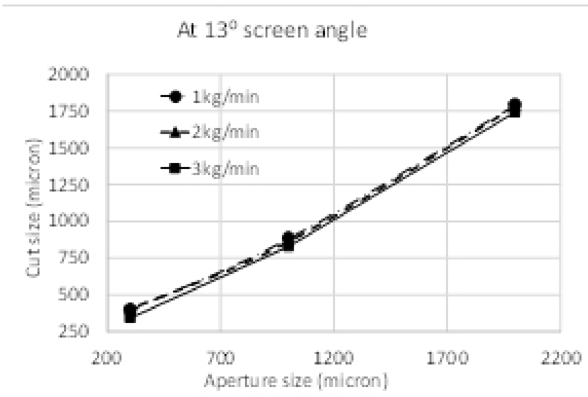


Figure 9: Influence of cut size on aperture size.

3.3 Imperfect Factor:

The influence of screen angle on imperfect factor is plotted at same feed rate of 1kg/min and experimental results are compared. The obtained results reveal that on increasing the screen angle, the imperfection value was found to be decreasing correspondingly. At aperture size of 2 mm and 0.3 mm, the imperfection value initially decreased sharply and then gradual decrease in imperfection value was observed afterward as shown in fig. 10.

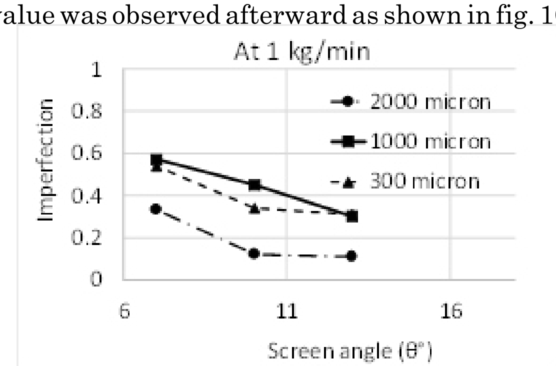


Figure 10: Influence of imperfect factor on screen angle.

As it can be seen in fig. 11, the influence of feed rate on imperfection value is plotted and experimental results reveal that on increasing the feed rate from 1kg/min to 3 kg/min, the imperfection value was found to be increasing correspondingly at each screen's aperture size.

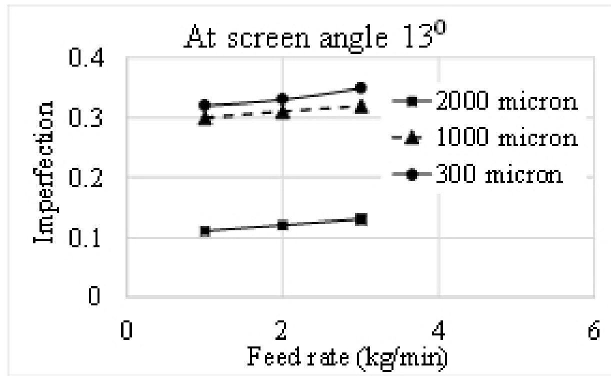


Figure 11: Influence of imperfection factor on feed rate.

Similarly, from fig. 12, it can be observed that imperfection value was found to be decreasing at different feed rates when screen's aperture size increased from 0.3 mm to 2 mm.

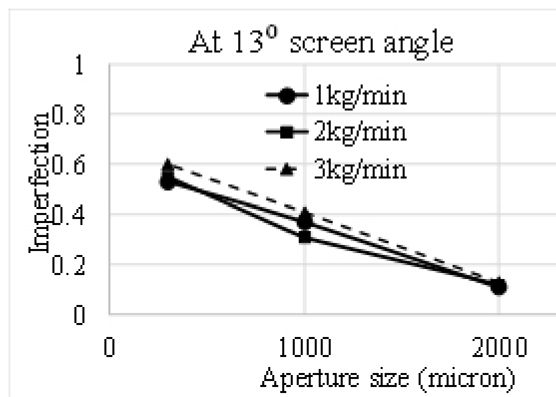


Figure 12: Influence of imperfect factor on aperture size.

4. Conclusions:

MDS screens efficiency was investigate using different performance factors and the obtained results have shown that efficiency of indigenously designed MDS is improved with increase in screen angle and aperture size whereas its efficiency is reduced with increase in feed rate. The maximum efficiency was found to be 95% approximately at screen angle of 13°, feed rate of 1 kg/min and screen's aperture size of 2 mm, where the cut size and imperfection value was found to be 1788 micron and 0.11 respectively. The minimum efficiency was found to be 66% approximately at screen angle of 7°, feed rate of 1 kg/min and aperture size of 0.3 mm, where the cut size and imperfection value was found to be 429 micron and 0.54 respectively.

5. Acknowledgment:

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