CHAPTER 3
DESIGN AND FABRICATION OF DISTRIBUTORS

3.1 INTRODUCTION

The most important part of a fluidized bed is its distributor. A distributor, as the name implies, distributes the air uniformly to the bed. In a conventional fluidized bed, air is admitted vertically upwards to the bed. On the other hand, in a swirling fluidized bed, air enters the bed at an angle and this is achieved by providing inclined holes or inclined slots in the distributor. It is a well accepted fact that high distributor pressure drop is required for good fluidization in conventional fluidized beds. On the other hand, quality fluidization can be achieved in a swirling fluidized bed with a comparatively lower distributor pressure drop.

This chapter deals with the design and fabrication of the following types of distributors.

1. Single row vane type distributor
2. Inclined hole type distributor
3. Three row vane type distributor
4. Perforated plate distributor.

For all other types except the perforated plate distributor, two distributors were fabricated with vane/hole angles of 15° and 20°.

3.2 SINGLE ROW VANE TYPE DISTRIBUTORS

3.2.1 Design

Single row vane type distributors were made by a number of overlapping vanes, shaped as truncated sectors of a circle with a gap between the vanes. The vanes are made from truncated sectors to form an annular region of airflow between the outer
and inner diameters of the distributor. The opening between vanes is of trapezoidal shape and its area is dependent on the vane angle, the gap width between the vanes and the vane thickness. The number of vanes required in the annular region depends on the vane angle and the gap width between the vanes. Hence the design is essentially the determination of the number of vanes and percentage area of opening in a distributor for a known set of parameters.

Consider top edge of two adjacent vanes at its outer radius \( r_o \). The distance between these two points (a and c in figure 3.2.1b) is given by the relation

\[
x_o = r_o \times \sqrt{2 \times (1 - \cos \phi)}
\]  
(3.1)

The gap width between the vane \( \delta_o \) at radius \( r_o \) is given by

\[
\delta_o = r_o \times \sqrt{2 \times (1 - \cos \phi)} \times \sin \theta - t
\]  
(3.2)

The number of vanes can be calculated from equation 3.2 as

\[
N = \frac{360}{\cos^{-1}\left[1 - \frac{( \delta_o + t \cos \theta)}{2 r_o \sin \theta}\right]^2}
\]  
(3.3)

Area of one trapezoidal opening\( = \frac{( \delta_o + \delta_i )}{2} (r_o - r_i) \)

\[
= \left[ r_o \times \sqrt{2 \times (1 - \cos \phi)} \times \sin \theta - t + r_i \times \sqrt{2 \times (1 - \cos \phi)} \times \sin \theta - t \right] (r_o - r_i) \frac{1}{2}
\]

\[
= \left[ \frac{\sqrt{2 \times (1 - \cos \phi)} \times \sin \theta \times (r_o^2 - r_i^2) - t \times (r_o - r_i)}{2} \right]
\]  
(3.5)
Figure 3.2.1 Geometric relationship of vanes in single row vane type distributor
Total area of opening \[ = N \times \left[ \frac{\sqrt{2(1-\cos \phi)}}{2} \times \sin \theta \times (r_0^2 - r_1^2) - t \times (r_n - r_i) \right] \] (3.6)

Percentage area of opening = \[ \frac{N \times \left[ \frac{\sqrt{2(1-\cos \phi)}}{2} \times \sin \theta \times (r_0^2 - r_1^2) - t \times (r_n - r_i) \right]}{\pi (r_0^2 - r_1^2)} \times 100 \] (3.7)

Percentage useful area of the distributor = \frac{(D^2 - D_1^2)}{D^2} \times 100 \] (3.8)

Length of vane \[ = (r_n - r_i) + 2a \] (3.9)

where, the length inserted in the vane holder on one side, \( l = 5 \text{ mm} \)

Width of the vane at radius \( r \), \( W_r \) \[ = r \times \sqrt{2(1-\cos \phi)} \times \cos \theta + l \] (3.10)

where, the overlapping length of the vane, \( l = 15 \text{ mm} \)

Based on the above relations, single row vane type distributors were designed with 15° and 20° vane angles. The design details of single row vane type distributors are given in Table 3.2.1

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Particulars</th>
<th>Vane angle (θ )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>15°</td>
</tr>
<tr>
<td>1</td>
<td>Maximum gap width between vanes, (δ) mm</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Vane thickness, (t) mm</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>Outer radius, (r_o) mm</td>
<td>150</td>
</tr>
<tr>
<td>4</td>
<td>Inner radius, (r_i) mm</td>
<td>90</td>
</tr>
<tr>
<td>5</td>
<td>Number of vanes, (N)</td>
<td>64</td>
</tr>
<tr>
<td>6</td>
<td>Width of vane at ( r_o ), mm</td>
<td>37</td>
</tr>
<tr>
<td>7</td>
<td>Width of vane at ( r_i ), mm</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>Percentage area of opening</td>
<td>19</td>
</tr>
<tr>
<td>9</td>
<td>Percentage useful area of the distributor</td>
<td>64</td>
</tr>
</tbody>
</table>
3.2.2 Fabrication

A square perspex plate of size 400 mm and 10 mm thickness was used to make the distributor. An annular ring having 180 mm inner diameter and 300 mm outer diameter was cut off from this plate, thereby a square plate having a circular hole of 300 mm diameter and a circular disc of 180 mm diameter was obtained. Based on the number of vanes to be used, the outside of the circular disc as well as the inside of the square plate was divided equally and marked with the help of a template. Through these markings inclined grooves corresponding to the vane angle (15° and 20° with horizontal) were cut using a hacksaw. A fixture was specially designed and used for ensuring accuracy while making the inclined grooves. The grooved circular disc and square plate were then screwed to a plywood base in such a way that the 300 mm diameter hole of the square plate and circular disc were concentric.

Vanes were made as per the design using 0.8 mm thick steel plate. These vanes were inserted into the grooves in such a manner that the top edge of each vane was flush with the surface of the distributor and was in the radial direction. The vanes were then fixed in position with epoxy resin. Figure 3.2.2 shows the photograph of a single row vane type distributor fabricated.

![Figure 3.2.2 Photograph of single row vane type distributor](image_url)
3.3 INCLINED HOLE TYPE DISTRIBUTORS.

In general, there is practical difficulty in increasing the useful area of single row vane type distributors beyond a certain limit. This is because the gap width between two adjacent vanes decreases inwards as the radius reduces and as a result, the fabrication of a full spiral distributor is difficult. However, instead of trapezoidal openings, if circular openings are provided in the distributor, the useful area of the distributor can be increased. This thinking lead to the design of inclined hole type distributor. The following section deals with the design and fabrication of inclined hole type distributors.

3.3.1 Design

The following factors were considered for the design of inclined hole type distributor.

1. **Size of hole**  
   - governed by the minimum size of bed particle.
2. **Radial pitch of hole**  
   - selected to achieve the maximum percentage area of opening
3. **Circular pitch of hole**  
   - selected to achieve the maximum percentage area of opening which depends on the inclination of the hole.

The percentage area of opening and percentage useful area of the distributors can be calculated from the following expressions.

\[
\text{Percentage area of opening} = \frac{(d^2 \times n)}{(D^2 - D^2_c)} \times 100 \quad (3.11)
\]

\[
\text{Percentage useful area of the distributor} = \frac{(D^2 - D^2_c)}{D^2} \times 100 \quad (3.12)
\]

The following parameters have been considered for the present study.

1. Inclination of hole to the horizontal \((\theta)\) = 15° and 20°
2. Diameter of the distributor \((D)\) = 300 mm
3. Diameter of the hole \((d)\) = 3 mm  
4. Radial Pitch = 10 mm  
5. Thickness of the distributor \((t)\) = 10 mm  
6. Diameter of the cone \((D_c)\) = 75 mm

Based on the above parameters, two distributors have been designed and details of the distribution of holes within the distributor are given in Table 3.3.1

Table 3.3.1 Distribution of holes in inclined hole type distributors

<table>
<thead>
<tr>
<th>Sl.No.of Concentric ring</th>
<th>Ring diameter (mm)</th>
<th>Number of holes on the ring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(\theta = 15^\circ)</td>
</tr>
<tr>
<td>1</td>
<td>80</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>160</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>180</td>
<td>26</td>
</tr>
<tr>
<td>7</td>
<td>200</td>
<td>29</td>
</tr>
<tr>
<td>8</td>
<td>220</td>
<td>32</td>
</tr>
<tr>
<td>9</td>
<td>240</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>260</td>
<td>39</td>
</tr>
<tr>
<td>11</td>
<td>280</td>
<td>42</td>
</tr>
<tr>
<td>Total number of holes</td>
<td></td>
<td>285</td>
</tr>
</tbody>
</table>

3.3.2 Fabrication

Due to the difficulties in drilling holes at low angles (15° and 20° to the horizontal), tubes with appropriate inner diameter have been considered for holes. Accordingly, brass tubes with 5 mm outer diameter and 3 mm inner diameter were selected and it was proposed to place these tubes at an appropriate angle and cast them in resin, to make the inclined hole type distributors.

For accurate cutting of tubes with required angle and length, special fixtures were
fabricated. The fixture essentially consists of a 90 mm long HCHC steel with a square cross section of side 25 mm. A 5 mm diameter hole was drilled centrally in the axial direction of the fixture. One end of the fixture was shaped to the required angle. Parallel to the shaped face of the fixture and at a distance of 10 mm from it, a slot with 0.8 mm width and 16 mm depth was made. Provision was made in the fixture to hold the tube in position during the cutting operation. A three dimensional view of the fixture is shown in figure 3.3.1

![Figure 3.3.1 Three dimensional view of the fixture](image)

The fixture was first fixed in a bench vice. One end of the tube was inserted through the hole and was fixed in position with the bolt provided. The tube was then cut through the slot of the fixture with a hacksaw so as to obtain the required angle (15° or 20°) on one end of the tube. The tube was then advanced through the hole and the cut end of the tube was made flush with the inclined surface and fixed. Now, cutting the tube through the slot of the fixture will give one piece of the tube with the designed dimensions.

Concentric circles were drawn with a radial pitch of 10 mm, starting from a radius of 80 mm to 280 mm on the drawing sheet which was fixed to plywood with adhesive. On each circle, markings were made based on the radial pitch. The tube pieces were
aligned and fixed on the markings with adhesive. While fixing the tubes, they were aligned tangential to the circles drawn with a fixture. A metallic ring of 330 mm inside diameter and 10 mm height was fixed on the drawing sheet in such a way that the ring and the circles drawn on the sheet were concentric. The space within the metallic ring was carefully filled with epoxy. The whole set-up was kept undisturbed for 24 hours. Distributor faces were polished to have an even surface. A cone (75 mm base diameter and 60° apex angle) was fixed at the center of the distributor by bolts. Figure 3.3.2 shows the photograph of the distributor thus fabricated.

![Figure 3.3.2 Photograph of inclined hole type distributor](image)

While the percentage useful area of both the distributors came to 94, the percentage area of opening for the distributors with 15° and 20° hole angle works out to be 3 and 5 respectively.

### 3.4 THREE ROW VANE TYPE DISTRIBUTORS

It is felt that without much reduction from the percentage area of opening of a single row vane type distributor, the percentage useful area of the distributor can be increased by arranging the vanes in the form of circular rows. This is a new method proposed by the investigator.
3.4.1 Design

In the present study, an attempt has been made to arrange vanes in three rows. Each row of the distributor can be designed similar to that of single row vane type distributor. The following parameters were selected for this design.

1. Length of opening in each row = 30 mm
2. Maximum gap width between vanes = 3 mm
3. Vane thickness, \( t \) = 0.8 mm
4. Width of vane holder = 8 mm
5. Vane angle \( \theta \) = 15° and 20°

Based on the above parameters, two distributors were designed and the details are given in Table 3.4.1

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Particulars</th>
<th>Vane angle( ( \theta ) )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>15°</td>
</tr>
<tr>
<td>1</td>
<td>Diameter of the distributor, mm</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>Number of vanes in the outer row</td>
<td>64</td>
</tr>
<tr>
<td>3</td>
<td>Number of vanes in the middle row</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>Number of vanes in the inner row</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>Diameter of the cone, ( (D_c) ), mm</td>
<td>88</td>
</tr>
<tr>
<td>6</td>
<td>Percentage area of opening</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>Percentage useful area of the distributor</td>
<td>91</td>
</tr>
</tbody>
</table>

3.4.2 Fabrication

A 10 mm thick mild steel plate was used to fabricate the vane holders. The vane holders are in the form of three annular rings and a circular disc. Three 8 mm wide metallic rings were cut from a 10 mm thick metallic plate. Depending on the number of vanes to be provided in each row, markings were made on the periphery of the rings or disc, as the case may be, using a template. Through these markings, inclined
grooves corresponding to the designed vane angles were cut using hacksaw. A fixture was designed and used for ensuring accuracy while making inclined grooves. The rings and circular disc were screwed concentrically on a plywood sheet and vanes were fixed in their corresponding slots with epoxy. Figure 3.4.1 shows the photograph of one of the distributors fabricated

![Photograph of three row vane type distributor](image_url)

**Figure 3.4.1 Photograph of three row vane type distributor**

### 3.5 PERFORATED PLATE DISTRIBUTOR

A perforated plate distributor was fabricated for the purpose of determining the minimum fluidization velocity of bed materials. Perspex sheet of 10 mm thickness was used for the distributor and circular holes were drilled. The fabrication details are presented below.

- Diameter of the distributor (D) = 300 mm
- Diameter of hole (d) = 2.5 mm
- No. of holes (n) = 1258
- Percentage area of opening = 9%

### 3.6 CONCLUSIONS

A total of seven distributors have been designed and fabricated namely single row vane type distributors (15° and 20° vane angle), inclined hole type distributors (15° and...
and 20° hole angle), three row vane type distributors (15° and 20° vane angle) and perforated plate distributors. The useful area of distributor of single row vane type, three row vane type and inclined hole type distributors are 64 %, 91 % and 94 % respectively. The method of fabrication, and design details have been explained for each distributor.