6.1 Introduction

This chapter explains the modelling and analysis of plane jets like single jet, twin jets, triple jets and differential triple jets. The necessary designation methodology followed for assigning the jet combinations are explained in this chapter. Each type of jet is dealt separately regarding its modelling and solution domain details. A grid independency study is done for single plane jet and the best grid pattern is selected which is followed in other jets also. Multiple jet combinations are analyzed for its merging details. A detailed discussion of the results is presented in this chapter.

6.2 Single Jet

In this section three configurations of plane jets are studied to get better understanding about the jet characteristics. The plane jets are designated by ‘d by t PJ’. The selected configurations are 10 by 10 PJ, 12 by 10 PJ and 14 by 10 PJ. A grid independency study is carried out to find the best grid structure for the analysis using the 10 by 10 PJ model. The model is given 7 different grid structures, 75000, 65000, 60000, 53000, 48000, 44000 and 37000
(75K, 65K, 60K, 53K, 48K, 44K and 37K). The solution domain for analysis is shown in Fig 6.1 along with the necessary boundary types used. The pressure difference across the tile is assigned a value of 37.376 Pa (0.15 inches of water column).

Fig 6.1 Solution domain and boundary types of plane jet
The results of the grid independency study are given in the figures 6.2 to 6.6.

Fig 6.2  Centreline Velocity decay for various grid structures.

Fig 6.3  Near field velocity development for various grid structures.

Fig 6.4  Velocity profile at 30d for various grid structures.

Fig 6.5  Velocity profile at 50d for various grid structures.

Fig 6.6  Velocity profile at 70d for various grid structures.

The grid independency study reveals that the solution is independent of grid pattern; hence the grid pattern corresponding to 37K model is selected for further analysis.
6.3 Twin Jet

Twin jets are developed using the basic single jet configurations analyzed in the previous section. The distance between the two single jets is designated as pitch (P). The pitch values selected for analysis are 4mm and 6mm. All the twin jet combinations are analyzed for two sets of pressure differences. The selected pressure differences are 37.376 Pa and 18.688 Pa. The twin jets are designated by the following method, ‘d by t PxTJ(y)’. Where d- the diameter of jet, t- the thickness of tile, P- pitch, x- pitch value, TJ-twin jet and y- pressure difference across the tile (1 or 2). 1 refers to 37.376 Pa and 2 refer to 18.688 Pa. In this method 12 twin jet models are developed and analyzed. The solution domain and the boundary types are presented in Fig 6.7.

![Fig 6.7 Solution domain and boundary types of twin jet](image)

6.4 Triple Jet

Triple jets are developed by using the basis of single jet configuration; the jets are designated by ‘d by t PTrJ’. Triple jets are analyzed for only one pressure difference (37.376 Pa). The pitch values are taken as 4mm and 6mm. This will give six triple jet configurations for analysis. The solution domain and the boundary types are presented in Fig 6.8.
6.5 Differential Triple Jet

Differential triple jets are developed to study the interaction of jets of different diameters when they are placed in the same plane. This study will give an insight to the relative influence of a jet on other jets of different diameters. In differential triple jets, two jets will have the same diameter to form the top and bottom jet and another jet of a different diameter will form the central jet. The differential triple jets are represented as ‘2 by d₁ by t+d₂ by t PxDTrJ’. In this combination, the jet having diameter d₂ forms the central jet and the other two jets of diameter d₁ form the top and bottom jets. All the three jets have same thickness of 10mm and all are placed at a pitch of 4mm or 6mm. The differential triple jets are analyzed for a single pressure difference of 37.376 Pa. The solution domain of the triple jet configuration is based on the bigger jet diameter. The other details of the solution domain and boundary types are the same as that of triple jet configuration as given in Fig 6.8

6.6 Results And Discussion

The results of all the above jet models are summarized in the following sections and a detailed discussion is also made.
6.6.1 Single Jet

Three plane jets under consideration are modelled and analyzed using the 37K grid pattern. The half width variation, centreline velocity decay, development of near field velocity, the velocity profile comparisons and the self similarity plots are given in figures 6.9 to 6.22.

![Fig 6.9 Comparison of half width variation of different jet models](image)

![Fig 6.10 Comparison of velocity decay of different jet models.](image)

![Fig 6.11 Comparison of near field velocity of different jet models.](image)

![Fig 6.12 Velocity profiles of 10 by 10 jet at different locations.](image)

![Fig 6.13 Velocity profiles of 12 by 10 jet at different locations.](image)
Fig 6.14  Velocity profiles of 14 by 10 jet at different locations.

Fig 6.15  Comparison of velocity profiles of different jet models at 20d.

Fig 6.16  Comparison of velocity profiles of different jet models at 40d.

Fig 6.17  Comparison of velocity profiles of different jet models at 60d.

Fig 6.18  Comparison of velocity profiles of different jet models at 80d.

Fig 6.19  Comparison of velocity profiles of different jet models at 100d.
Fig 6.20 Self similarity velocity profiles of 10 by 10PJ at different locations.

Fig 6.21 Self similarity velocity profiles of 12 by 10PJ at different locations.

Fig 6.22 Self similarity velocity profiles of 14 by 10PJ at different locations.
The different velocity values of plane jets are summarized in Table 6.1

**Table 6.1 Comparison of velocities of single plane jets**

<table>
<thead>
<tr>
<th>Model</th>
<th>(U_0)</th>
<th>(U_{\text{max}})</th>
<th>x</th>
<th>(x/d)</th>
<th>(U_0)-Jet exit velocity m/sec</th>
<th>(U_{\text{max}})-Jet maximum velocity m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 by 10 PJ</td>
<td>7.7659</td>
<td>7.802</td>
<td>0.024</td>
<td>2.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 by 10 PJ</td>
<td>7.7662</td>
<td>7.8033</td>
<td>0.026</td>
<td>2.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 by 10 PJ</td>
<td>7.7663</td>
<td>7.8035</td>
<td>0.03</td>
<td>2.14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the half width variation plot of the jets, it can be seen that the three jets exhibit similar characteristics with respect to spread rates. The velocity decay and the near field velocity development are also similar for the three jets. The velocity profiles at different \(x/d\) positions show that as the diameter of the jet increases the spread increases in the \(y\) direction for \(x/d\) values beyond 40. This may be due to the increased mass flow and momentum occurring at higher jet diameters. The increase in mass flow and momentum will lead to higher entrainment of the surrounding air. This behaviour results in an extended velocity profile in \(y\) direction. From Table 6.1 it can be seen that the three jets have equal exit and maximum velocities for the same pressure difference. The location of maximum velocity increases slightly as the diameter increases. As the jet diameter increases, the strength of the jet is more and the decay is less. But this effect is not much significant to make a notable change in the velocity profile. From the self similarity figures of the jet it can be seen that the jets are self similar beyond \(x/d\) values of 20.
6.6.2 Twin Jet

The merging characteristics of different twin jet configurations are summarized in the Table 6.2.

Table 6.2 Comparison of twin jet velocities.

<table>
<thead>
<tr>
<th>Jet Model</th>
<th>U_o</th>
<th>U_m</th>
<th>U_av</th>
<th>(x/d)_m</th>
<th>(\Delta P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10by10P4TJ(1)</td>
<td>8.06051</td>
<td>6.78904</td>
<td>4.097584</td>
<td>17.9179</td>
<td>37.376 Pa</td>
</tr>
<tr>
<td>10by10P4TJ(2)</td>
<td>5.69736</td>
<td>4.78064</td>
<td>2.790963</td>
<td>17.2172</td>
<td></td>
</tr>
<tr>
<td>10by10P6TJ(1)</td>
<td>8.1343</td>
<td>6.58692</td>
<td>4.048058</td>
<td>18.6186</td>
<td></td>
</tr>
<tr>
<td>10by10P6TJ(2)</td>
<td>5.74997</td>
<td>4.63317</td>
<td>2.752152</td>
<td>17.9179</td>
<td></td>
</tr>
<tr>
<td>12by10P4TJ(1)</td>
<td>8.03217</td>
<td>6.87227</td>
<td>4.112664</td>
<td>18.5185</td>
<td></td>
</tr>
<tr>
<td>12by10P4TJ(2)</td>
<td>5.67718</td>
<td>4.84105</td>
<td>2.80458</td>
<td>18.1181</td>
<td></td>
</tr>
<tr>
<td>12by10P6TJ(1)</td>
<td>8.11322</td>
<td>6.69454</td>
<td>4.078335</td>
<td>19.1191</td>
<td></td>
</tr>
<tr>
<td>12by10P6TJ(2)</td>
<td>5.73484</td>
<td>4.71182</td>
<td>2.776728</td>
<td>18.5185</td>
<td></td>
</tr>
<tr>
<td>14by10P4TJ(1)</td>
<td>8.00783</td>
<td>6.93515</td>
<td>4.113829</td>
<td>19.019</td>
<td>37.376 Pa</td>
</tr>
<tr>
<td>14by10P4TJ(2)</td>
<td>5.66003</td>
<td>4.88669</td>
<td>2.813632</td>
<td>18.7187</td>
<td>18.688 Pa</td>
</tr>
<tr>
<td>14by10P6TJ(1)</td>
<td>8.09216</td>
<td>6.77494</td>
<td>4.089483</td>
<td>19.5195</td>
<td></td>
</tr>
<tr>
<td>14by10P6TJ(2)</td>
<td>5.71971</td>
<td>4.7709</td>
<td>2.796598</td>
<td>19.019</td>
<td></td>
</tr>
</tbody>
</table>

It can been seen that all the twin jet combinations show an increase in the jet exit velocity with respect to the corresponding plane jet values. This increase in velocity is due to the creation of an additional pressure drop resulting from the mutual entrainment of the jet. The rate of increase in velocity in all the configurations is the same. As the pitch increases the exit velocity shows an increase. This is due to the fact that as pitch increases, the merging point shifts to the downstream. This is clear from the \((x/d)_m\) values, which will provide an increase in the entrainment area below the merging point in between the jets. Since
the two jets are identical, their merging axis will be at the midway as shown in Fig 6.7. The merging point is located as the maximum velocity point on the merging axis. The merging velocity shows a decrease as the pitch increases. This is natural as they merge at a point further downstream in x direction where the individual velocities are lower. The average velocities beyond the merging point also shows a decreasing trend as pitch increases. This is also due to the reason that the merging velocities decrease as the pitch increases. The downstream velocities are still lower and the average velocity is also low. This shows that the pitch cannot be increased beyond 6mm with respect to the steady average velocity after merging as this average velocity plays an important role in data centre air flow through perforated tiles.

As the pressure difference across the tiles decreases (in the analysis it is reduced to half) all the parameters under consideration tend to decrease. The trend is identical and it is concluded that as the pressure difference across the tiles decreases the jet characteristics decline steadily. The figures 6.23 and 6.24 illustrate the comparison of jet velocities beyond the merging point and the velocity profiles at merging point of different twin jet combinations respectively.

**Fig 6.23** Comparison of velocity beyond merging point for different twin jet models.
Fig 6.24 Comparison of $y$ velocity at merging point for different twin jet models.

Fig 6.25 Comparison of velocity profile at $(x/d) = 40$ for different twin jet models.

The Figure 6.25 shows a comparison of velocity profile at $(x/d) = 40$, which shows that the velocity profiles differ as the jet diameter changes; but the velocity profiles are similar for a jet with same diameter but different pitches. This shows that after merging, the velocity profile is independent of the pitch.

The figure 6.26 illustrates the half width variation of different twin jet configurations for pressure difference of 37.376 Pa.
From the figure 6.27, it can be observed that the half width variation of the twin jet combinations for a particular pressure difference is similar after the merging point. All twin jet models merge before \((x/d) = 20\), from \((x/d)\) values 20 to 40 the jet spread shows a linear variation and beyond \((x/d) = 40\) it shows a non-linear variation. Up to \((x/d) = 40\) the merged jet stabilizes and after that the jet spreads in the y direction as a single jet. When the pressure difference across the tile reduces the half width variation follows the same trend but the half width variation slightly changes as the pitch changes for same diameter jets. These results
are highly encouraging as the velocity profile after merging is independent of jet diameter and the pitch. This information enables the tile designer to design different area ratio tiles without affecting the air flow pattern within the data centre.

The figures 6.28 to 6.35 illustrate the self similarity of the merged twin jets for different (x/d) locations.

**Fig 6.28** Self similarity of 10 by 10 P4TJ(1) at different locations

**Fig 6.29** Self similarity of 10 by 10 P6TJ(1) at different locations

**Fig 6.30** Self similarity of 12 by 10 P4TJ(1) at different locations.

**Fig 6.31** Self similarity of 12 by 10 P6TJ(1) at different locations.
From the above figures it is clear that the twin jets exhibit self similarity after they merge and shows the characteristics of a single jet thereafter. This is found to be true for all values of operating pressure differences across the jet.

6.6.3 Triple Jet

The merging characteristic of triple jet is totally different from that of twin jet. The twin jet exhibits a definite point of merging which can be located by the maximum velocity in the merging axis. In triple jet models there exist three axes of merging. The first axis is the merging axis of the top jet and the central jet and is drawn through the centre of the top jet and the central jet. The second axis is the merging axis of the bottom jet and the central jet and the third axis is the central jet axis itself. The merging process of the three jets is highly
complex as all the three jets will mutually entrain each other and merge. The top jet and the central jet will merge with each other, at the same time, the central jet and the bottom jet will merge at a symmetrical position. In the present analysis, it is assumed that the triple jet model is symmetric about the central jet axis so that the bottom merging axis need not be considered as it is similar to the top merging axis. The top merging axis velocity increases to a maximum value and then decreases. The maximum velocity point on the top merging axis is considered as the primary merging point of the top jet and the central jet. Corresponding to this it is possible to get a similar point on the bottom merging axis also. At this point of the triple jet model the velocity profile is expected to have a profile similar to that of a twin jet, as the top jet and central jet merges and bottom jet and central jet merges and both proceeds as independent jets downstream giving a twin jet profile. But the actual profile at the primary merging point is not distinctly as that of twin jet. This is because the lateral portion of the central jet merges with the respective jets over and below it, the core of the central jet is still moving with much higher velocities than the primary merging velocity.

In order to find the exact location where the three jets merge, the primary merging point velocity is located in the central jet velocity axis and this position along the central jet axis is considered as the complete merging point of the three jets. At this point the velocity profile shows similar characteristics as that of a single jet. The figure 6.36 shows the velocity profiles of all triple jet configurations at their respective complete merging point.
At the point of complete merging, it is observed that for all models of triple jets the central jet velocity decay shows an abrupt change in its slope. For a considerable distance upstream of this point, the velocity decay curve is flatter and immediately after this point the curve becomes steeper showing faster velocity decay. This behaviour of triple jet models is similar to that of a single jet whose velocity decay becomes faster beyond the potential core region. Hence the selection of the complete merging point can be justified since the velocity decay beyond this point is similar to that of single jet velocity decay. The figure 6.37 shows the complete merging point on the central jet axis where the slope changes.
The figure 6.38 shows the half width variation of triple jet and the comparison with twin jet.

From the figure, it is clear that the triple jet is having similar characteristics as that of a single jet beyond \((x/d)\) values of 40. The half width variation of a triple jet is less than that of a twin jet of similar configuration. It can be inferred that the triple jets are stronger than twin jets. The self similarity plots of triple jet are shown in figures 6.39 and 6.40.
The velocities of triple jet models are summarized in Table 6.3.

### Table 6.3 Comparison of triple jet velocities.

<table>
<thead>
<tr>
<th>Model</th>
<th>$U_{oc}$</th>
<th>$U_{ot}$</th>
<th>$U_{mt}$</th>
<th>$x_{mt}/d$</th>
<th>$x_{m}/d$</th>
<th>$U_{av}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10by10P4TrJ</td>
<td>8.46908</td>
<td>8.10183</td>
<td>6.84578</td>
<td>14.2142</td>
<td>27.5775</td>
<td>4.86916</td>
</tr>
<tr>
<td>12by10P4TrJ</td>
<td>8.38394</td>
<td>8.06397</td>
<td>6.94368</td>
<td>15.6156</td>
<td>31.3269</td>
<td>4.81689</td>
</tr>
<tr>
<td>14by10P4TrJ</td>
<td>8.31579</td>
<td>8.03317</td>
<td>7.00715</td>
<td>16.5165</td>
<td>33.3</td>
<td>4.78594</td>
</tr>
</tbody>
</table>

$U_{oc}$ - Central jet exit velocity m/s  
$U_{ot}$ - Top jet exit velocity m/s  
$U_{mt}$ - Top merging axis velocity m/s  
$x_{mt}/d$ - Top merging point location  
$x_{m}/d$ - Complete merging position on central jet  
$U_{av}$ – Average velocity beyond complete merging point m/s

The twin jet geometries exhibit slightly decreasing trend for jet exit velocity as the jet diameter increases. As the pitch increases the jet exit velocity increases and decreases as jet diameter increases. The triple jets also follow the same trend in jet exit velocities as that of twin jets. The corresponding velocities in triple jet configurations are greater than that in twin jet configurations. The central jet shows much higher velocities when compared to the other jets. This is due to the fact that the neighbouring jets entrain the central jet from two sides thereby enabling the central jet to accelerate more. The central jet will also entrain the neighbouring jets but the side jets will be entrained by the central jet only on one side. From the other side stagnant air entrains in to the side jets there by their acceleration and hence the velocities will be less than that of the central jet.

The merging point velocities in triple jets are higher than that of twin jet models for pitch values of 4mm. But for 6mm pitch the merging point velocities for triple jet is less than the corresponding values of twin jet. This is due to the increased influence of the recirculation zone present between the triple jets compared to twin jets. As pitch
increases this zone builds up more and will influence the velocity decay thereby reducing the merging point velocity. But this effect is not much significant to create a large velocity decrease. The average velocities beyond complete merging are higher in the case of triple jets. The velocity decay of triple jets after complete merging is shown in the figure 6.41.

![Figure 6.41](image)

**Fig 6.41** Comparison of velocity beyond merging point for various triple jet models.

### 6.6.4 Differential Triple Jet

The merging characteristics of differential triple jets are quiet similar to that of triple jet. The top merging velocity and the complete merging point are located in similar method for differential jets also. The different velocity values are given in Table 6.4.

<table>
<thead>
<tr>
<th>Model</th>
<th>$U_{oc}$</th>
<th>$U_{at}$</th>
<th>$U_{mt}$</th>
<th>$x_{mt}$</th>
<th>$x_{m}$</th>
<th>$U_{av}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2by10by10+12by10P4DTrj</td>
<td>8.3769</td>
<td>8.0946</td>
<td>6.8621</td>
<td>0.15775</td>
<td>0.35961</td>
<td>4.5316</td>
</tr>
<tr>
<td>2by10by10+14by10P4DTrj</td>
<td>8.3062</td>
<td>8.0898</td>
<td>6.8601</td>
<td>0.15515</td>
<td>0.40484</td>
<td>4.9056</td>
</tr>
<tr>
<td>2by12by10+8by10P4DTrJ</td>
<td>8.6567</td>
<td>8.1018</td>
<td>6.8121</td>
<td>0.23222</td>
<td>0.36817</td>
<td>4.4961</td>
</tr>
<tr>
<td>2by12by10+10by10P4DTrJ</td>
<td>8.4756</td>
<td>8.0698</td>
<td>6.9156</td>
<td>0.19258</td>
<td>0.26826</td>
<td>4.8919</td>
</tr>
<tr>
<td>2by10by10+12by10P6DTrJ</td>
<td>8.6613</td>
<td>8.2013</td>
<td>6.5361</td>
<td>0.19258</td>
<td>0.45395</td>
<td>4.4247</td>
</tr>
<tr>
<td>2by10by10+14by10P6DTrj</td>
<td>8.5781</td>
<td>8.1959</td>
<td>6.5308</td>
<td>0.19018</td>
<td>0.48623</td>
<td>4.8093</td>
</tr>
<tr>
<td>2by12by10+8by10P6DTrJ</td>
<td>8.8845</td>
<td>8.1988</td>
<td>6.6332</td>
<td>0.23222</td>
<td>0.36779</td>
<td>4.5042</td>
</tr>
<tr>
<td>2by12by10+10by10P6DTrJ</td>
<td>8.7789</td>
<td>8.1913</td>
<td>6.6441</td>
<td>0.23583</td>
<td>0.43921</td>
<td>4.5849</td>
</tr>
</tbody>
</table>
The differential triple jet model 2 by 10+12 by 10 P4DTrJ is developed by replacing the central jet of 10 by 10 P4TrJ by a 12 by 10 plane jet. The results from table 6.4 says that, the central jet exit velocity and top jet exit velocity of the differential triple jet is less than the corresponding value of the triple jet even though the third jet is a larger diameter jet. When the number of jets increases, the individual jet velocity will be higher than the corresponding plane single jet exit velocity. This is due to the additional momentum developed by mutual entrainment of the jets. When the central jet of a triple jet is replaced by a plane jet of higher diameter, a reduction in the individual jet velocity occurs and the additional momentum developed due to mutual merging is less than that in a similar triple jet. The bigger central jet, as it develops, will try to deflect the neighbouring jet outwards there by loose its momentum at the beginning and shows a reduced exit velocity. At the same time smaller jets experience a resistance towards their growth as the central jet deflects them outward and their exit velocities are also less. This trend will continue till the first merging location is reached. The top merging velocity of differential triple jet is higher than that in the triple jet. This is due to the fact that the differential triple jet merges little early where the velocities are higher. The average velocity after merging is still higher for triple jet configuration even though the top merging velocity is low. This is evident form the position of the complete merging point of differential triple jet. The complete merging of the differential triple jet takes place at a point further downstream compared with the triple jet.

When the central jet of a 12 by 10 P4TrJ is replaced by a 14 by 10 plane jet to develop 2 by 12 by 10+14 by 10 P4DTrJ, the results follow the same trend as before. Hence it can be generalized that when the central jet of a triple jet is replaced by a higher diameter jet, except the top merging velocity, all other important velocities decrease. The reduction in average velocity after merging is of big concern. Even though the merging takes place at a farther downstream location with respect to triple jet, the merging velocity is higher due to the dominance of the
higher momentum of the larger diameter jet. The reduction in the average velocity is due to the higher decay rates.

When the central jet of a 12 by 10 P4TrJ is replaced by a 8 by 10 plane jet to develop 2 by 12 by 10+8 by 10 P4DTrJ, the central jet exit velocity and the top jet exit velocity increases while the top merging velocity decreases. This behaviour is exactly opposite to that seen in the previous cases. The increase in the exit velocities of the jet can be explained as follows. Since the central jet is smaller, it cannot deflect the bigger outer jets; rather, the bigger jets entrain the smaller jet completely thereby increasing the potential for higher velocities. The differential triple jet and the triple jet merge at a similar position. The reduction in merging velocity indicates that the decay rates are larger for differential triple jets. The average velocity after complete merging shows a decreasing trend which needs further explanation. The central jet of 12 by 10 P4TrJ is replaced by a 10 by 10 plane jet to make another combination to investigate this interaction. All velocities except the average velocity follow the same trend after complete merging. The average velocity shows an increasing trend. In order to confirm the trend of average velocity another combination is tried by replacing the central jet of a 10 by 10 P4TrJ by an 8 by 10 plane jet. All the velocities are found to follow the same trend, but the average velocity shows a different trend. Hence it can be concluded that when the central jet of a triple jet is replaced by a smaller diameter jet, all velocities including the merging velocity increases, which is a desirable result for data centre tile flow. But the average velocity after complete merging is dependant on the relative diameters of the central and the main jets.

When the pitch of the models is increased the trends are exactly the same as that of the previous cases. A comparison of the differential triple jets with respect to different pitch values was made. Even though the individual jet velocities increase due to the presence of increased reversed flow region between the jets, the merging velocity and the average velocities decrease considerably. From the results, it is clear that whether it is a triple jet combination or differential triple jet
combination, the performance of the model is better with respect to merging characteristics when the pitch is lower. This trend is evident from the Table 6.4. The complete merging point located in the triple jet models indicated a sudden change in slope in the central jet velocity decay curve as shown in figure 6.37. In differential triple jets also, it is possible to have the same trend, which is shown in the figure 6.42.

![Fig 6.42](image.png)

**Fig 6.42** Position of complete merging point of a differential triple jet model.

The figure 6.43 shows the half width variation of a differential triple jet and the comparison with a triple jet. It can be seen that the differential triple jets are having lesser spread rate than that of a triple jet combination.

![Fig 6.43](image.png)

**Fig 6.43** Comparison of half width of a differential triple jet and triple jet models.
The self similarity plots of the differential triple jet are shown in figures 6.44 and 6.45.

![Figure 6.44](image1.png)  ![Figure 6.45](image2.png)

**Fig 6.44** Self similarity of 2by10by10+12by10P4DTrJ at different locations.

**Fig 6.45** Self similarity of 2by10by10+12by10P6DTrJ at different locations.

The figure 6.46 shows the velocity profiles of all differential triple jet configurations at their respective complete merging point.

![Figure 6.46](image3.png)

**Fig 6.46** Comparison of velocity profiles of differential triple jet models at merging point.
The velocity decay of triple jets after complete merging is shown in the figure 6.47

Fig 6.47 Comparison of velocity beyond merging point of differential triple jet models.

6.7 Conclusion

In this chapter a detailed study of different plane jet and multiple jet configurations are carried out. The grid independency study conducted on plane jet confirmed that the solution is independent of grid structure. The self similarity condition of plane jet and different multiple jet models are studied. The multiple jet models are found to be self similar beyond the complete merging point. The relative advantage and disadvantages of triple jets and differential triple jets are analyzed in detail. The mass flow rates of plane jets are used only for a qualitative analysis. The plane jets, which are 2D in nature, will assume unit thickness in the third dimension and hence the flow rates will be higher. The velocities also follow these higher values. Therefore, for the purpose of comparison with 3D data, the trend of the results of the 2D jets is used. The results obtained for plane jets are found to be highly significant for further study and design of multiple array of similar jets and combination of dissimilar jets.

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