

Inline Array of Impinging Jets

1 Case description and boundary conditions

The set-up consist of a total of 9 jets. These are arranged in a rectangular manner. The spacing between the jets (*pitch*) is $4D$. A sketch of the nozzle plate of the set-up is shown in Figure 1.

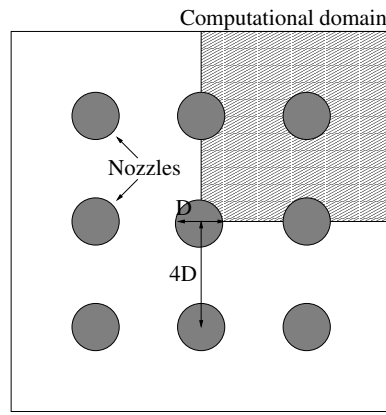


Figure 1: Top view of the nozzle plate of the set-up. The set-up has a total of 9 jets.

The Reynolds-number for the calculations, based on the diameter of the nozzle, equals $Re_D = 20000$. The distance between the nozzle and the impingement plate (H) is $H/D = 4$. At the inlet, uniform profiles of all variables (velocities, turbulent quantities and temperatures) were applied. At the outlet a prescribed pressure boundary condition was used. Because of geometric symmetry, calculations are done on one quarter of the full geometry, as indicated by the shaded area in Figure 1. A sketch of the resulting domain and the boundary conditions for the calculations are given in Figure 2.

2 Results

The results will be presented in different ways. The results on planes in the domain will be drawn. The position of the visualization planes in the domain is indicated in Figure 3. The vertical planes "slice" through two jets each. The horizontal plane is at a distance of $0.54D$ above the impingement plane.

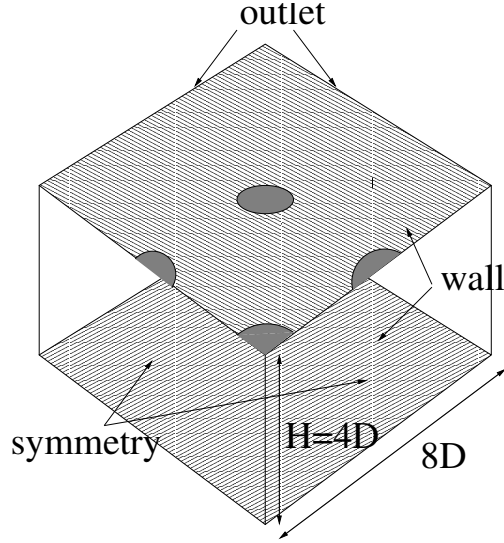


Figure 2: Calculation domain and boundary conditions. The light-grey regions indicate the walls, while the dark-grey regions are the nozzles.

For a more detailed comparison with experiments, profiles of variables at selected locations will be shown. In the vertical planes (Plane 1 and 2), two "sets" of profiles are taken. In one set the lines, along which profiles are taken, are parallel to the impingement plane. The profiles are evaluated at $z/D = 3.5$, $z/D = 3.0$, $z/D = 2.5$, $z/D = 2.0$, $z/D = 1.5$, $z/D = 1.0$, $z/D = 0.5$ and $z/D = 0.1$. For the second set the lines are perpendicular to the impingement plane. The locations are $y/D = 0.0$, $y/D = 0.5$, $y/D = 1.0$, $y/D = 1.5$, $y/D = 2.0$, $y/D = 2.5$, $y/D = 3.0$, $y/D = 3.5$ and $y/D = 4.0$. In the horizontal plane at $z/D = 0.54$ profiles are taken along lines parallel to the impingement plane and the y -axis, at $x/D = 0.0$, $x/D = 0.5$, $x/D = 1.0$, $x/D = 1.5$, $x/D = 2.0$, $x/D = 2.5$, $x/D = 3.0$, $x/D = 3.5$ and $x/D = 4.0$. A sketch of the positions of the profiles is given in Figure 4.

3 Experimental data

The experimental data comprise two component PIV measurements for the flow field and liquid crystal thermography (LCT) measurements for the heat transfer. In the experiments the bulk velocity was 23.88m/s and the diameter of the nozzles was 0.013m . This leads to a Reynolds number of 20.000. All the measurements are courtesy L. Geers (Geers, 2004).

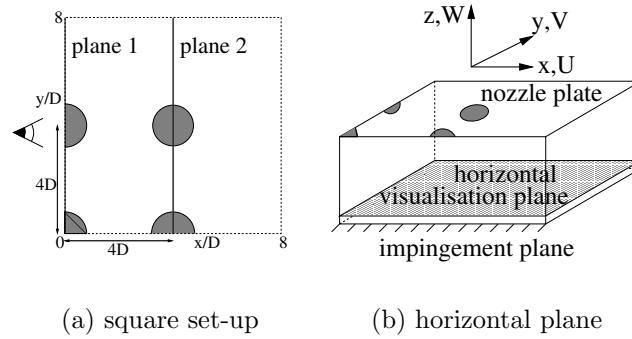


Figure 3: Position of the planes, on which the results are visualized and the coordinate-system used. The eyes indicate the view direction used to visualize the planes.

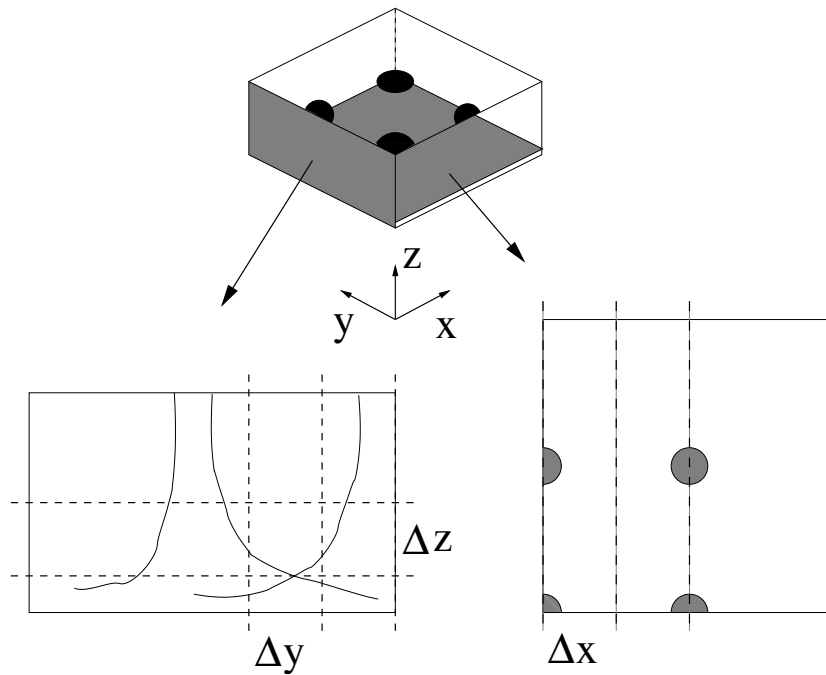


Figure 4: Sketch of the location of profiles. In a plane perpendicular to the impingement plane two sets of profiles are taken. In a plane parallel to the impingement plane only one set is evaluated. The dashed lines are the lines along which the profiles are plotted.

4 Description of profile data files

Experimental profiles of the variables are also available. They are constructed from the 2-D measurement data (*.msf files). The filenames consist of a letter and a number, followed by the extension .dat, for instance u1.dat. The letters in the filenames (here u) identify the variable in the profile (here U-velocity) and the identification number (here 1), is an indication for the position. The position of the identification numbers can be seen in figure 5.

In the files, the data is present as a sampling point id and a value. For example:

```
0   -1.00
1   -1.01
2   -1.03
...
```

In the files also the coordinates of the first and last sampling point are given, so the coordinate of each sampling point can easily be calculated from:

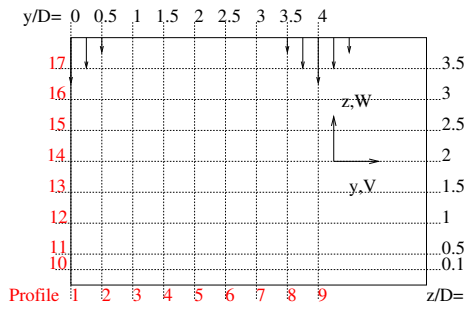
$$x(\textit{point}) = \textit{sampling point id} \times \frac{x_{\textit{last}} - x_0}{\# \textit{ of points} - 1} \pm \textit{offset} \quad (1)$$

where offset is the coordinate of the first point of the profile.

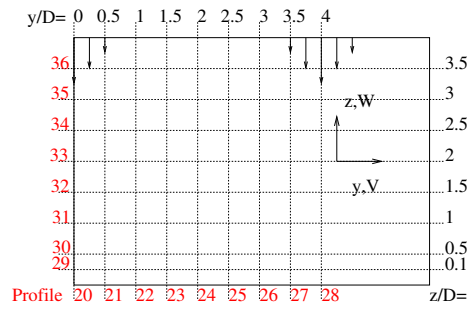
Note: In the horizontal planes only velocity profiles are present.

5 Literature list

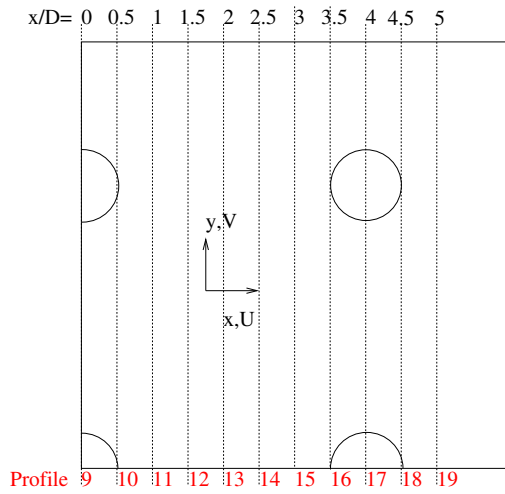
- L. Geers. *Multiple impinging jets: an experimental study of flow and heat transfer*. PhD thesis, Delft University of Technology, 2004.
- L.F.G. Geers, M.J. Tummers, and K. Hanjalić. PIV measurements in impinging jets at a high Reynolds number. In *Proc. Second Int. Symp. on Turbulence and Shear Flow Phenomena*, volume II, pages 289–294, 2001.
- L. Thielen. *Modelling and calculation of flow and heat transfer in multiple impinging jets*. PhD thesis, Delft University of Technology, 2003.
- L. Thielen, H. Jonker, and K. Hanjalić. Symmetry breaking of flow and heat transfer in multiple impinging jets. *Int.J. Heat and Fluid Flow*, 24(4): 444–453, 2003.



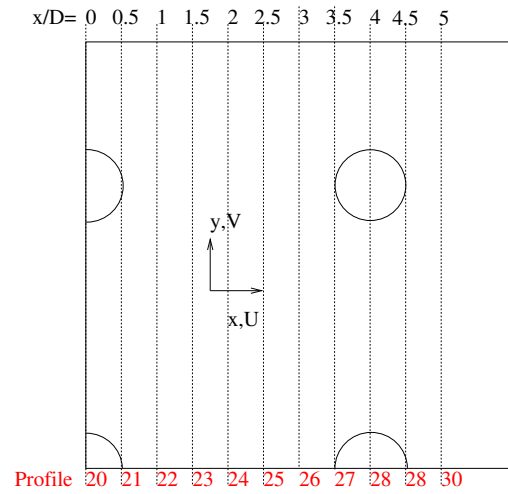
(a) Plane 1 (arrows indicate the jets)



(b) Plane 2 (arrows indicate the jets)



(c) Plane $z/D=0.23$ (circles indicate the jets)



(d) Plane $z/D=0.54$ (circles indicate the jets)

Figure 5: Exact location and name of the profiles in Plane1, Plane2, the horizontal plane at $z/D = 0.23$ and at $z/D = 0.54$.