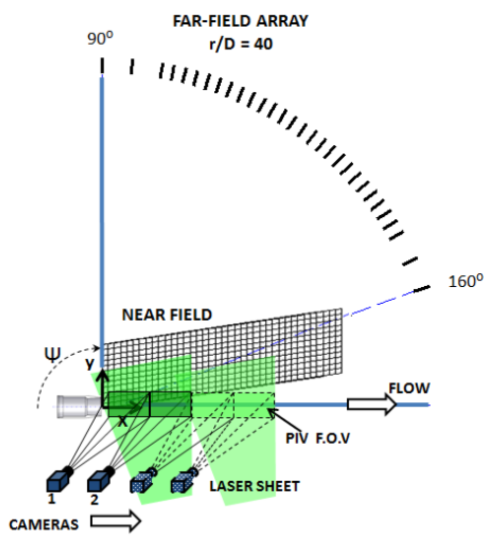
Chapter 1

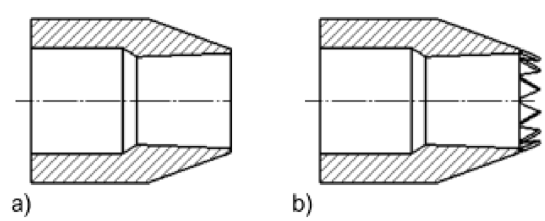
Methodology

1.1 Setup

All the experimental data has been collected by Pablora et.al[**?**]. Heated Jet Noise Rig, dual CCD cameras, dual pulse Nd:YAG Laser, 1.0μ Aluminium Oxide as particle seeds, Olive oil as ambient seed, C-D conical nozzle of diameter(D_e) 0.813in and design mach number 1.5, 12 equally distributed chevrons with length 0.2D and spacing 0.08D have been used for the setup. Each of the four images taken are of resolution 130*170(w*h) with spacing of about 2mm ($0.01D_e$) and then merged to form complete domain.



(a) Experimental setup



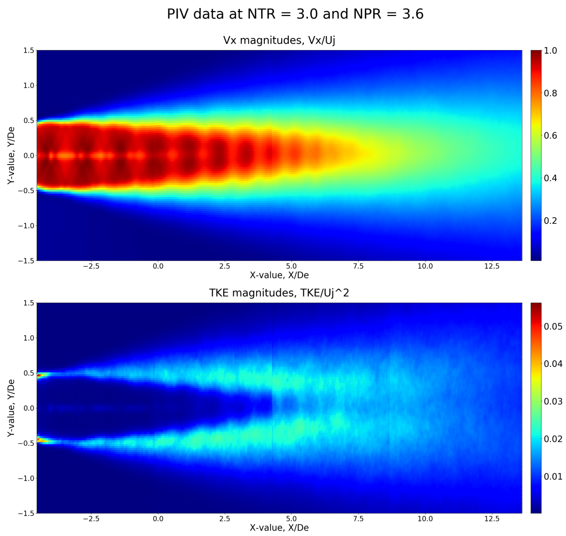
(b) Nozzles with and without chevrons

Figure 1.1: Nozzles and Experimental setup by Pablo Mora et.al.,

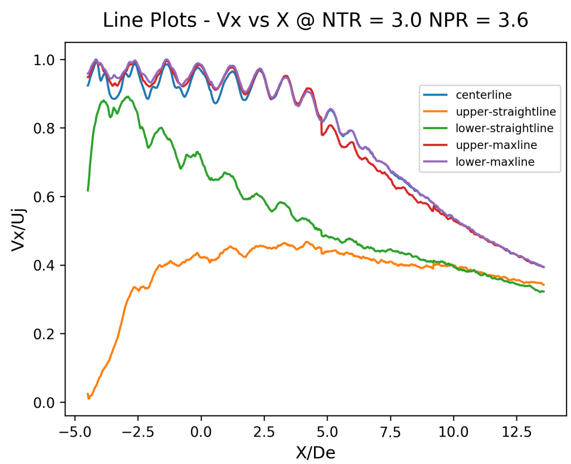
Python3.6 has been used to convert experimental column data into array form and create all the plots. Complete code[1] is included in the appendix. The only steps to be taken to run the code is to ensure that exit diameter, temperature ratio (NTR) and pressure (NPR) are updated manually in the code (*TRPR* array) and the centre of jet has to be adjusted according to the experimental data . Input files expected are

[1] Code and LaTeX files can also be accessed on https://github.com/ravirejo/PIVAnalysis.

B0001up, B0001Down for V_x; B0002up, B0002Down for V_y; B0004up, B0004Down for TKE with _ntr_npr added to their names where ntr, npr are numerical values in the form of 1p0, 3p6 etc.,



(a) TKE and Vx at NTR 3.0, NPR 3.6



(b) Lineplot of Vx at NTR 3.0, npr 3.6

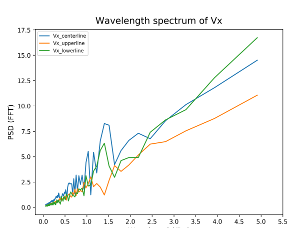
Figure 1.2: Domain plot for TKE and Vx, Lineplot for Vx at NTR3.0, NPR3.6.

1.2 2D image reconstruction

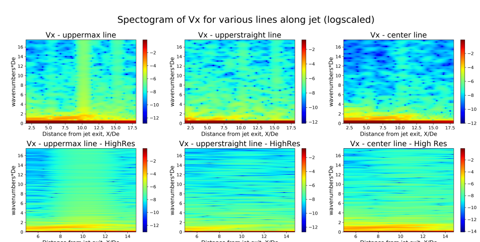
Both Velocity and Turbulent Kinetic Energy (TKE) (fig 1.2a) have been normalized with U_j and U_j^2 where U_j is jet velocity i.e., max velocity at the exit of nozzle.

1.3 Lineplots

Lineplots (fig 1.2b) have been drawn for Vx, Vy and TKE for five lines; Centreline is along the centre of jet. Upper and lower straight lines are along the straight lines at lips of jet. Upper and lower maxlines are curves of maximum values above and below centreline. Due to the complexity of experimental setup, exact position of jet centre is not usually at origin and hence has to be accounted manually in the code. But slight discrepancy in vertical position should not be an issue in the present context, since we are more interested in length scales along X.



(a) wavelength analysis for Vx at NTR 3.0, NPR 3.6



(b) Spectogram of TKE at NTR 3.0, npr 3.6

Figure 1.3: Spectogram for TKE at NTR3.0, NPR3.6.

1.4 Spatial FFT

Fast Fourier Transform (FFT) (fig 1.3a) is a widely used technique to analyse various frequency components in an audio signal. Since we are restricted to steady state analysis for this report, we do not have time data. But we can still apply FFT to the line plot data and obtain velocity scale spectrum (Power Spectral Density Vs Wavelengths). This can be used to study shock cell lengths and positions with a perspective different from previous methods. FFT has been calculated for three lineplots; centre, upper and lower straightlines. Resolution in x direction is about $1/40^{th}$ of D_e. After giving some margin, sampling interval is chosen as 1/35. Linear increase in psd with wavelength could be detrended as we are only interested in the characteristic wavelengths, but has been ignored.

1.5 Spectogram

FFT is a great tool for component analysis but it does not give information at a specific time instant, or specific position in this context. Spectogram (fig 1.3b) can be used for this purpose. Essentially, spectogram is short FFT taken over a chosen window of fragments of input signal and averaged if fragments are overlapping. So, we have spectrum at centre point of every fragment. Shorter the fragment, higher the resolution in x direction but we have to ensure the fragment is sufficiently longer than length of shock cell to ensure that the relevant wavelength is captured. Higher the overlap between fragments, smoother the transition. Resolution seems to increase in y (wavelength) direction as observed in 1.3b. But the output to input domain ratio is far less than 1 since the spectogram starts only from the centre of first fragment. Moreover, precision decreases in the direction of x as the signal is smeared because of high overlap.

1.6 Shockcell Length

Shockcell length has been calculated from the analytical equation derived by Tam et.al [**?**].

$$L_s \approx \pi\sqrt{(M_j^2 - 1)}D_j/\mu, \; where \; \mu \; = \; 2.40483 \tag{1.1}$$

D_j, diameter of jet along the flow, is higher or lower than D_e depending on whether the flow is underexpanded or overexpanded. M_j, mach number at the jet centre, generally decreases along the jet as expected.

just testing 1.1