Velocity field and stream line in a square section test duct by Particle Image Velocimetry system

Omprakash Yadav[1]

[1]*Department of Mechanical Engineering, G.L Bajaj, Gr Noida*

ABSTRACT

The aim of this experimental work is to investigate the velocity field and stream line in a square section test duct by Particle Image Velocimetry system. The two components of the velocity i.e. velocity field in a plane and stream line are visualize by Particle Image Velocimetry (PIV) system. A new setup for swirling flow in a square section test duct in the PIV laboratory is designed which is four feet long with aspect ratio one. The aspect ratio of test duct is defined as ratio of larger dimension to smaller dimension of the cross section of the test duct. Venturimeter is used to measure the discharge through four nozzles. Pump is used to supply water to the nozzles through pvc pipe. The swirling in the test duct is created by the nozzles incorporated at four faces which supply water tangentially into the section. Pure water loaded with seeding particle known as tracer is used to trace the path of flow. The PIV system consists of laser, CCD camera, synchronizer, computer etc. Two pulses of laser illuminate the seed particle at the section and two photographs are taken by high speed CCD camera which is analyze by PIV using INSIGHT3G software to get one velocity vector. The laser and CCD camera are perpendicular to each other. INSIGHT software measures velocity using one of three correlation processes: Autocorrelation, 1-Frame Cross-Correlation and 2-Frame Cross-Correlation.

Keywords— Velocity field, stream line, Particle Image Velocimetry (PIV), square section test duct, venturimeter, nozzle etc.

I. INTRODUCTION

PIV is a 2-D measurement technique wherein a pulse laser light sheet is used to illuminate a flow field seeded with tracer particle small enough to follow the flow. The position of particle are recorded on CCD camera at each instant the light sheet is pulsed. Knowledge of time interval between light sheet pulses then permits computation of velocity field. While the method of adding particles or objects to a fluid in order to observe its flow is likely to have been used from time to time through the ages no sustained application of the method is known. The objective of this experiment is to find out velocity field and stream line in square section duct by particle image velocimetry system. In contrast to single-point measurements, a two-dimensional velocity distribution can provide local velocity gradients. In the PIV technique, a light sheet i.e. pulse from the laser is passed through a seeded flow field, illuminating the particles at time, t. At a time t + Δt, a second sheet of light i.e. pulse is sent through the same plane in the flow field. The images of the particles from both laser sheets are

saved on a recording medium. Measurement of the separation between two images of the same particle throughout the field of view by autocorrelation can provide the local fluid velocities as depicted in figure-1.

$$u(x,t) = \frac{\Delta x(x,t)}{\Delta t}$$
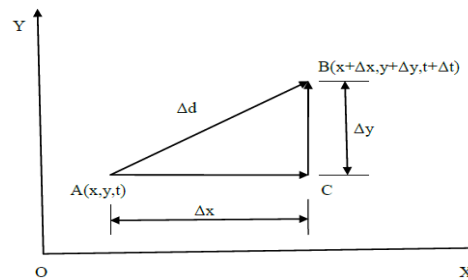
$$v(y,t) = \frac{\Delta y(y,t)}{\Delta t}$$

Figure:1. *Principle of Particle Image Velocimetry*

The velocity vector field is given by, $$\vec{V} = \vec{u}.\hat{i} + \vec{v}.\hat{j}$$

By knowing the displacement in known time, velocity field, vorticity, shear strain etc can be finding by the piv software.

II. PARTICLE IMAGE VELOCIMETRY (PIV) SYSTEM

Particle image velocimetry (PIV) system is a two-dimensional quantitative instantaneous velocity measurement technique. In contrast to single-point measurements, a two-dimensional velocity distribution can provide local velocity gradients. The main component of Particle Image Velocimetry system are Light sources i.e. Laser, High speed CCD Camera, Synchronizer and Computer.
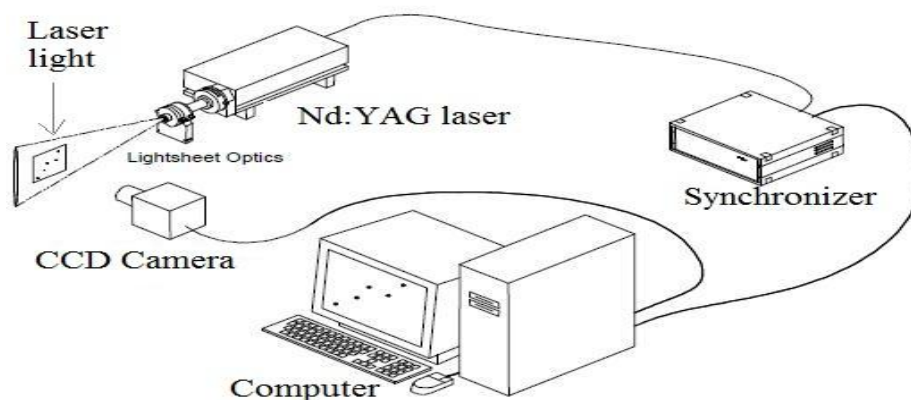

Figure:2 Particle image velocimetry (PIV) system

A. Working Principle: A pump circulates the water through the piping system and venturimeter to nozzles which are tangentially fitted to the test duct at section 1 and at section 2. The same water is again circulated to the pump. The sequence of events for capturing a series of frames is as follows.

1. Synchronizer triggers the camera to start exposure.

2. Camera starts exposure and triggers the Synchronizer that the shutter is open with the flash sync output.

3. Synchronizer sends fire signals to the laser for the first pulse.

4. Synchronizer waits the selected pulse separation time.

5. Synchronizer sends signals for the second pulse of light.

6. The camera shutter closes at the end of the exposure time.

7. Camera outputs the video data.

8. Repeat the sequence for the number of frame to capture. The camera must be ready for the next exposure trigger before the frame rate time or an error will occur.
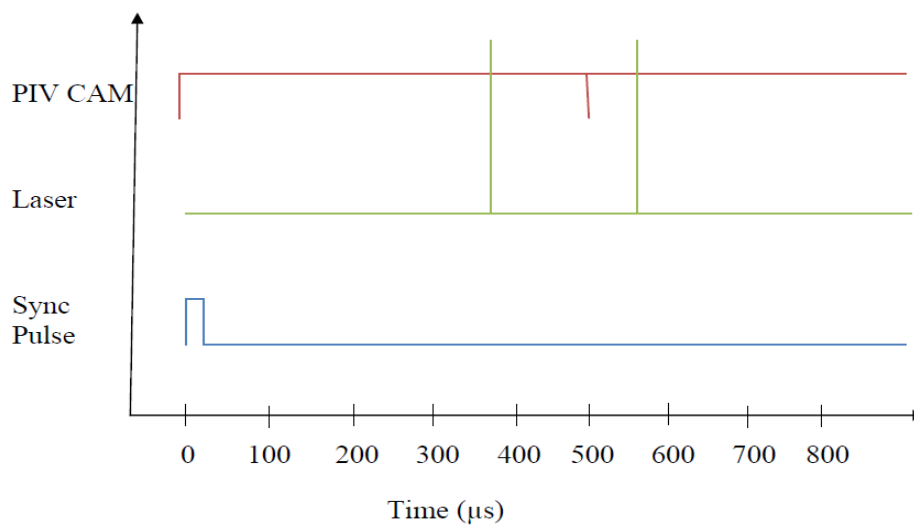

Figure:3 Capture timing diagram.

III.   EXPERIMENTAL SETUP

A. EXPERIMENTAL TEST DUCT

The complete test duct is made of Flexi glass sheet (transparent) to enable visualization of the flow as well as PIV measurements at the section 1 and section-2. The other side of chamber is vertical and open to the atmosphere. The test duct is full of water loaded with seeding particle. The test duct is fitted with 4 nozzles at section 1 and 4 nozzles at section-2 tangentially to supply the water into test duct such that the flow is swirling. The experimental test duct is as shown in figures -4 and figure-5.
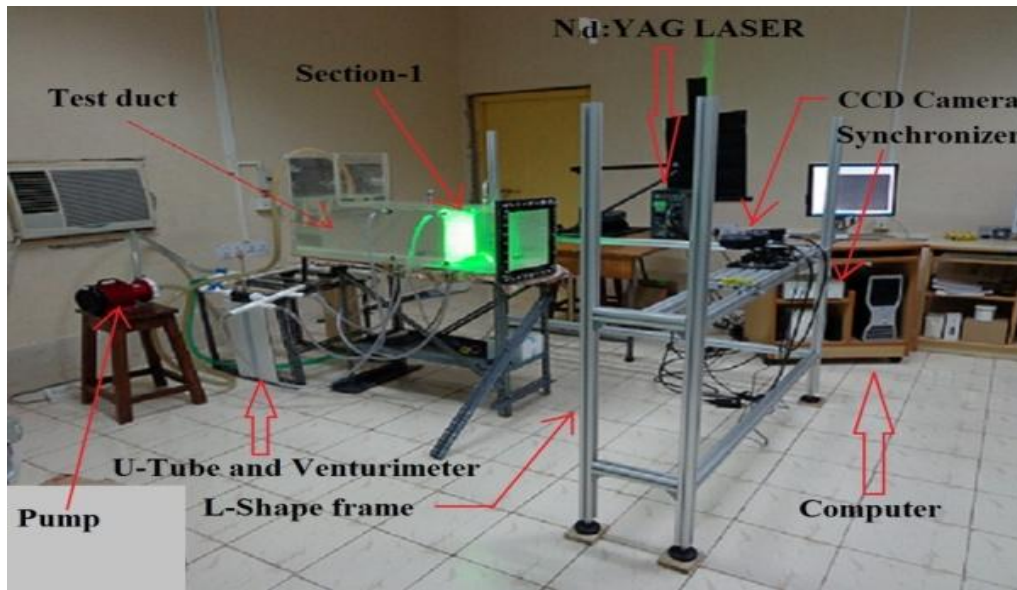
Figure 4. Experimental test ducts

B. **VENTURIMETER**

I have design and fabricate two venturimeter to measure discharge through each section. Maximum deflection of 45cm can be allow, otherwise mercury will flow out.
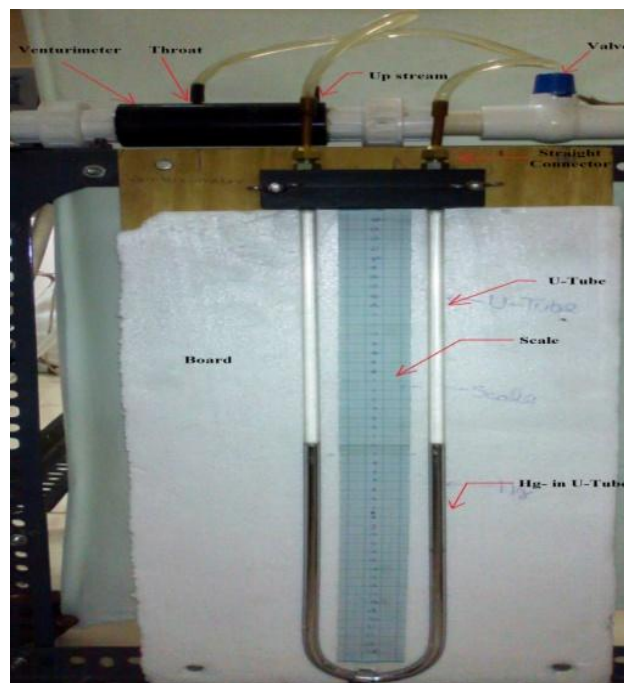

Figure:5 Venturimeter

IV RESULTS AND DISCUSSION

C. **Average velocity field***:* Discharge, q_{total}=52.38 lpm and discharge through one nozzle, q_1=13.10 lpm, Reynolds number at nozzle-1 exit, r_e=43783.56 (from venturimeter)
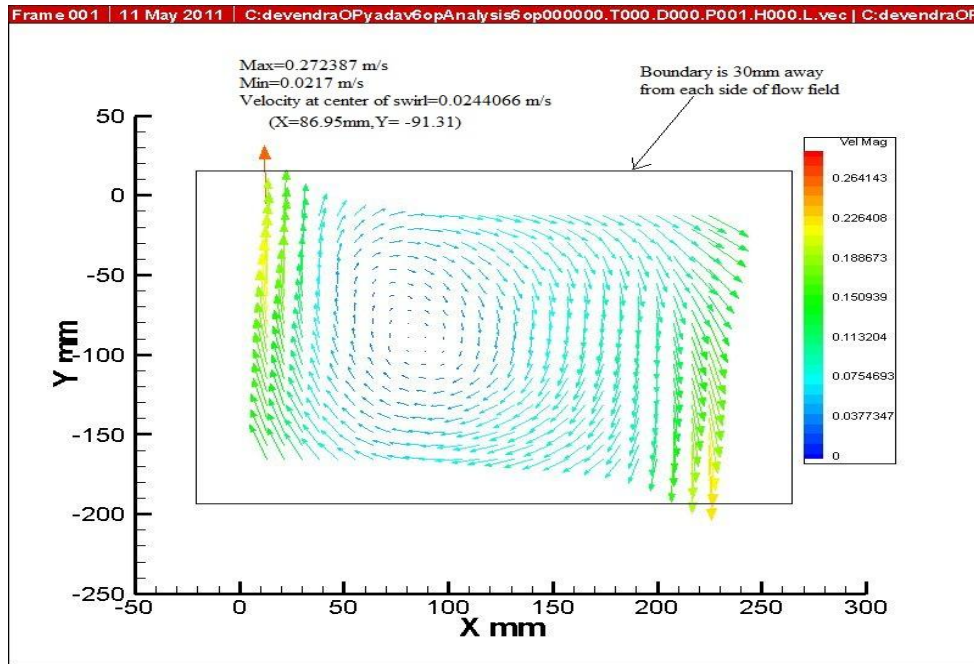

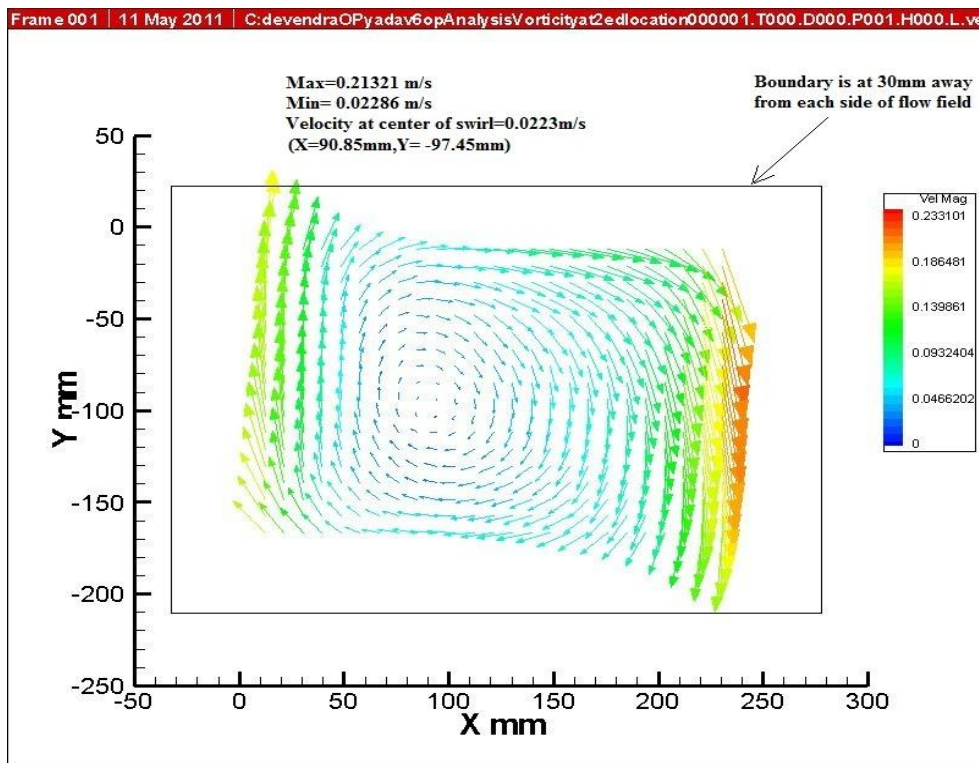**Figure:** 6 Average velocity vector at section-1

Figure:7 average velocity field at section-2
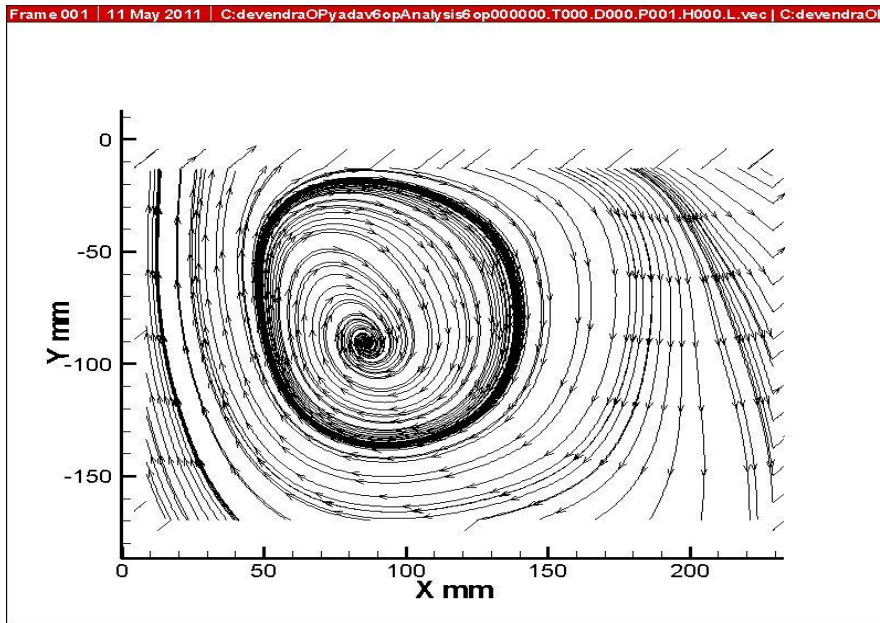
D. **STREAMLINE**

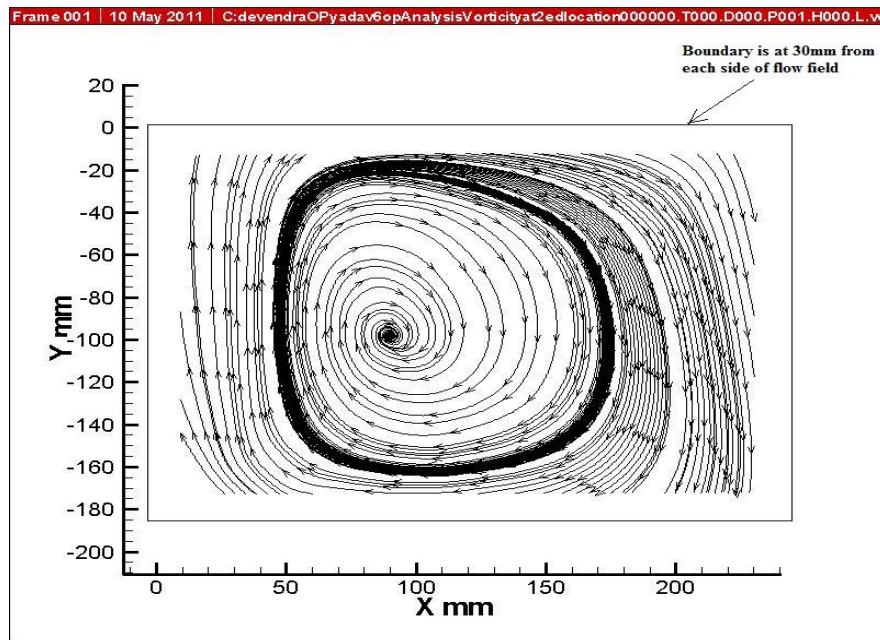**Figure:8** Stream line for average field at section-1

Figure:9 stream line for average velocity field at section-2

V CONCLUSIONS

From the PIV resulting velocity is maximums at nozzle exit for all range of discharges. Take the case of medium discharge, from PIV resulting maximum velocity of 4.79m/s and maximum velocity measured by venturimeter is 6.08m/s. The maximum velocity measured from two approaches is approximately same. Small error is due to density of seed particle, calibration, light etc. Density of seeding particle must be equal to the density of fluid but in my experiment density of seeding particle is little bit more which gives the lower velocity compared to venturimeter. From the velocity field field we see that velocity is zero at the centre of swirling.

REFERENCES

[1] Jan Visscher, Helge I. Andersson, Mustafa Barri, Henri Didelle, Samuel Viboud, Damien Sous and Joel Sommeria. A new set-up for PIV measurements in rotating turbulent duct flows. Flow measurement and instrumentation, 22:71-80, (2011).

[2] Fude Guo, Bin Chen, Liejin Guo and Ximin Zhang. Investigation of turbulent mixing layer flow in water channel by piv. The Canadian journal of chemical engineering, Vol.88:919-928, (2010).

[3] M. Pashtrapanska, J. Jovanovic, H. Lienhart and F. Durst. Turbulence measurements in a swirling pipe flow. Journal of experimental fluids, 41: 813-827,(2006).

[4] S.V.Alekseenko, P.A Kuibin, V.L Okulov and S.I Shtork. Helical vortices in swirl flow. Journal of fluid mechanics, Vol. 382:195-243, (1999).

[5] Yehia A. Eldrainy, Hossam S. Aly, Khalid M. Saqr, and Mohammad Nazri Mohd Jaafar. A multiple inlet Swirler for Gas Turbine Combustors. World Academy of Science, Engineering and Technology Vol: 53,(2009).

[6] Dr.R.K.Bansal. A text book of Fluid mechanics and Hydraulic machine, (2003).