NUMERICAL SIMULATION OF FLOW PAST A SQUARE CYLINDER AT DIFFERENT INCIDENCE USING ADAPTIVE MESH TECHNIQUE

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ABSTRACT

Flow past a square cylinder placed at different incidence angle was investigated computationally and experimentally .The computation is carried out with FLUENT software and flow visualization done with water table facility. In this work mesh adaption has been implemented to check its validity in simulating vortex dominated flows. Four different incidence angles (θ=0, 22.5, 30 and 45^{o}) have been chosen to determine the effects on drag coefficient, Strouhal number, vorticity field, shape and size of the recirculation bubble downstream of the cylinder in the near wake region. The Reynolds number has taken as 410 which is the range of laminar flow. The effect of square cylinder was studied for different angle orientation depend on Reynold number which has chosen.

Keywords: Cylinder; Drag coefficient; Experiment; Numerical simulation; Strouhal number; Incidence angle

I. INTRODUTION

Bluff body wakes are important for application in aerodynamics, wind engineering and electronics cooling. Bluff body cross section that are often employed in circular and square. Separation mechanism and the consequent dependence of lift, drag and Strouhal number on the Reynolds number are significantly different between circular and square. The motion of fluid passing square cross-section cylinder is encountered in numerous industrial applications, as well as offshore and environmental settings, including tall buildings and structures such as bridges, chimneys, trash racks, cooling towers, heat exchangers, etc.Periodic vortex shedding patterns and fluctuating velocity fields behind the bluff bodies can cause structural damage as a result of periodic surface loading, acoustic noise and drag forces.

Most work has been done on the flow passing a circular cylinder (CC) rather than a square cylinder (SC). Even though their near wake flow structures are expected to be topologically similar to one another, the reasons for flow separation on the cylinder surfaces are totally different. That is, flow separation occurs
due to an adverse pressure gradient in the downstream direction for the Circular Cylinder and the separation points on the Square Cylinder surface move back and forth depending on the Reynolds number. However, the locations of the separation points are fixed at the upstream corners of the SC due to the abrupt geometrical changes.

II. LITERATURE SURVEY

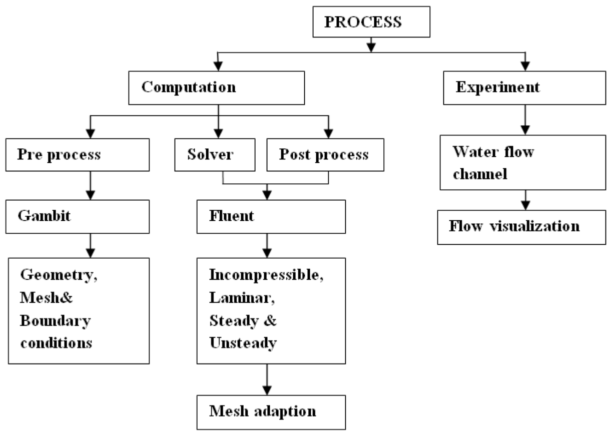
Dutta (2008) Flow past a square cylinder placed at an angle to the incoming flow is experimentally investigated. The Reynolds number based on cylinder size and the average incoming velocity is set equal to 410. Data for four cylinder orientations (θ=0, 22.5, 30, and 45°)and two aspect ratios (AR=16 and 28) are reported.

Yoon (2010) Flow past a square cylinder inclined with respect to the main flow in the laminar flow region. Reynolds number and angle of incidence are the key parameters which determine the flow characteristic. In this investigation, the effects of Re and θ on the characteristics of flow past a square cylinder immersed in cross free stream were studied in detail in the laminar flow regime by using numerical simulation.

Sohankar (1995) Flow past a quadratic cylinder at zero angle of attack performed at Reynolds number of 45-250 under laminar flow.

Dutta (2004) Experimental investigation of flow past a square cylinder at an angle of 0^{o} and 60^{o} at Reynolds number 97 and 187. Measurement have been carried out in the near wake, mid wake and far wake of the cylinder. Among the angle studied the wake of a cylinder whose orientation I 22.5 with repect to incoming flow.

III METHODOLOGY



Mesh adaption:

This project main motivation is the adaptive mesh technique. The adaptive mesh is refinement or coarsening of cells where it required to obtain better accuracy in result.

Isovalue Adaption:

The isovalue adaption will adapt equal number cell in each boundaries.

Experiment

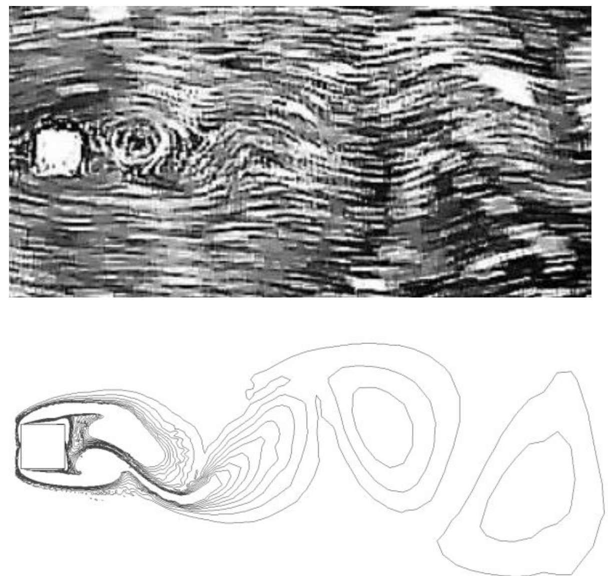
The experimental investigation has done with water flow channel. The water has been chosen as working fluid. The camera was mounted above the water flow channel for respective direction to capture the flow visualization image. The experimental flow investigation has recorded for four incidence angle and the image was analyzed using analysis software. This results have compared with simulation results for respective angle. The r.p.m range taken as 25-30 because there will be some fluctuation in the motor' r.p.m.

Schematic of experimental and numerical region around a square cylinder

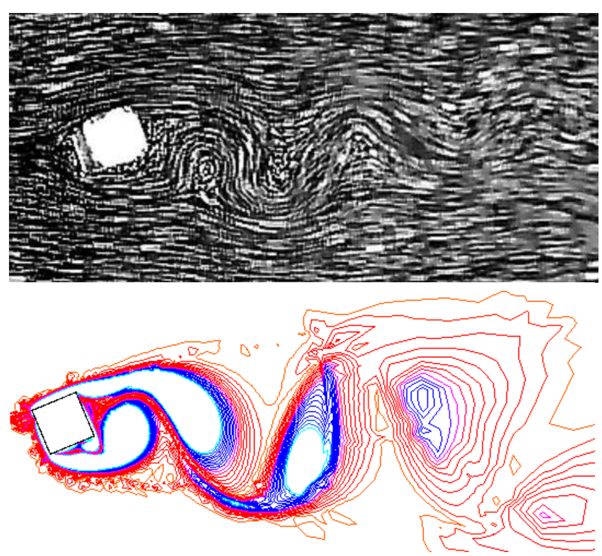
IV RESULT AND DISCUSSION

The main aim of this project is to be compare both results experiment and computation. We have predicted the vorticity field around a square cylinder and the drag coefficient, strouhaul number were determined by comparison of both result for each four angle incidence.

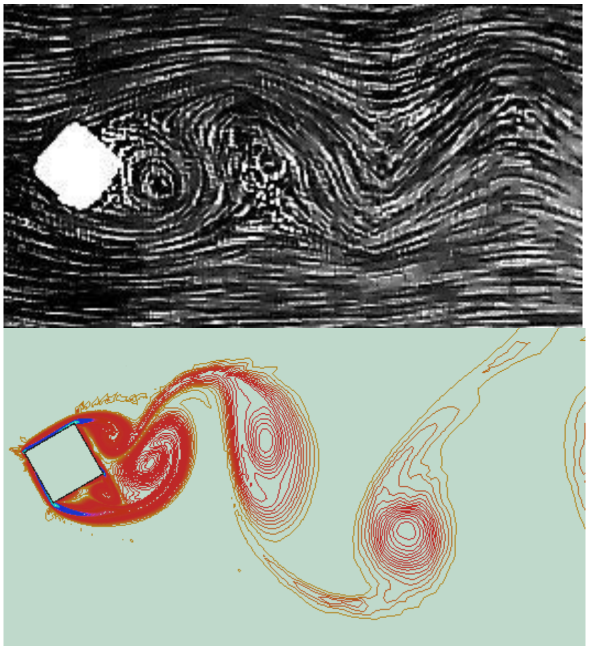
Comparison of vorticity field:



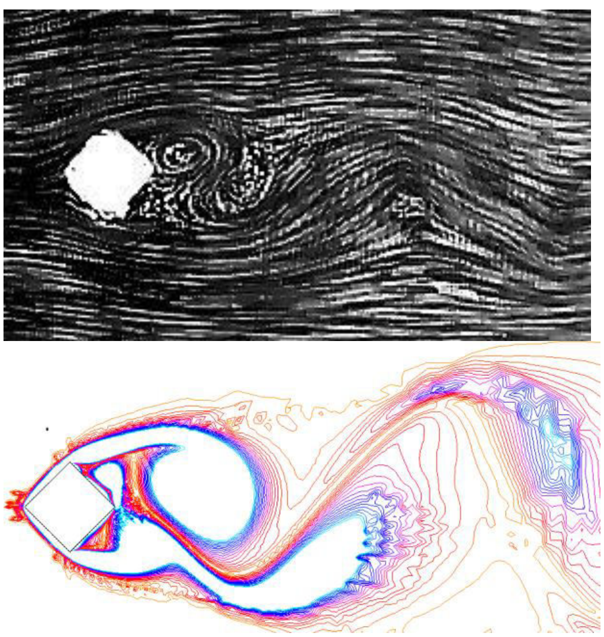
Θ=0°



Θ=22.5°



Θ=30°

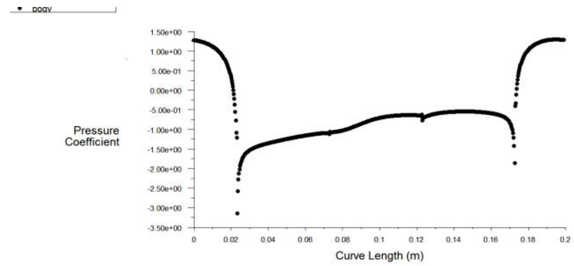


Θ=45°

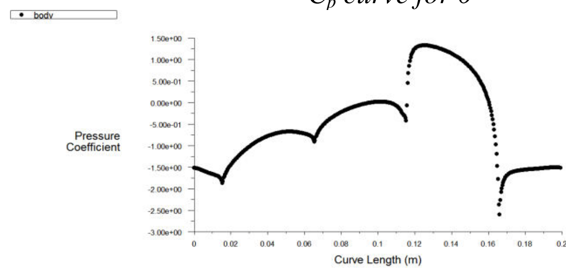
Comparison of experimental and numerical data for four angle incidence

From the above comparison of vorticity field for four angle incidence 0 and 45° angle incidence the vorticity is symmetrical and 22.5 and 30 angle both side is unsymmetrical. Because the flow reattachment distance is varying for 22.5 and 30 angle incidence.

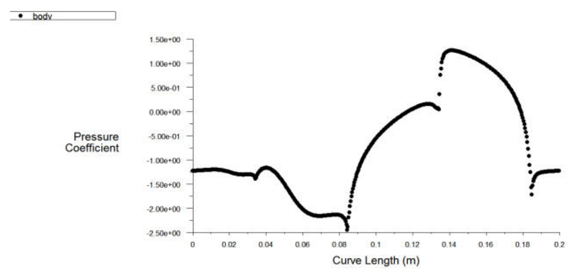
Coefficient of pressure (C_p):



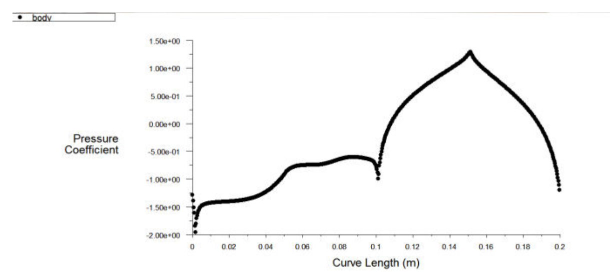
C_p curve for 0°



C_p curve for 22.5°



C_p curve for 30°

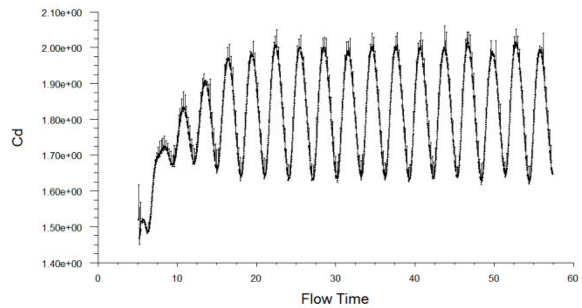


C_p curve for45°

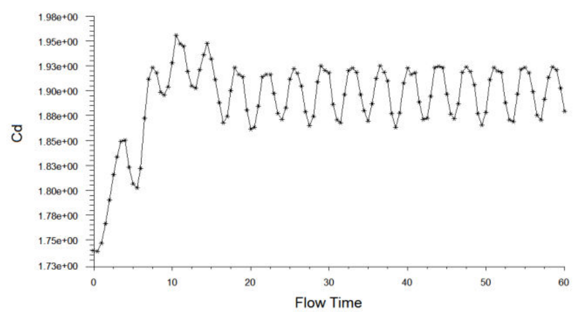
Pressure curve for four incidence angle of cylinder (0, 22.5, 30 and 45°)

From four coefficient of pressure curve for 0 and 45 angle at both side of edge of the cylinder the pressure is decreases evenly up to its corner then it increases gradually, from this curve we have proven both 0 and 45 incidence angle the vorticity field is symmetrical. And other two incidence angle of 22.5 and 30 at both corner of the cylinder the pressure is varying with respect to flow time. At an angle of 22.5 and 30 incidence angle one side corner of the cylinder the vortex forms near to the corner and other side of the corner the vortex forms beyond from the corner.

Coefficient of drag (C_d):



C_d for 0^o



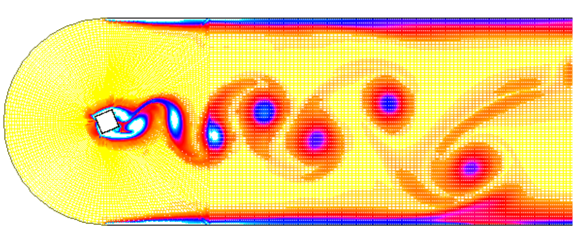
C_d for 45^o

Drag coefficient with respect to time

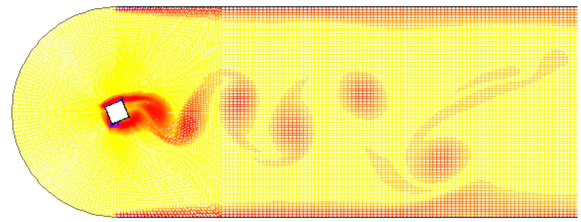
The drag coefficient is shown in fig. The drag will increasing by decreasing in strouhal number. The drag coefficient is inversely proportional to the strouhal number. This plot is relation between C_d with respect to flow time. The drag convergence is increasing in every time step when the pressure increases.

Mesh adaption:

The mesh adaption has increased the accuracy in solution and the flow visualization has improved in the vorticity field.



With adaption

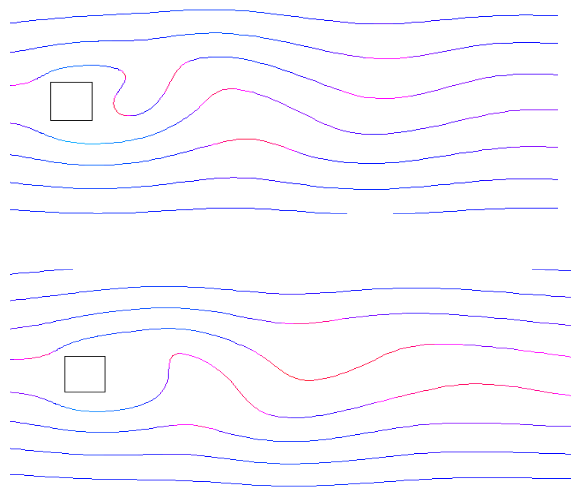


Without adaption

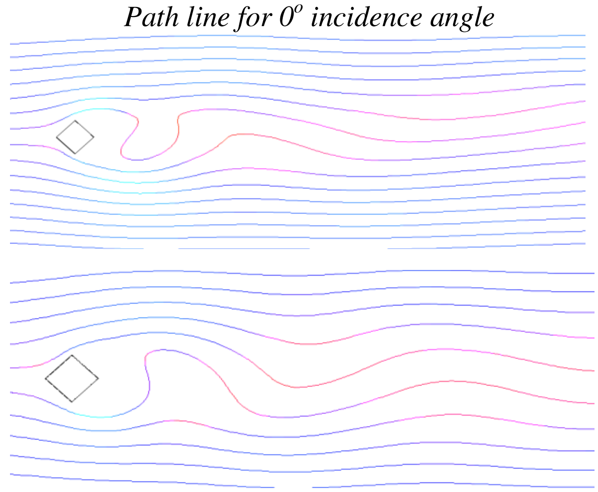
From above fig the accuracy improvement has shown in the flow visualization. The respective diagram shown in fig for 22.5^o angle incidence. The difference between with and without adaption the number of cells will be added where required. In each area the number of cell will increase automatically. Because here dynamic mesh adaption has used so the cells will develop along with flow. The adaption cells have added 1% from total number of cell. The blue colour indicates more number of cells in the particular region.

Path line:

A path line is traced out mass less particles move along with flow. It has shown in below fig.



Path line for 0^o incidence angle

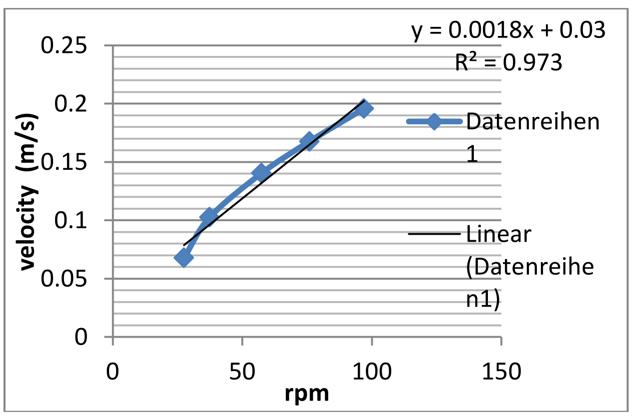


Path line for 45^o incidence angle

The path line shown for 0 and 45° angle symmetrical formation of vorticity field but when compare with other incidence angle those paths are not symmetrical. So the path lines also even for both 0 and 45° angle incidence. From these plot and path line vortex formation of two corner of two angle incidence is same.

Experimental calculation

Calibration of water flow channel is done at different r.p.m range and the time is noted to determine the velocity. Here water is preferred as working fluid. The Reynolds number is taken as 410 which come under the laminar flow. Calculation is done and the graph is ploted for r.p.m and velocity (x,y). Calibration is important to ensure the efficiency and reliablity of a apparatus. The r.p.m range was taken as 20 different between each range because there is fluctuation in each r.p.m range which will be nearly 10 to 15. Calculation curve is shown different velocity at different r.p.m range.



Calibration curve relation between r.p.m and velocity for experimental test

Geometry details of numerical simulation:

Level	Cells	Faces	Nodes	Partitions
0	**31360**	**64169**	**32809**	**1**
Cell zone		**1**		
Face zone		**5**		

Strouhal number (St) and coefficient of drag(C_d):

Formula for Strouhal number:

$$St = F_s * D / U_x$$

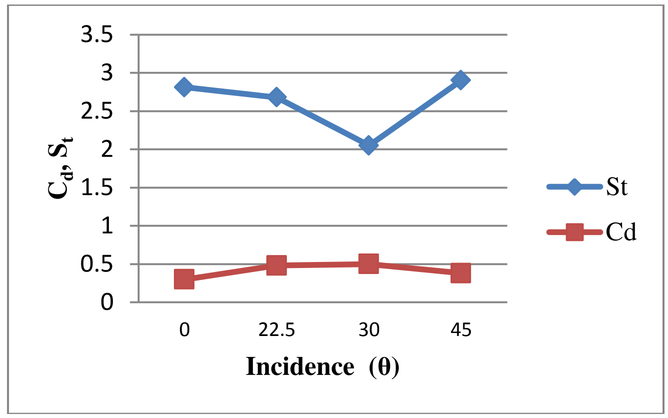
St – Strouhal number
F_s _ Shielding vertex frequency
D _ Dimension of the cylinder
U_x _ Free stream velocity

Formula for C_d calculation:

$$Cd = 2F_d/(\rho V^2 A)$$

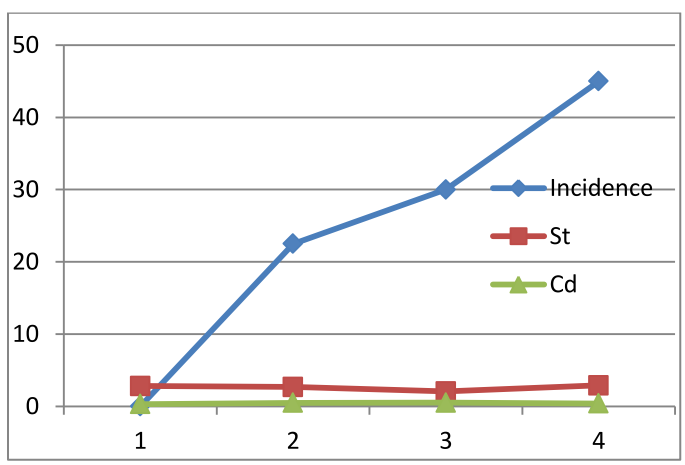
Where **C_d** coefficient of drag
F_d drag force
ρ Density
V velocity
A area

But here 'h' is consider as 'A' and it is consider as vertical distance of cylinder



S_t and C_d relation with respect to different angle incidence

The above graph is shown graphical representations of strouhal number and drag coefficient. As we know if the C_d is increase then the strouhal number will be decrease. The C_d is inversely proportional to the stouhal number. We can see the variation in drag coefficient and strouhal number. In S_t the difference is more than C_d. And the second graph represents variation in C_d and S_t at difference incidence angle.



S_t and C_d relation with respect to different angle incidence for four different cylinder orientation

If the angle is increasing then the St will be decrease and the Cd will be decrease. The maximum angle inclination of square cylinder at 45^{o} and minimum at 0^{o}.

V CONCLUSION

The effect of square cylinder at different incidence has been investigated computationally as well as experimentally. The Reynolds number set equal to 410 depend on cylinder aspect ratio. Drag coefficient, strouhal number, vorticity field, downstream bubble have been reported. The adaptive mesh technique has used to obtain better accuracy in flow field. From the result maximum St and minimum Cd at an angle of 0 and 45^{o}. We have been proven at an angle of 0 and 45^{o} angle inclination strouhal number, coefficient of dag and vorticity is symmetrical. And the study of downstream recirculation bubble at 22.5 and 30 one side is near the corner and other side is beyond from the corner. So we have proven at an angle of 22.5 and 30^{o} unsymmetrical in strouhal number, coefficient of drag and vortices field. The computational and experimental result have been proven. The adaptive mesh improved accuracy in flow field.

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