Influence of Corner Cutoffs on Flow Past Square Cylinder

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Abstract--- Flow past square body with and without corner modification for Reynolds number 100 and 200 is carried out numerically by using commercial CFD code fluent. The results are presented in the form of streamlines, pressure distribution, monitored velocity, Lift coefficient and Strouhal number. Results indicate that the tangential velocity of the Square cylinder is large when compared with corner Rounded and chamfered, and enlarges the separation area of square cylinder side face. Therefore, the width of the wake behind the Square cylinder with corner modification becomes small, and thereby the lift coefficient decreases. The velocity behind the cylinder with corner modification becomes large. The large velocity behind the cylinder decreases the lift coefficient. The lift coefficients of Square cylinder with corner modification decreases but strouhal number increases when compared with a square cylinder without corner modification. The decrease in the vortex wavelength is due to increase in strouhal number. Strouhal number remains same even if magnitude of oscillations is increased while monitoring the velocity behind the cylinder.

Keywords--- Square Cylinder, Corner Cutoffs, Lift Coefficient, Strouhal number, Numerical Analysis.

I. Introduction

Flow passing any square body with a corner modification has attracted a great deal of attention in the literature because of its practical significance in engineering e.g., Tall buildings, monuments, and towers are permanently exposed to wind. Similarly, piers, bridge pillars, and legs of offshore platforms are continuously subjected to the load produced by maritime or fluvial streams. These bodies usually create a large region of separated flow and a massive unsteady wake region in the downstream. Vortex shedding observed in the wake of these bodies generates unsteady (periodic) lift and drag forces also velocity fluctuations in the wake region. An initially smooth and steady flow across a square cylinder may bring about damaging oscillations, in cases where the natural frequency of the obstacle is close to the shedding frequency of the vortices. If the resulting excitation frequency synchronizes with the natural frequency of the square cylinder, the phenomenon of resonance is the obvious outcome. A lot of research has been carried out on flow past single square cylinder; however, there has been no complete investigation is carried on the effect of corner cutoffs on the flow characteristics around a square cylinder. Therefore, the simulation of unsteady flow past square cylinder with corner cutoffs has practical relevance. Bearman et al. (1984) investigated the corner radius effect on the hydrodynamic forces on cylindrical bluff bodies subjected to an oscillatory flow in which the Keulegan Carpenter (KC) number ranged from 1 to 100. They found that the drag coefficient, Cd, was sensitive to the corner radius in a steady flow and even more so in an oscillatory flow. Kawai (1998) also has investigated the effects of corner modifications (such as corner cut, recession and rounding) on the aero-elastic instabilities of square (and rectangular) prisms placed in a turbulent boundary layer. He concluded that corner rounding is the best option to provide aerodynamicstability to prisms Tamura et al. (1998) and Tamura and Miyagi (1999) investigated numerically and experimentally the aerodynamic forces on square cylinders and observed a decrease in the wake width as well as Cd with the corner chamfer or rounded. Zheng and Dalton (1999) studied numerically the corner effect in an oscillatory flow and argued that vortex attachment occurred at irregular high frequency modes when KC>3 for a square cylinder with rounded corners. The calculated drag and inertia coefficients were in good agreement with the experimental data of Bearman et al. Dalton and Zheng (2003) presented numerical results for a uniform approach flow past square and diamond cylinders, with and without corner modifications at Re=250 and 1,000. They noted that rounding corners of the bluff bodies produced a noticeable decrease in the calculated drag and lift coefficients.. Hu et al. (2003) have investigated the effects of corner radius on the near wake of a stationary square prism at Reynolds number values of 2600 and 6000, at low free stream turbulence intensity condition. They found that corner radius significantly influences the wake characteristics such
as vorticity shed, Strouhal number and vortex formation length amongst other parameters. B. H. Lakshmana Gowda et al. (2009) studied the near wake flow field features of transversely oscillating square section cylinders with different corner radii. Results indicate that increasing the corner radius suppresses the possible instabilities of the cylinder. Similar studies emphasizing corner effects were also conducted by Delany and Sorensen (1953), Naudascher et al. (1981), Kwok et al. (1988) and Okamoto and Uemura (1991). These investigations largely focused on the effect of corner radii on the aerodynamic or hydrodynamic characteristics, such as drag/lift forces and shedding frequency, of bluff bodies. How the corner variation may alter the near wake, however, has yet to be sufficiently documented, particularly in the base region. Therefore, one objective of this work is to characterize quantitatively the corner effects on the near-wake flow structure, complementing the data in the literature. A lot of research has been carried out on flow past single square cylinder. However, there has been no complete investigation is carried on the effect of corner cutoffs on the flow characteristics around a square cylinder. Hence this has motivated to take up for present study. The results are presented in the form of streamlines, pressure distribution, monitored velocity, Lift coefficient and Strouhal number.

1.2 Geometry and Boundary Conditions

The problem considered here is the flow past a square cylinder with and without corner modification for Reynolds numbers 100 and 200. The inflow, top and bottom boundaries have been located 6.5 square cylinder with respect to the center of the square cylinder. The computational domain has been extended to 30 square cylinder Perimeters in the downstream of the cylinder.

In the present investigation, flow past square cylinder with and without corner modification has been computed by applying boundary conditions as follows.

(a) Inlet - Uniform flow \((U = 1.0, V = 0.0)\)

(b) Cylinder surface -No slip \((U = 0.0, V = 0.0)\)

(c) Top and Bottom Boundaries –symmetry boundary condition.

(d) Outlet Boundary -Continuative boundary condition can be expressed as \((P = 0.0)\)
1.3 Streamlines

In the case of flow over a square cylinder with and without corner modification for Re=100, the flow is uniform and symmetrical in the upstream of the cylinder. The eddies are alternatively formed on either side of the square cylinder in the downstream. As the flow forms a clockwise eddy, it rushes past the top of the square cylinder somewhat faster than the flow across the bottom. When the clockwise eddy breaks away, the opposite pattern develops at the bottom. The eddies grow in size as they move away from the cylinder up to a certain length from the cylinder and then gradually die out and the flow becomes uniform as in the upstream. The tangential velocity of the Square cylinder is large when compared with corner Rounded and chamfered, and enlarges the separation area of square cylinder side face. Therefore, the width of the wake behind the Square cylinder with corner modification becomes small, and thereby the lift coefficient decreases. In case of corner modification a large eddy is formed behind the cylinder. This is presented in the form of streamlines as shown in Figure. When Reynolds number increased from 100 to 200 a similar flow pattern has been observed except the length of is vortex formation.

![Streamlines](image-url)

Figure 1.3: Computational Results of the Streamlines around the Square Cylinder with Corner Chamfered and Rounded for Re = 100 and 200

1.4 Monitored Velocity

The temporal histories for the cross-stream component of velocity (v), along the axis of symmetry (in the downstream region), at X=8 for Re=100 and Re=200. It can be seen from the plots that Strouhal number remains same even if magnitude of oscillations is increased. A typical plot of the monitored velocity is shown in Fig. 1.4(a)–(c).
Figure 1.4 (a): Monitored Velocity in the Downstream of Square Cylinder at X=8 and Y=6.5 for Re=100 and Re=200

Fig. 1.4 (b): Monitored Velocity in the Downstream of Square Cylinder with Corner Chamfered at X=8 and Y=6.5 for Re=100 and Re=200

Figure 1.4 (c): Monitored Velocity in the Downstream of Square Cylinder with Corner Rounded at X=8 and Y=6.5 for Re=100 and Re=200

1.5 Pressure Distribution around a Square Cylinder with and without Corner Modifications

Pressure changes accordingly with the vortices motion in the vicinity of the bodies. Flow separates alternately around symmetrical bodies with and without sharp corners such as the leading edge of a square section to form vortices around the cylinder. This usually introduces periodic forces on the body due to the pressure changes. This situation is particularly significant in flow involving fluid and structure interaction such as the flow around a tall
building or suspension bridge. Although pressure induced force does not affect the simulation on a fixed square cylinder very much. Vortex formation and progression induce forces on the bodies enveloped in the flow. A vortex creates a negative pressure suction area adjacent to the surface where it progresses. Thus the study of pressure distribution is important in the analysis of the aerodynamic forces around a structure. The pressure distribution near to the surface of the cylinder, flow momentum is quite low due to viscous effects and thus is sensitive to the changes of the pressure gradient. In case of square cylinder with and without corner modification one can say by the numerical Results that pressure on the downstream side of the cylinder is smaller than that on the upstream side of the cylinder. It is clear that the pressure on the downstream side of the square cylinder with corner modification becomes greater than on the downstream side of the square cylinder without corner modification. Also for square cylinder without corner modification pressure is more at front end of upstream square cylinder.

Figure 1.5: Shows a Typical Pressure Distribution Plot for the Flow Around a Square Cylinder with and without Corner Modification for Re = 100 and 200

1.6 Lift Coefficient

In Figure 1.6 (a) - (c). It can be seen from the graph that the Lift coefficient gradually increases upto a certain time and becomes steady periodic. Lift coefficient is more for Square cylinder with sharp corner when compared with chamferd and Rounded corner. The strouhal number for square cylinder is less compared to chamferd and Rounded corner cylinder which can be seen by Fourier Transform graph.
II. CONCLUSIONS

The results of the numerical analysis around square cylinders with and without corner modification lead to the following conclusions:

- The tangential velocity of the Square cylinder is large when compared with corner Rounded and chamfered, and enlarges the separation area of square cylinder side face. Therefore, the width of the wake behind the Square cylinder with corner modification becomes small, and thereby the lift coefficient decreases.
- The velocity behind the cylinder with corner modification becomes large. The large velocity behind the cylinder decreases the lift coefficient.
- The lift coefficients of Square cylinder with corner modification decreases but strouhal number increases when compared with a square cylinder without corner modification.
- The increase in strouhal number decrease the vortex wavelength.
- Strouhal number remains same even if magnitude of oscillations is increased while monitoring the velocity behind the cylinder.

REFERENCES


