CONTROL OF HYDRAULIC FORCES ON A SQUARE AND CIRCULAR CYLINDER USING MULTI-ELEMENT SPLITTER PLATE

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Abstract- Vortex shedding is an oscillating flow that takes place when a fluid such as air or water flows past a bluff body. Von Karman vortex shedding is a repeating pattern of swirling vortices caused by vortex shedding. The vortex regime behind the body has a lower pressure in its core when compared to the freestream velocity which creates a lift force (FL) and the pressure field at the rear part of the body creates drag force.

The proposed project involves numerical analysis (two dimensional) of vortex structure behind the square and circular cylinder. Splitter plate has considerable effect in stabilizing the transverse flow behind the body by rearranging the vortex street. The current works involves optimizing the splitter plate configuration by using different values of D/H(0, 1, 1.5,2.0) and employing multi-element splitter plate. The width of the splitter plate is taken as 30mm and its thickness as 2mm to minimize flow interaction. Numerical flow visualization is carried out using transient simulation and the numerical simulation is carried out in ANSYS FLUENT with an inlet condition of Re=1.0×104 taking the gap between the square cylinder and splitter plate and angle of splitter plate as a variable geometric parameter. The project is aimed at numerically investigating the reduction in lift coefficient (CL) in various splitter plate configurations and using the results to evaluate the potential benefits of employing multi-element splitter plate configuration.

1.INTRODUCTION

This project deals with variation of different hydraulic properties such as pressure, velocity and streamline. These variations are analyzed in different configurations. These different configurations are arranged with a ratio of diameter/side length and distance between cylinder and splitter plate. The proposed project involves numerical analysis (two dimensional) of vortex structure behind the square and circular cylinder. Splitter plate has considerable effect in stabilizing the transverse flow behind the body by rearranging the vortex street. The current works involves optimizing the splitter plate configuration by using different values of D/H (0, 1, 1.5,2.0) and employing multi-element splitter plate. The width of the splitter plate is taken as 30mm and its thickness as 2mm to minimize flow interaction. The project is aimed at numerically investigating the reduction in lift coefficient (CL) in various splitter plate configurations and using the results to evaluate the potential benefits of employing multi-element splitter plate configuration.

2. Literature review

2.1 reduction of fluid forces and vortex shedding frequency of a circular cylinder using rigid splitter plates.

Rezvan Abdi et.al (2017) conducted a study on reduction of fluid forces and vortex shedding frequency of a circular cylinder using rigid splitter plates. A comprehensive parametric study was performed to identify the optimum arrangement of the plates using the commercial finite element software, Comsol Multiphysics. The results show that the location and the number of the plates have crucial effects on the wake control.

2.2 Active control of the hydraulic forces of a body by a splitter plate.

Norio Arai and Masatomo Komatsu (1991) investigated on active control of the hydraulic forces of a body by a splitter plate.The two-dimensional incompressible Navier-Stokes equation is solved numerically. The interaction between the transverse flow (behind the body) and the splitter has considerable influence on the rearrangement of the vortex street. With the splitter plate suitably located, the peak of the lift coefficient is reduced to 40% of the isolated body case. Also, the frequency of the variation of the lift coefficient becomes smaller. It is found that there is an optimal location for the splitter plate.

2.3 Bifurcation analysis of flow over a rotatable cylinder with a splitter plate.

J. Xu et.al, (1991) conducted a bifurcation analysis of flow over a rotatable cylinder with a splitter plate. The two-dimensional, incompressible, unsteady Navier-Stokes equations expressed in stream function and vorticity are solved by using a finite-difference method on a numerically generated, boundary-fitted and moving curvilinear coordinate system. Detailed study of the flow field suggests that the observed offsetting of the plate are mostly influenced by the separation process behind the body.

2.4 Suppression of vortex shedding of circular cylinder in shallow water by a splitter plate.

Huseyin Akilli et.al, (2005) conducted a study on suppression of vortex shedding of circular cylinder in shallow water by a splitter plate. The flow behavior around a vertical circular cylinder placed in shallow water was controlled by a splitter plate inserted at various locations downstream of the cylinder. The splitter plate has a substantial effect on the suppression of the vortex shedding for the gap ratio (G/D) between 0 and 1.

METHODOLOGY

1. Study of CFD tools.
2. Literature review.
3. Modelling and Meshing of the configuration.
4. Numerical flow visualization of vortex structures without splitter plate.
5. Numerical flow visualization of vortex structures with various splitter plate configuration.
6. Theoretical study of vortex structures.
7. Investigating the influence of multi-element splitter plate.

Ansys tools and taken parameters.

Sl.no	Ansys tool	Taken as:-
1	Type of flow	Transient
2	Step time	0.025s
3	Time steps	600
4	Scheme of equations	SIMPLE

Table-2.1, Ansys tools and taken parameters.

FLUID PROPERTIES

Sl.no	Fluid property	Assigned value	Unit
1	Fluid density	1000	Kg/m^3
2	Fluid velocity	10	m/s
3	Kinematic viscosity	0.001	Pa.s
4	Reynold's number	$2 * 10^5$	

Table-2.2, Fluid properties taken.

Different configurations used.

Sl.no	Diameter (D) (mm)	Distance between bluff body and splitter plate (H) (mm)	D/H ratio
1	10	0	0
2	10	20	0.5
3	10	10	1

Table-3, Configurations of bluff body and splitter plate.

MESH

Square cylinder

Object Name	Mesh
State	Solved
Display	
Display Style	Body Color
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Export Format	Standard
Element Order	Linear
Sizing	
Size Function	Curvature
Relevance Center	Coarse
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (1.5958e-004 m)
Max Face Size	Default (1.5958e-002 m)
Growth Rate	Default (1.20)
Automatic Mesh Based	On

Defeaturing	
Defeature Size	Default (7.9789e-005 m)
Minimum Edge Length	1.e-003 m
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.900000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	2
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Assembly Meshing	
Method	None
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	
Number of Retries	0
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Triangle Surface Mesher	Program Controlled
Topology Checking	No
Use Sheet Thickness for Pinch	No
Pinch Tolerance	Default (1.4362e-004 m)
Generate Pinch on Refresh	No
Sheet Loop Removal	No
Statistics	
Nodes	50137
Elements	49634

Circular cylinder

Object Name	Mesh
State	Solved
Display	
Display Style	Body Color
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Relevance	0
Export Format	Standard
Element Order	Linear
Sizing	
Size Function	Curvature
Relevance Center	Coarse
Span Angle Center	Fine
Curvature Normal Angle	Default (18.0 °)
Min Size	Default (1.5958e-004 m)
Max Face Size	Default (1.5958e-002 m)
Growth Rate	Default (1.20)
Automatic Mesh Based Defeaturing	On
Defeature Size	Default (7.9789e-005 m)
Minimum Edge Length	1.e-003 m
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.900000)
Smoothing	Medium
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	2
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Assembly Meshing	
Method	None
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	
Number of Retries	0
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
Triangle Surface Mesher	Program Controlled

Topology Checking	No
Use Sheet Thickness for Pinch	No
Pinch Tolerance	Default (1.4362e-004 m)
Generate Pinch on Refresh	No
Sheet Loop Removal	No
Statistics	
Nodes	50298
Elements	49812

Simulation

For stimulation activates we are using ANSYS software. The requirements of the boundary condition will be asked according to the name information in meshing.

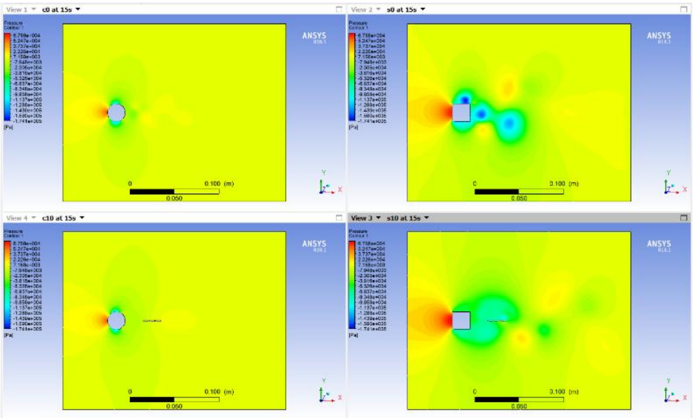

Figure-8.1 Pressure contour in all cases.

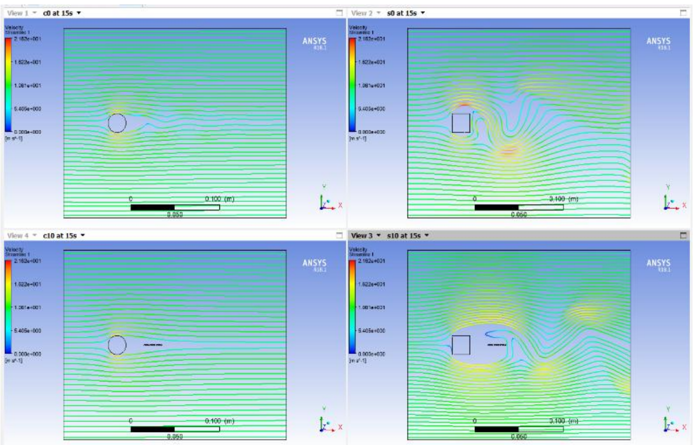

Figure-8.2 Streamlines in all cases.

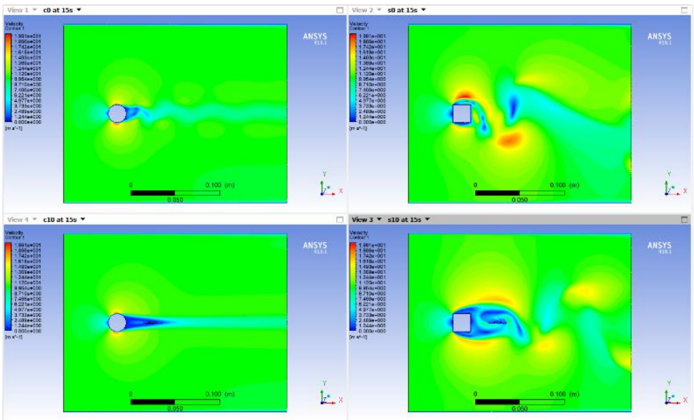

Figure-8.3 Velocity contour in all cases.

Result and Analysis

We use CFD Post for result and post processing. Here we compare the result of flow of water in a Reynold's number of $2 * 10^5$.

9.1Graphical results and result comparison

9.1.1 Graph of pressure on the body

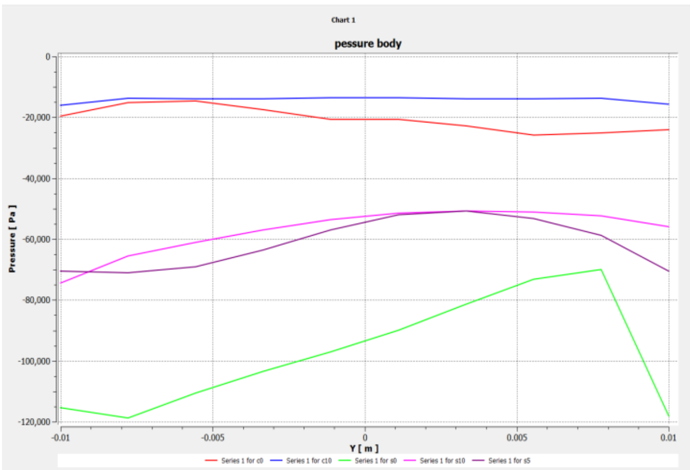

Figure-9.1.1 Graph of pressure on the body.

The graph shown above shows the variation of pressure with distance from the body to right. The point taken as zero is the right most point in the body. The colour code is defined below.

- ____ The red line indicates the pressure exerted on the circular cylinder with no splitter plate.
- ____ The blue line indicates the pressure exerted on the circular cylinder with splitter plate in a D/H ratio of 1.0.

- ____ The green line indicates the pressure exerted on the square cylinder with no splitter plate.
- ____ The pink line indicates the pressure exerted on the circular cylinder with splitter plate in a D/H ratio of 1.0.

9.1.2 Pressure comparison

Sl no.	Geometry	Configuration D/H	Pressure at reference point Y=0 (Pa)	Pressure at maximum of variation Y=8 mm (Pa)	Variation (Pa)
1	Square cylinder	0	-55,000	-70,000	15000
2		1	-95,000	-50,000	-45000
3	Circular cylinder	0	-20,000	-15,000	-5000
4		1	-15,000	-15,000	0

Table-9.1.2 Pressure comparison.

9.1.3 Graph on transient pressure

Figure-9.1.2 Graph on transient pressure.

The graph shown above shows the variation of pressure with distance from the body to right. The point taken as zero is the right most point in the body. The colour code is defined below.

- ____ The red line indicates the pressure exerted on the circular cylinder with no splitter plate.
- ____ The blue line indicates the pressure exerted on the circular cylinder with splitter plate in a D/H ratio of 1.0.
- ____ The green line indicates the pressure exerted on the square cylinder with no splitter plate.
- ____ The pink line indicates the pressure exerted on the circular cylinder with splitter plate in a D/H ratio of 1.0.

9.1.4 Transient pressure comparison

Sl. no	Geometry	Configuration (D/H)	Maximum amplitude after 8s (Pa)	Minimum amplitude after 8s (Pa)	Variation (Pa)
1	Square cylinder	0	-50,000	-1,40,000	90,000
2		1	-40,000	-30,000	-10,000
3	Circular cylinder	0	-15,000	-25,000	10,000
4		1	-15,000	-15,000	0

Table-9.1.4 Transient pressure comparison.

9.1.5 Variation of lift force in circular cylinder with no splitter plate.

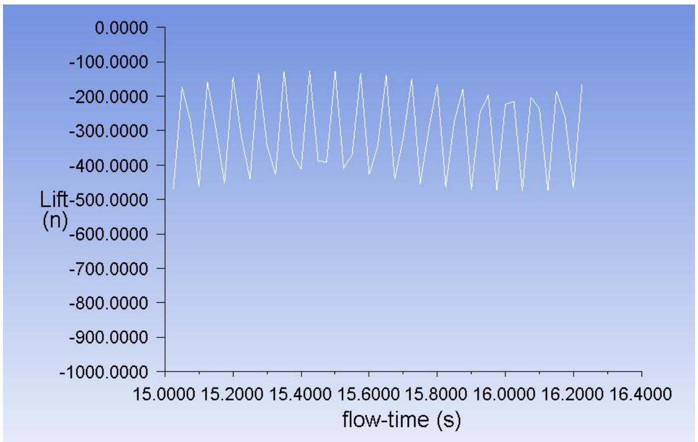

Figure-9.1.5 Variation of lift force in circular cylinder with no splitter plate.

The graph shown above shows the variation of lift force in circular cylinder with no splitter plate. There is an average amplitude of -225N and -475N. So a mean variation of 250N is obtained.

9.1.6 Variation of lift force in circular cylinder with splitter plate in a D/H ratio of 1.0.

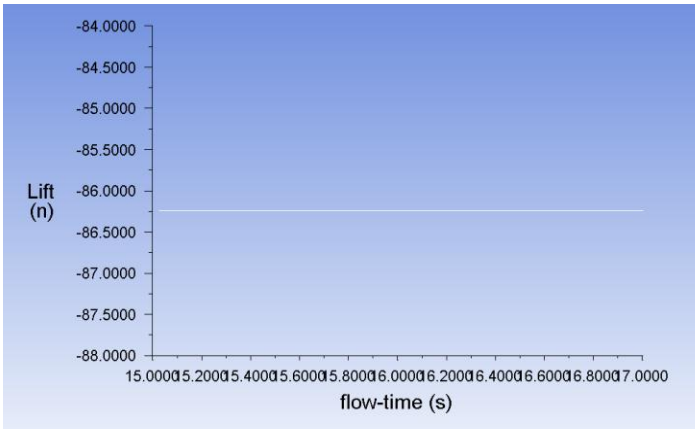

Figure-9.1.6 Variation of lift force in circular cylinder with splitter plate in a D/H ratio of 1.0.

The graph shown above shows the variation of lift force in circular cylinder with splitter plate in a D/H ratio of 1.0. There is an average amplitude of -86.75N and -86.75N. So there is no variation at all.

9.1.7 Variation of lift force in square cylinder with no splitter plate.

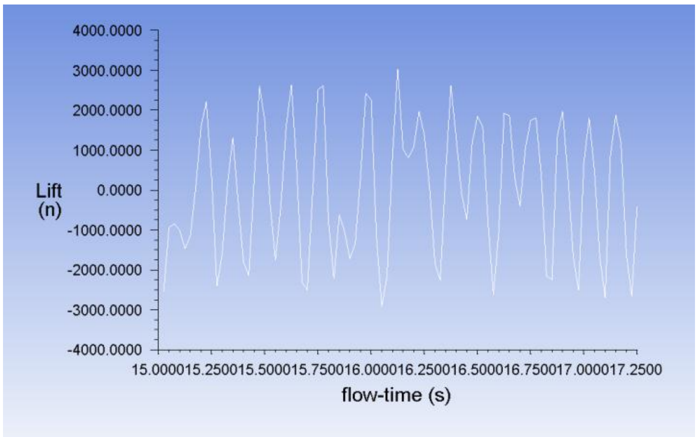

Figure-9.1.7 Variation of lift force in square cylinder with no splitter plate.

The graph shown above shows the variation of lift force in square cylinder with no splitter plate. There is an average amplitude of 225N and -250N. So a mean variation of 475N is obtained.

9.1.8 Variation of lift force in square cylinder with splitter plate in a D/H ratio of 1.0.

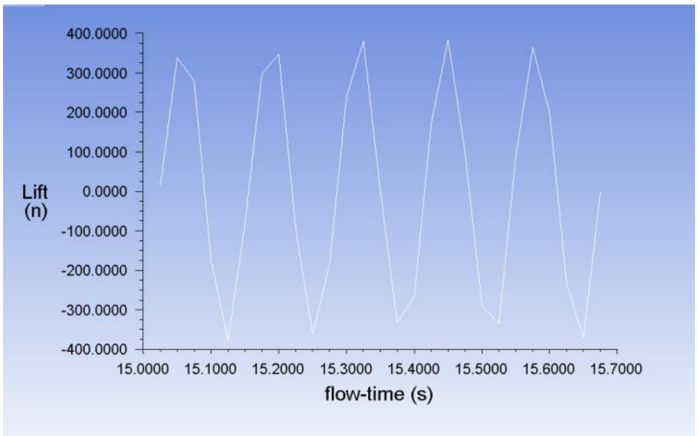

Figure-9.1.8 Variation of lift force in square cylinder with splitter plate in a D/H ratio of 1.0.

The graph shown above shows the variation of lift force in square cylinder with splitter plate in a D/H ratio of 1.0. There is an average amplitude of 350N and -375N. So a mean variation of 250N is obtained.

9.1.9 Lift force comparison

Sl.no	Geometry	Configuration (D/H)	Maximum amplitude after first cycle (N)	Minimum amplitude after first cycle (N)	Variation (N)
1	Square cylinder	0	225	-250	475
2		1	350	-375	725
3	Circular cylinder	0	-225	-475	250
4		1	-86.75	-86.75	0

Table-9.1.9 Lift force comparison.

Conclusion

In the isolated case, it is observed that the von Karman vortex street generates alternately and regularly. When the gap is small, the shed vortex collides with the splitter plate and is prevented from growing. This causes a reduction in the peak values of the lift and drag coefficients. It seems that the reduction in the peak value of the lift coefficient is caused by the rearrangement of, the vortices due to the splitter plate. When the gap becomes wider, vortices occur between the bodies and the wake is reattached.

The variation of different flow properties pressure, velocity and streamline are analysed. The vortex suppression for different configurations are considered. The maximum vortex suppression was obtained from placing a multi-element splitter plate at a distance as same as the diameter of the circular cylinder. Even though splitter plates are used, vortex suppression was low for square cylinder.

When a circular cylinder is placed in a flow of Reynold's number of $2*10^5$ with an accompany by a splitter plate placed in a distance which is equal to the diameter of the cylinder, the flow is maintained in a stable condition.

Properties like lift, pressure, velocity and streamline has no changes experienced. It is almost equal to a laminar flow.

But in case of a square cylinder, even splitter plates are present, changes have been occurred.it was not a negligible one.

Reference

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