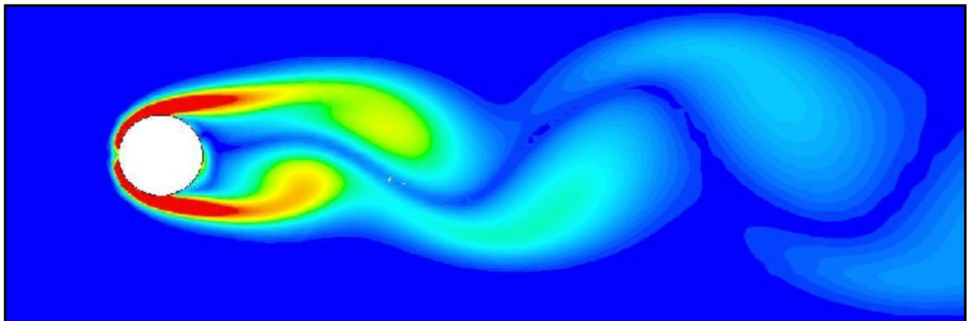

MASTER THESIS PRESENTATION

NUMERICAL SIMULATION OF THE 3D FLOW AROUND JUNCTURES

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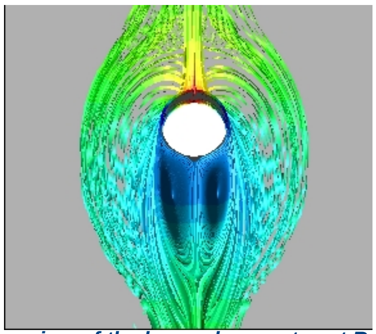
Outline

- 1) Introduction
- 2) The studied problem
- 3) Choosing the best grid and turbulence model
- 4) The solution of steady simulation
- 5) The solution of unsteady simulation
- 6) Conclusion and future work

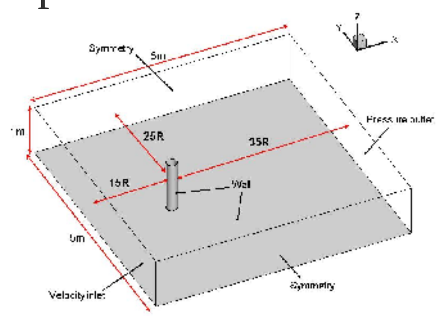
Introduction

- Junction flow is characterized by the horseshoe vortex and the boundary layer separation caused by the adverse pressure gradient. The circular cylinder mounted on the plate is the most popular representative juncture
- Many studies have been conducted for recent decades, but, there is no established method to understand the 3D flow around the cylinder mounted on the curved plate.
- Primary objective: The 3D flow around the inclinded cylinder mounted the flat and curved plate at Re=3,900 and Re=10^6.



Rear view of the horseshoe vortex at Re=3,900 ***at Re=10^6***

The studied problem



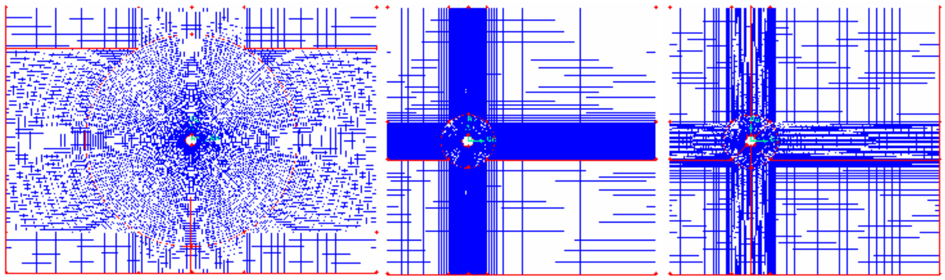
Flat plate case

- The radius of cylinder is 0.1m
- The depth of cylinder is 1m.
- The plate is either flat or curved (convex or concave)
- The three different curvature radii of the plate: 30D, 40D, 50D, where D is the diameter of cylinder.
- The cylinder is inclined at every 10 degrees, from 0º to 30º laterally, downstream and upstream

➡ **140 configurations to cover all the combinations**

Choosing the best grid and turbulence model

- FVM used to discretize the equations in space,
- H-O type grids are used for the PDE discretization,
- Re=3,900 and Re = 1,000,000,



Grid 1 *Grid 2* *Grid 3*

The number of cells in each Grid

Type of grid	2D	3D	First cell size
Grid 1	15,068	1,356,120	0.0001
Grid 2	21,492	1,934,280	0.0005
Grid 3	16,964	1,526,760	0.0001

Which is the best mesh?

Choosing the best grid and turbulence model

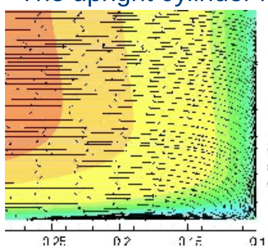
The drag coefficient of an upright circular cylinder at Re=10^6

Mesh	Turbulence models	C_d in Simulation	C_d in Experiment [75]	Error (%)
Grid 1	S-A	0.3759	0.4	6.025
	k-epsilon RNG	0.35183991		12.04002
	k-epsilon Realizable	0.34843775		12.89056
	k-omega SST	0.45771024		14.42756
Grid 2	S-A	0.48268798		20.672
	k-epsilon RNG	0.41781923		4.454807
	k-epsilon Realizable	0.36106899		9.732753
	k-omega SST	0.55113265		37.78316
Grid 3	S-A	0.39060602		**2.348495**
	k-epsilon RNG	0.35844181		10.3888
	k-epsilon Realizable	0.36169221		8.826948
	k-omega SST	0.46612037		16.53009

The S-A model is the most suitable turbulent model and the Grid 3 is the best mesh which will be used to simulate the next complex cases.

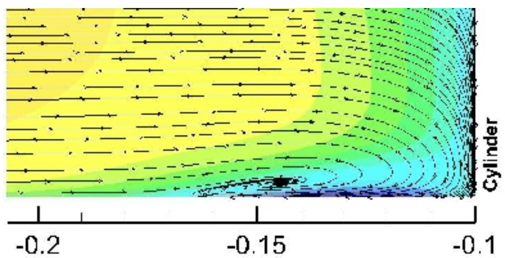
The solution of steady simulation

- The upright cylinder mounted on the flat plate:



From simulation at Re = 3,900

From Baker's test with Re = 4370

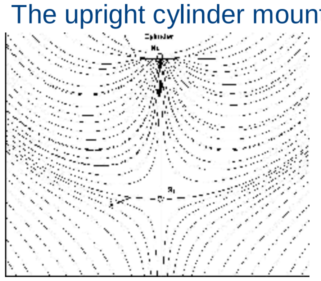


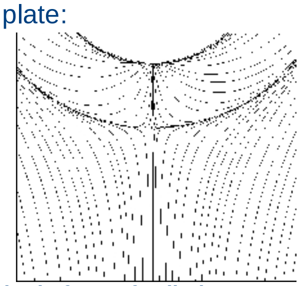
From simulation at Re=10^6

The vortex structure in front of the cylinder

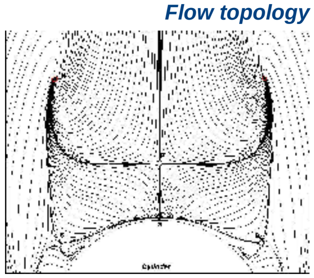
The solution of steady simulation

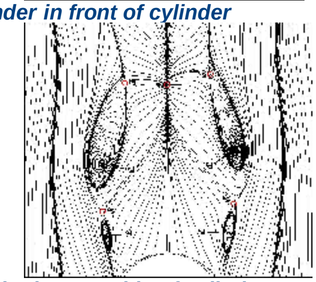
- The upright cylinder mounted on the flat plate:





Flow topology around the cylinder in front of cylinder



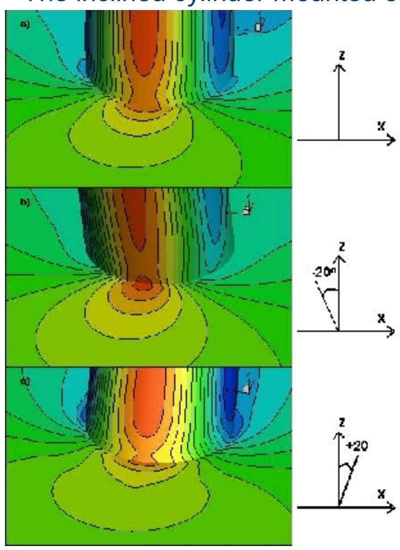


Flow topology around the cylinder in the rear side of cylinder

Re=3,900 *Re=10^6*

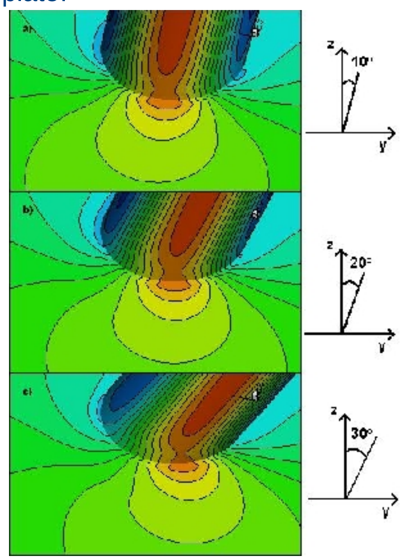
The solution of steady simulation

- The inclined cylinder mounted on the flat plate:



Pressure fields around a cylinder inclined longitudinally

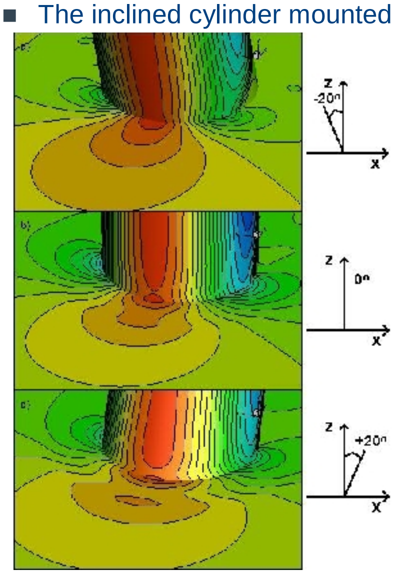
Re = 3,900



Pressure fields around a cylinder inclined laterally

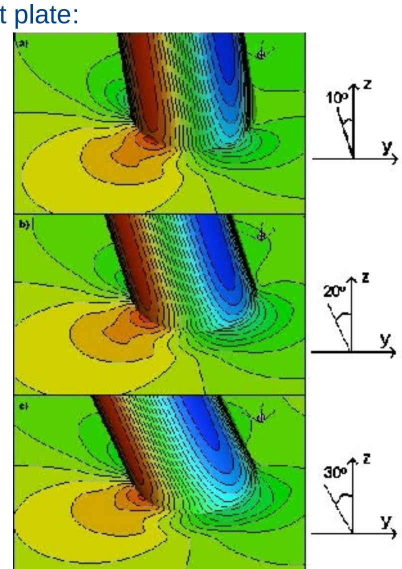
The solution of steady simulation

- The inclined cylinder mounted on the flat plate:



Pressure fields around a cylinder inclined longitudinally

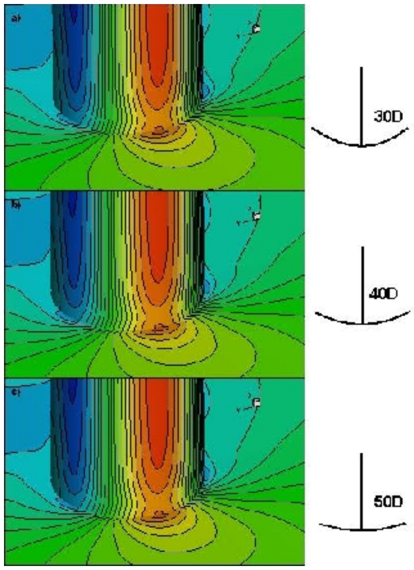
Re = 10^6



Pressure fields around a cylinder inclined laterally

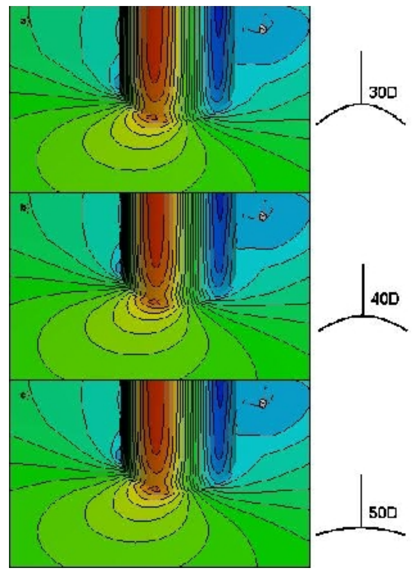
The solution of steady simulation

- The upright cylinder mounted on the curved plate:



Pressure fields in concave plate case

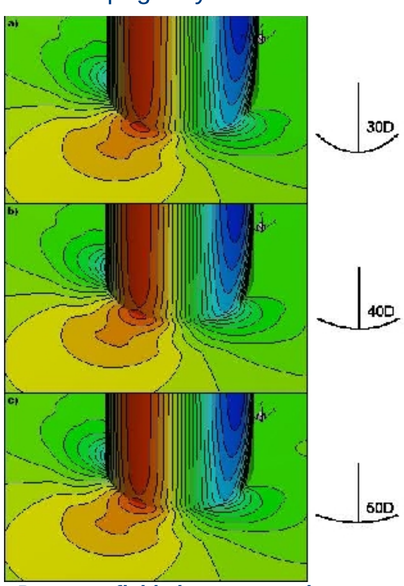
Re = 3,900



Pressure fields in convex plate case

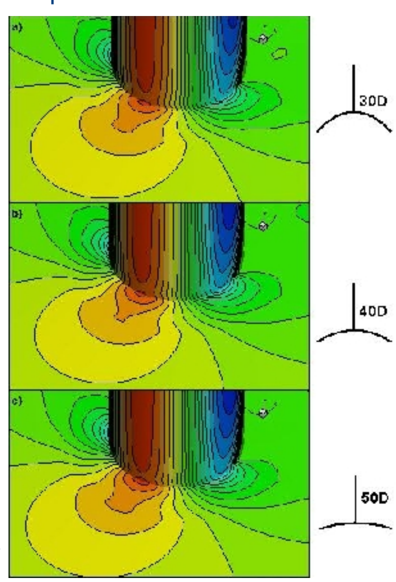
The solution of steady simulation

- The upright cylinder mounted on the curved plate:



Pressure fields in concave plate case

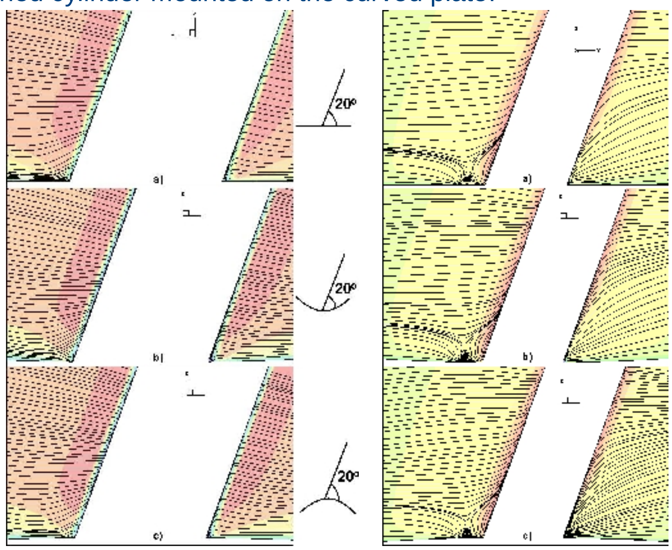
Re = 10^6



Pressure fields in convex plate case

The solution of steady simulation

- The inclined cylinder mounted on the curved plate:

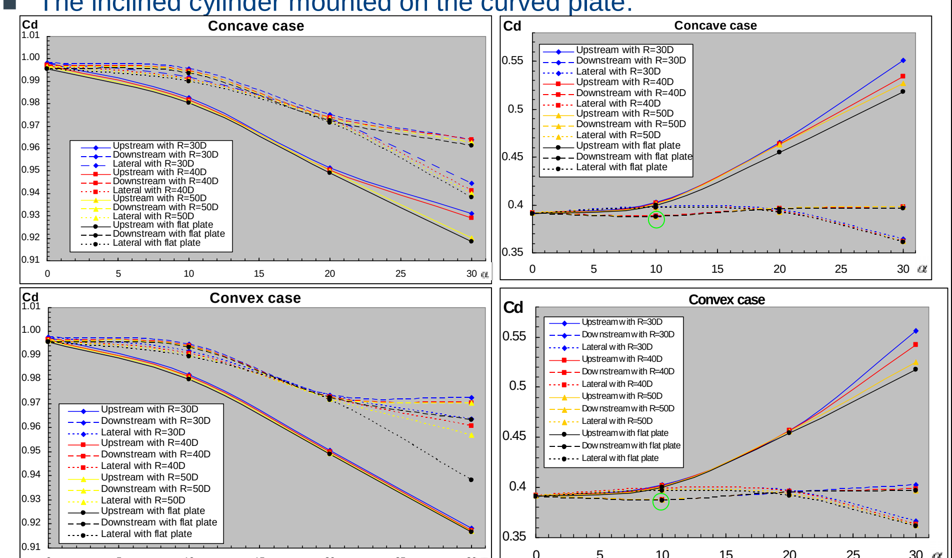


Re = 3,900 ***Re = 10^6***

Transversal streamlines around the cylinder inclined at 20°

The solution of steady simulation

- The inclined cylinder mounted on the curved plate:

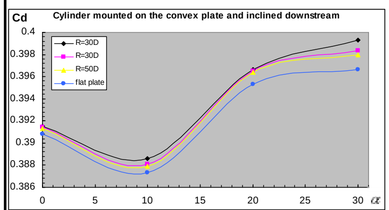


Re = 3,900 ***Re = 10^6***

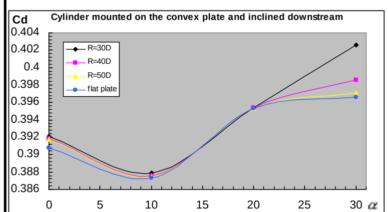
Curvature influence on the drag coefficient of the cylinder

The solution of steady simulation

- The inclined cylinder mounted on the curved plate:



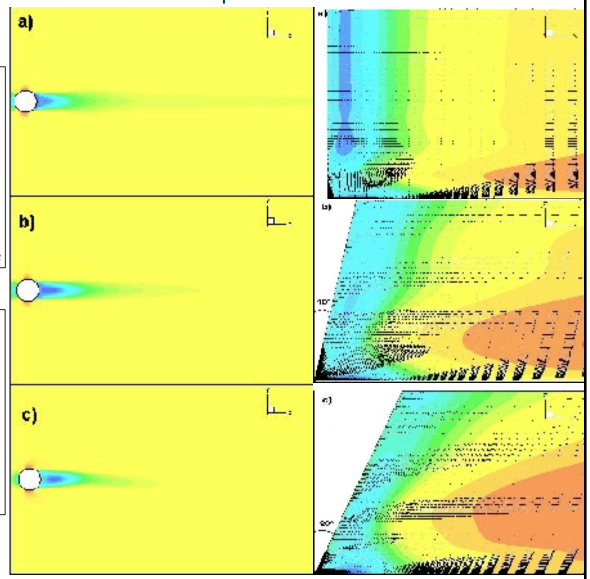
Concave case



Convex case

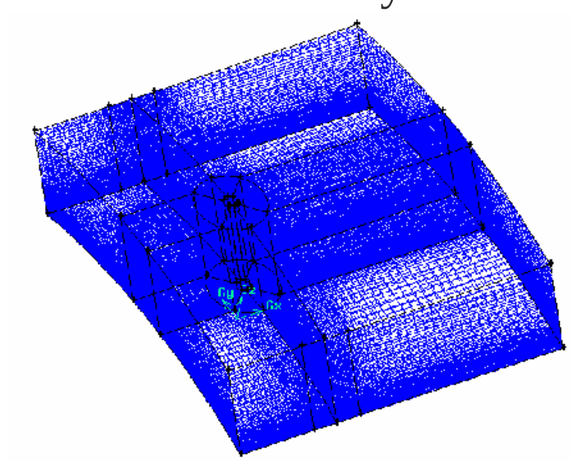
The drag coefficient of the cylinder

Inclined downstream



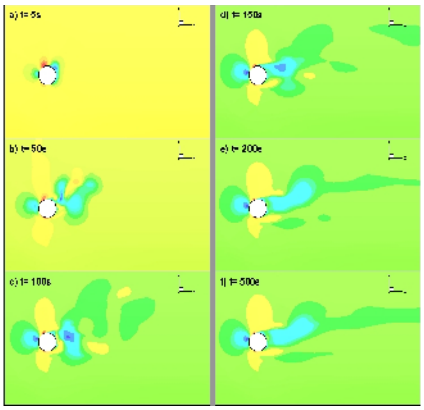
Velocity fields

The solution of unsteady simulation

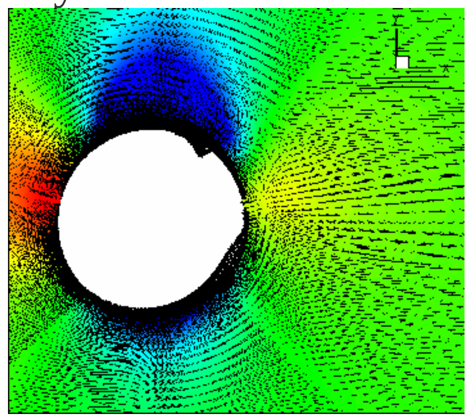


- The circular cylinder is inclined laterally with an angle of 30º and mounted on the convex plate that has the curvature radius of 50D.
- Re=3,900
- The turbulence model: Spalart-Allmaras model
- Computational time: time step of 0.005s, number of time steps of 50,000, residuum of 10^{-6}

The solution of unsteady simulation



Velocity contours at the different time

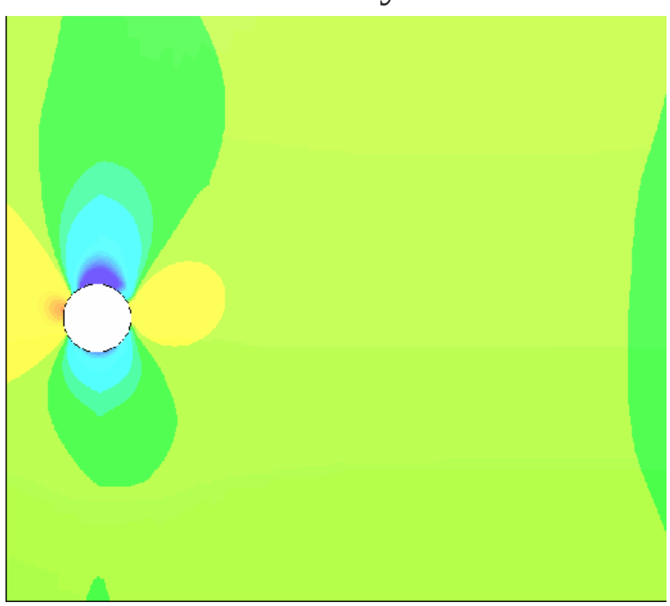


The velocity vectors existing near the cylinder

	Unsteady	Steady
Drag coefficient of the cylinder	0.95035344	0.956929
Drag coefficient of the plate	1.0544992	1.115424

⇨ The unsteady simulation shows that the total drag coefficient of the cylinder is reduced comparing with the steady simulation

The solution of unsteady simulation



The pressure contour around the cylinder

Conclusion

- The direction of cylinder inclination affects the juncture flow. The stronger pressure gradients reveals at the root of the cylinder inclined longitudinally towards to upstream.
- The smaller curvatures determine the larger pressure. This leads to an increase of the total drag coefficient.
- At Re = 3,900, the total drag coefficients decrease when the inclination angle of cylinder increases, regardless the direction of the cylinder inclination as well as the plate curvature.
- At Re = 10^6, the total drag coefficient mostly increases along with the increase of cylinder inclination angle in upstream and downstream cases, except for the case of 10^{o} angle in downstream for all convex and concave cases.

Future work

- Carrying out the experiments with the circular cylinder mounted on the curved plate.
- The simulation of free surface.

Thank You For Your Attention!