REDUCTION OF FLUID FORCES ON A SQUARE CYLINDER IN A LAMINAR FLOW USING PASSIVE CONTROL METHODS

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COMSOL CONFERENCE
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Agenda

- Introduction
- Problem statement, equations, and grid
- Results and discussion
- Conclusions

Introduction

- Unsteady wake causes fluid forces and flow induced vibration.
- Flow control can reduce:
  - Unsteadiness
  - Forces
  - Wake
  - Separation of flow
- Effective flow control can: save energy, increase propulsion efficiency, and reduce induced vibration of the body.

Introduction

- Examples of applications of flow control in industry:
  - Chimneys
  - Parallel suspension bridges
  - Vibration of radar masts
  - Heat exchanger pipes
  - High structures.

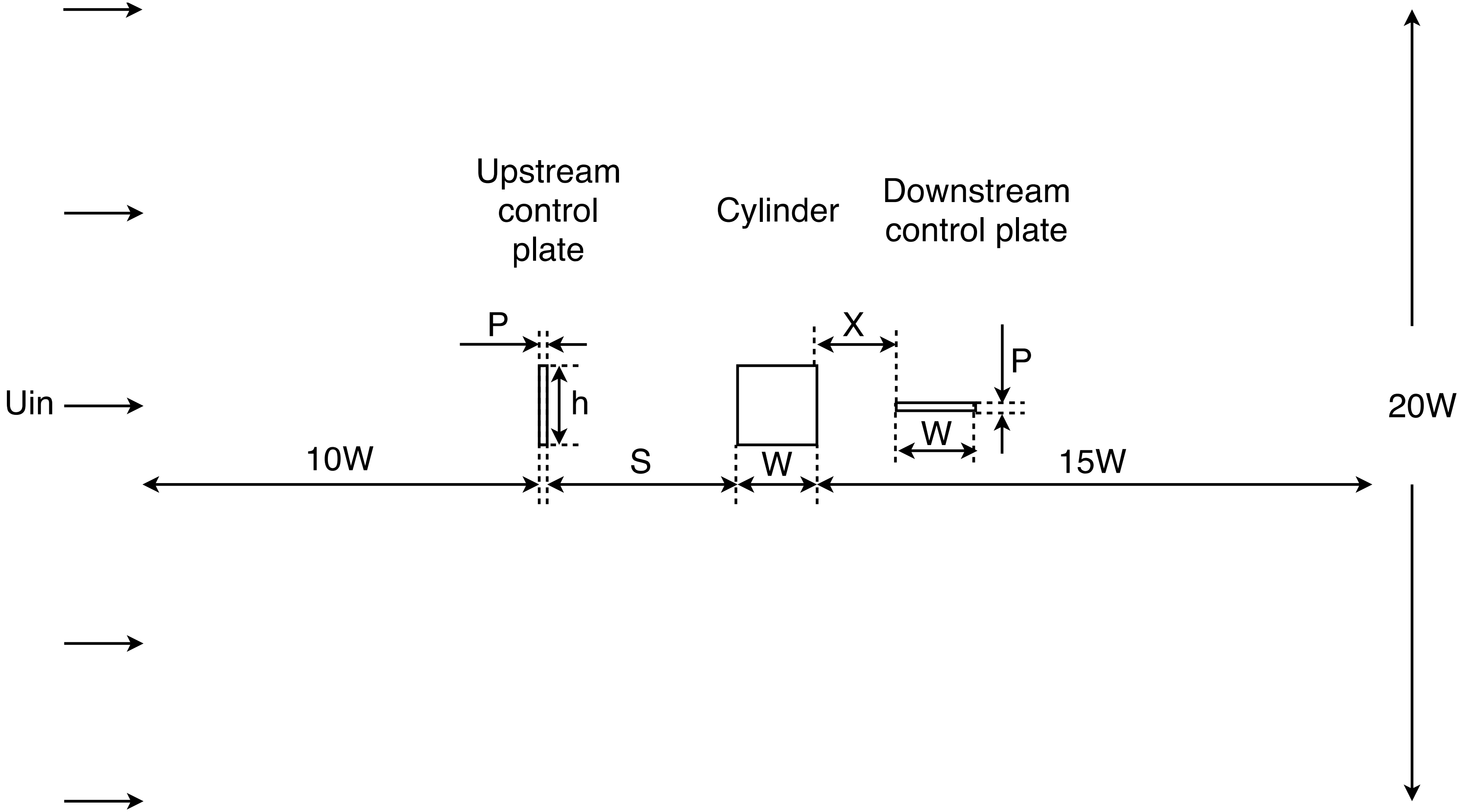




Introduction

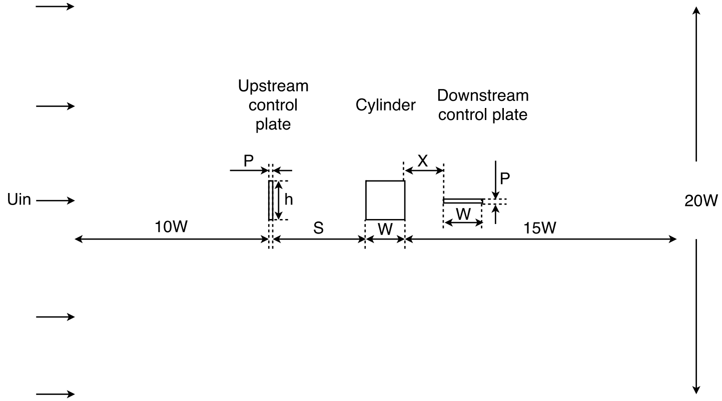
- This study validates the results of Malekzadeh and Sohankar.
- The study focuses on improving the best results found in the validation of Malekzadeh and Sohankar.
- The validation studied the use of a vertical control plate upstream of the square cylinder with a varying height (0.1-0.9W) and varying distance (1.1-7W).
- The results are improved by adding a horizontal downstream control plate of width of W and varying distance (0-2W).

Problem Statement, Equations, and Grid



Problem Statement, Equations, and Grid

- Study is made for:
  - Unsteady
  - Laminar (Re=160)
  - Incompressible flow
  - Two dimensional case



The continuity equation:

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0$$

The momentum equation in the x direction:

$$\frac{\partial U}{\partial \tau} + \frac{\partial (UU)}{\partial X} + \frac{\partial (VU)}{\partial Y} = -\frac{\partial P}{\partial X} + \frac{1}{Re}\left(\frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2}\right)$$

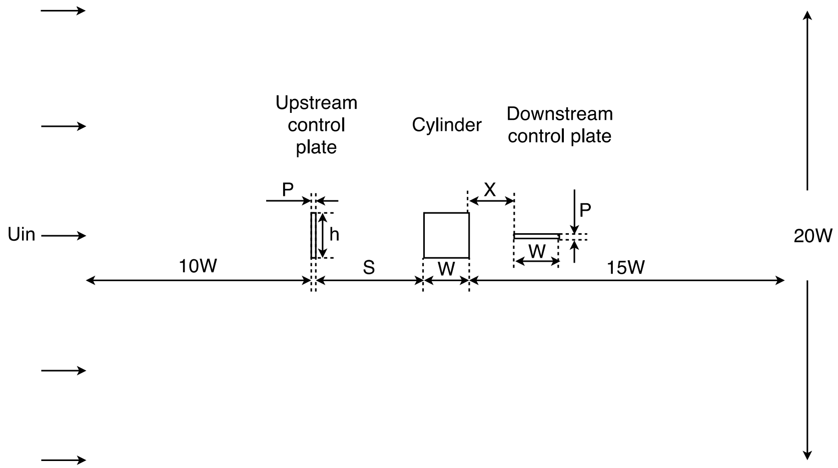
The momentum equation in the y direction:

$$\frac{\partial V}{\partial \tau} + \frac{\partial (UV)}{\partial X} + \frac{\partial (VV)}{\partial Y} = -\frac{\partial P}{\partial Y} + \frac{1}{Re}\left(\frac{\partial^2 V}{\partial X^2} + \frac{\partial^2 V}{\partial Y^2}\right)$$

Problem Statement, Equations, and Grid

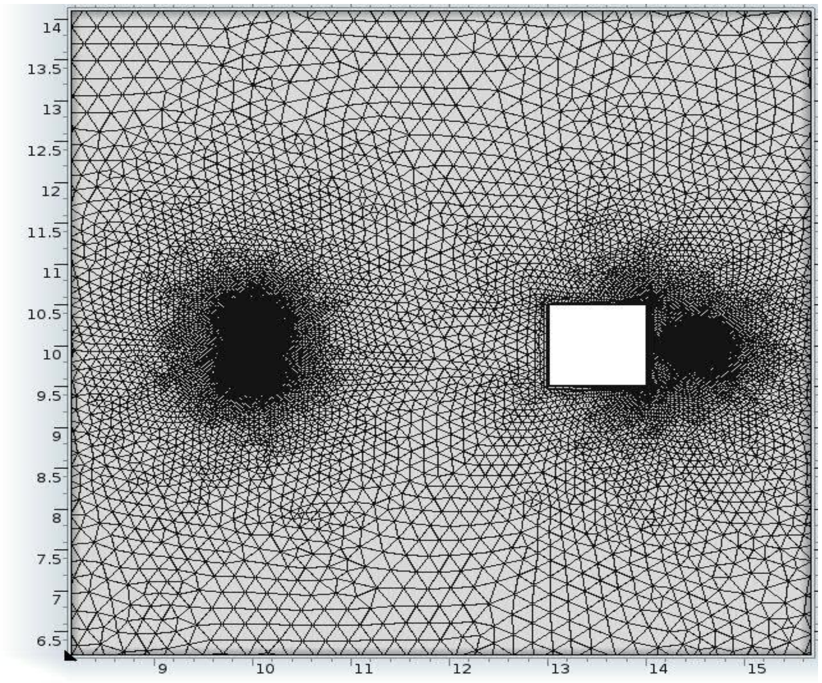
The boundary conditions used in the simulation of the model are:

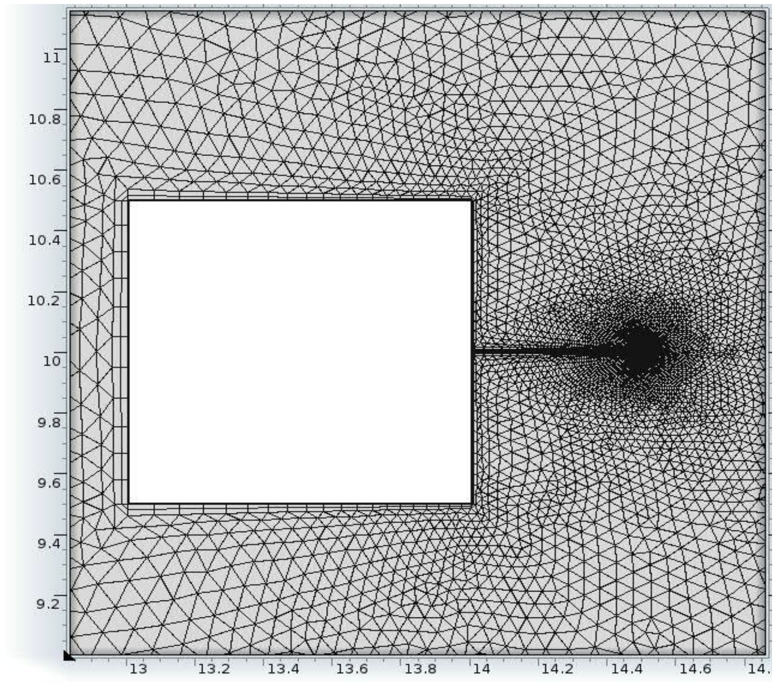
- Slip top and bottom boundaries resemble far field condition.
- No-slip boundary conditions on the square cylinder and control plates' sides.
- Normal inflow velocity at the inlet: *u=Uin, and v=0.*
- Pressure, no viscous stress at the outlet.



Problem Statement, Equations, and Grid

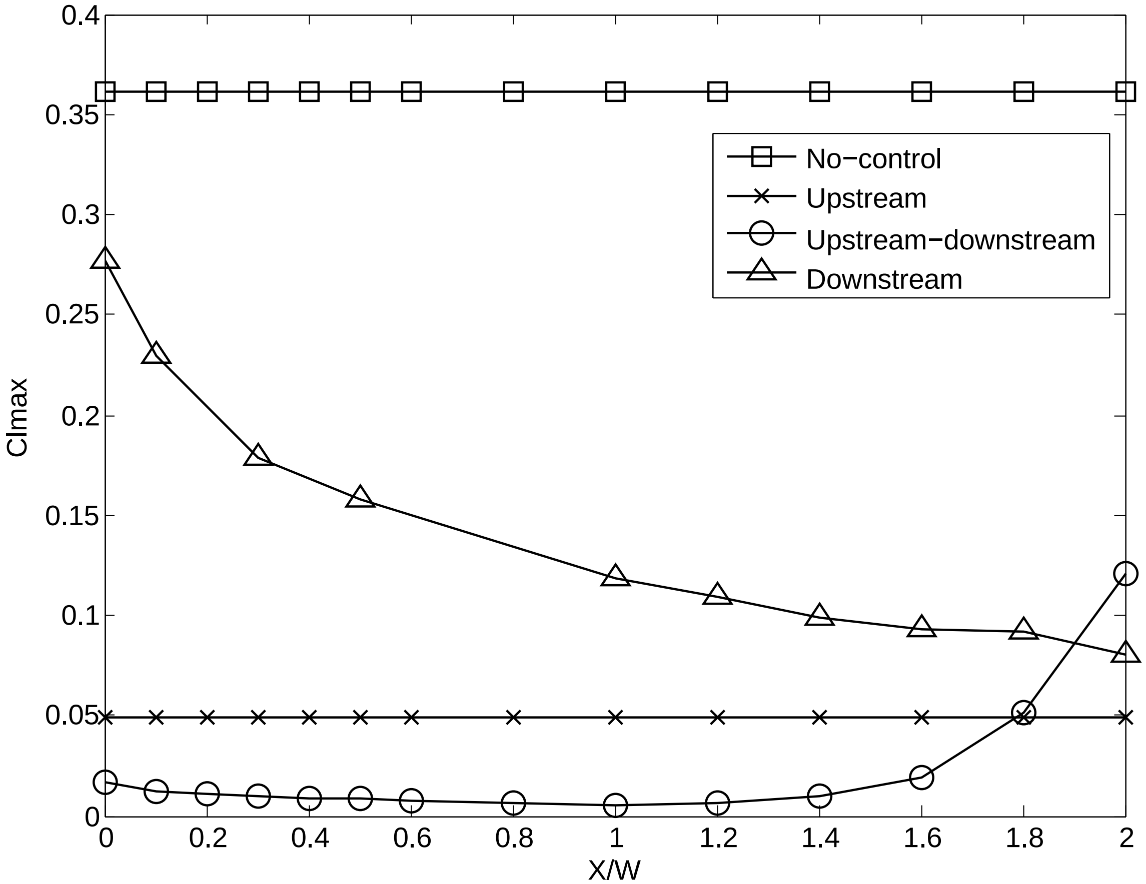
- Time stepping of simulation 0.025 seconds.
- Extremely fine mesh was used for all simulations.





Results and Discussion

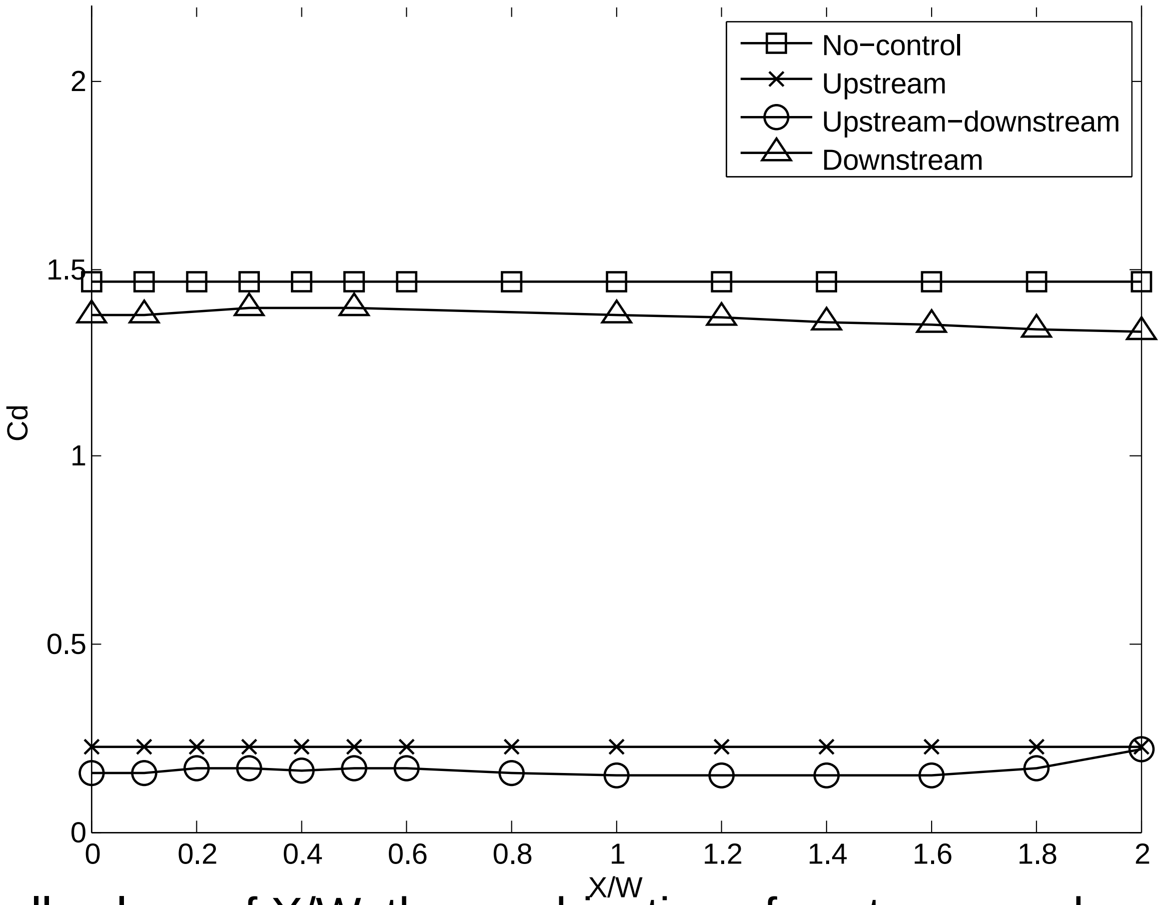
Optimum case



- Maximum reduction combination of upstream and downstream case up to X/W=1.8.
- Maximum reduction for X/W greater than 1.8 upstream case.

Results and Discussion

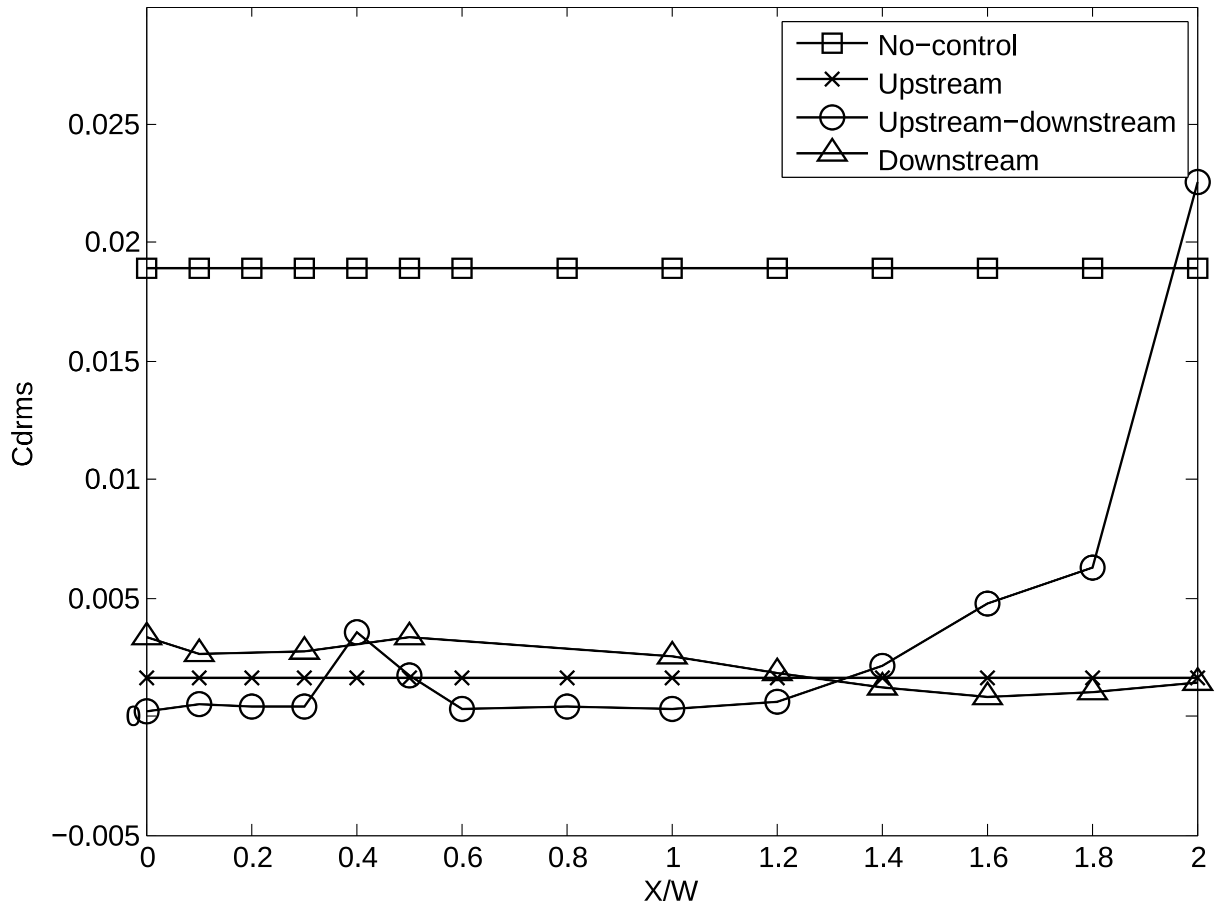
Optimum case



- For all values of X/W, the combination of upstream and downstream case has the least values.
- The use of either combination upstream and downstream case or upstream case reduces the values significantly.

Results and Discussion

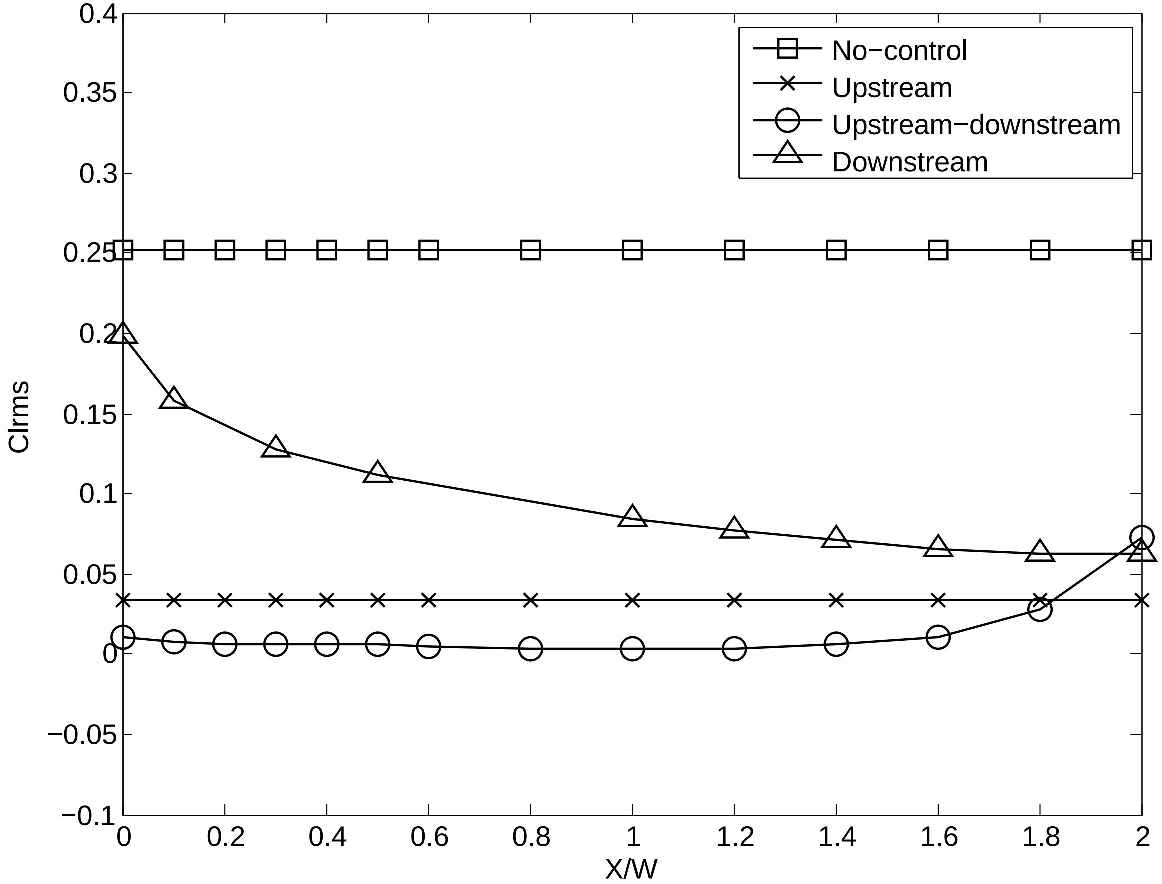
Optimum case



- When X/W is between 0 to 0.3 and 0.5 to 1.3, the upstream and downstream case has the minimum values.
- When X/W is between 0.3 to 0.5 upstream case has the minimum values.
- When X/W is greater than 1.3, downstream case is the best.

Results and Discussion

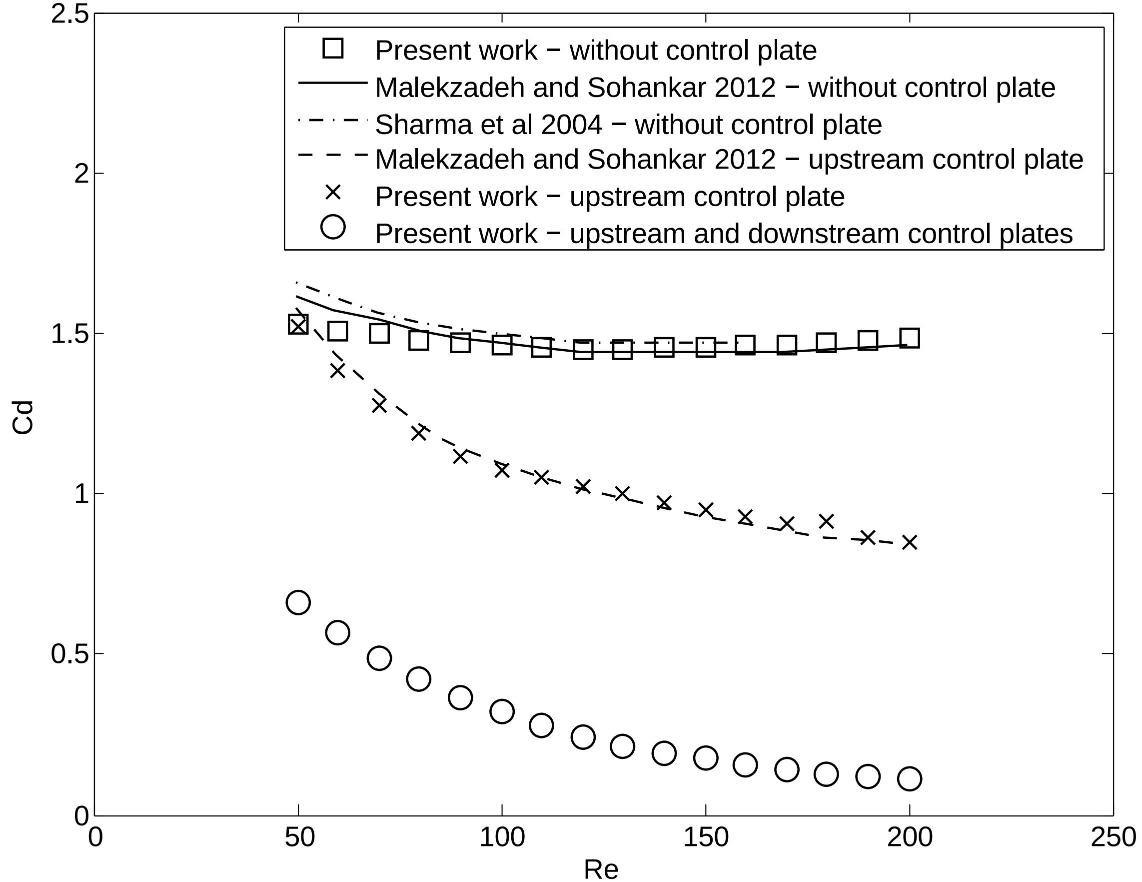
Optimum case



- When X/W is less than 1.8, upstream and downstream combination case has the minimum values.
- When X/W is greater than 1.8, upstream case has the minimum values.

Results and Discussion

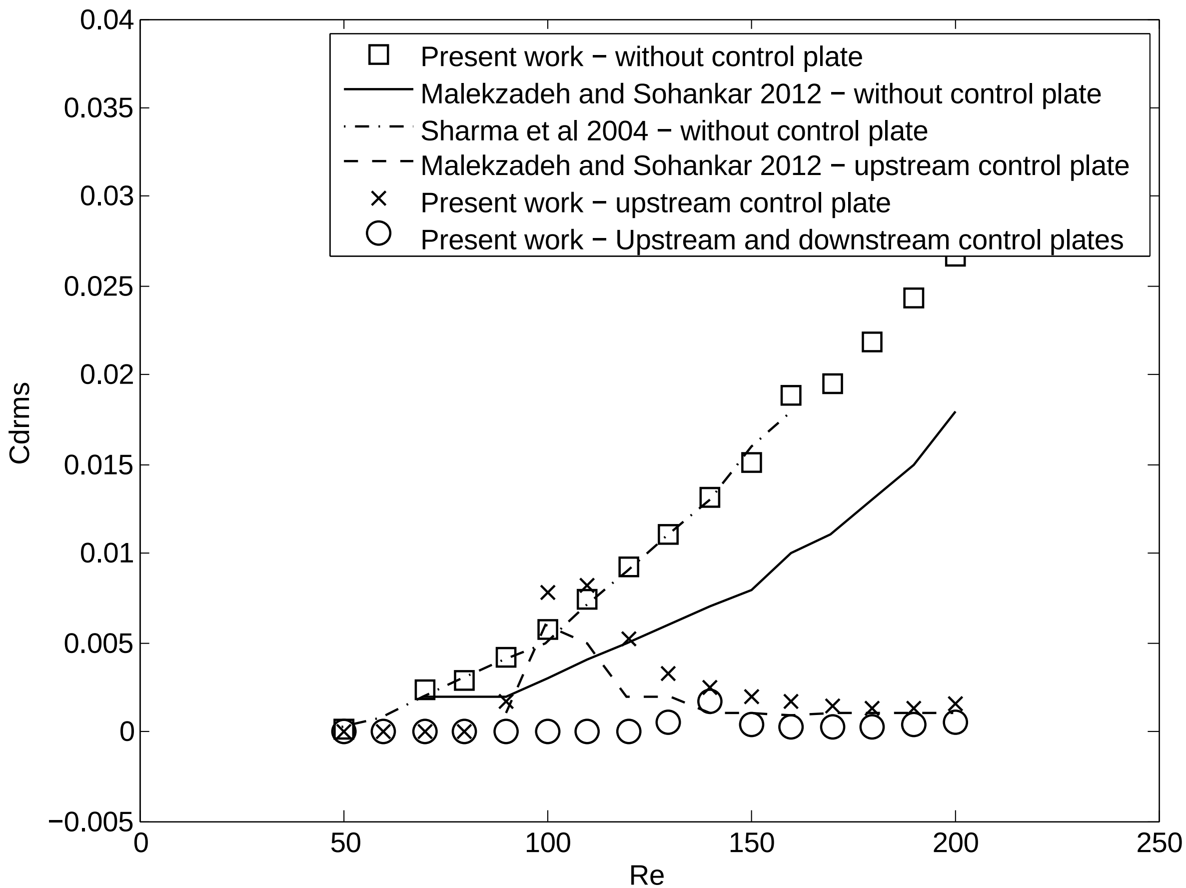
Reynolds effect



- As Reynolds number increases, time averaged drag coefficient on cylinder decreases.
- The upstream and downstream combination case decreases the drag for all Reynolds number significantly.
- Good agreement with literature.

Results and Discussion

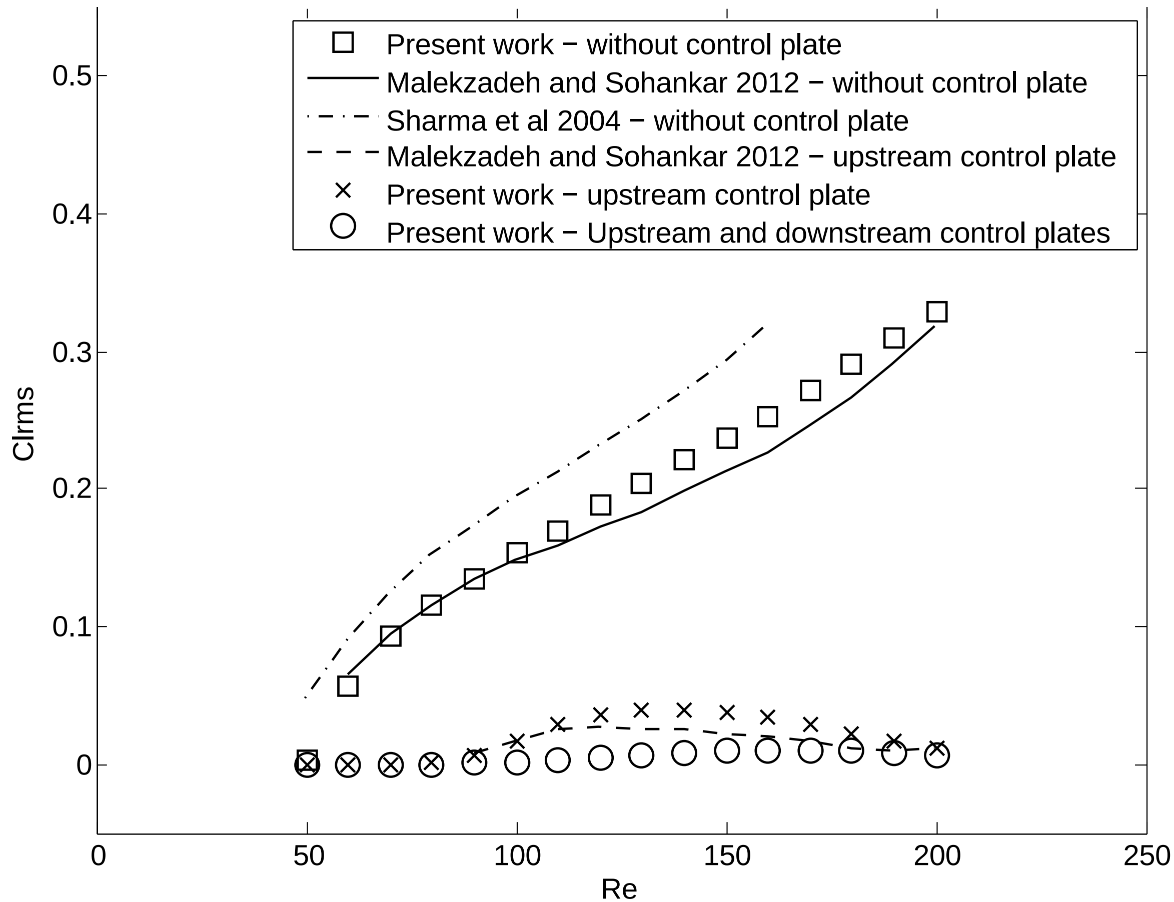
Reynolds effect



- As Reynolds number increases, Cdrms increases for all cases.
- Cdrms remains almost constant for the case of upstream and downstream combination
- The slope is maximum for the case of no control
- Good agreement with literature.

Results and Discussion

Reynolds effect



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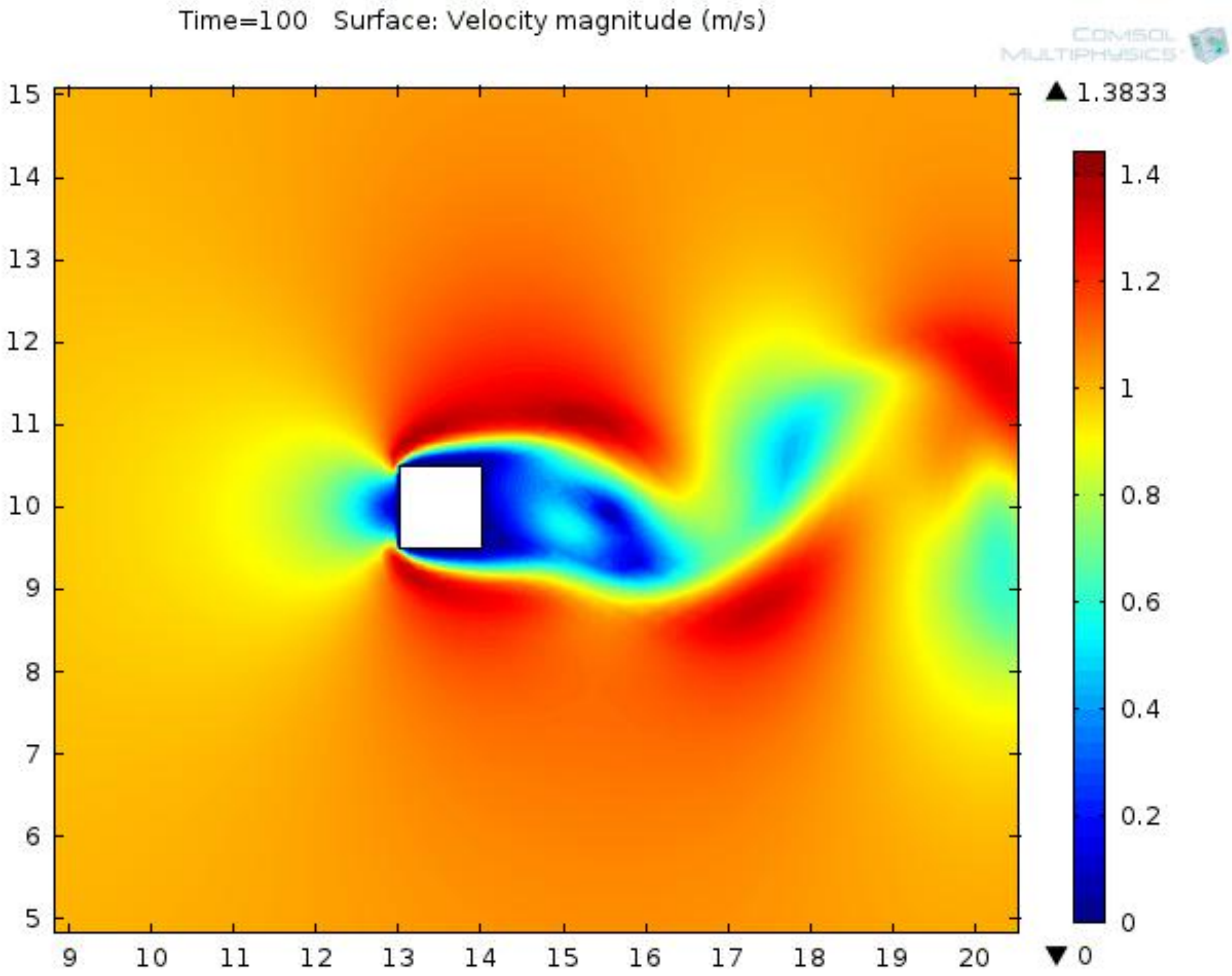
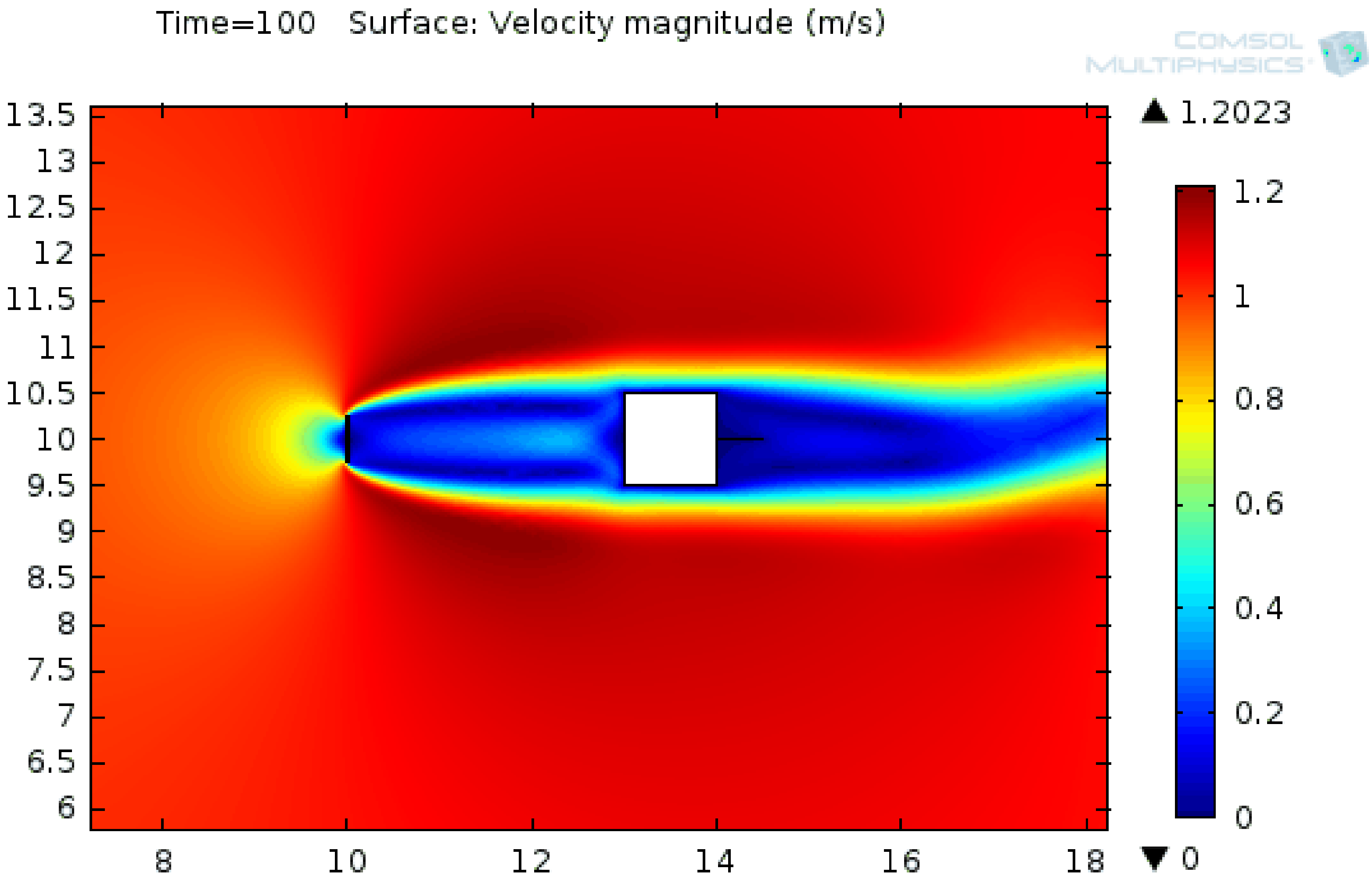

Time=100 Surface: Velocity magnitude (m/s)
15
14
13
12
11
10
9
8
7
6
5
9 10 11 12 13 14 15 16 17 18 19 20
▲ 1.3833
1.4
1.2
1
0.8
0.6
0.4
0.2
0
▼ 0


Time=100 Surface: Velocity magnitude (m/s)
COMSOL MULTIPHYSICS
13.5
13
12.5
12
11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
8
10
12
14
16
18
▲ 1.2023
1.2
1
0.8
0.6
0.4
0.2
0
▼ 0

Conclusion

1. The use of control plate regardless of the position and size reduces the fluid forces on the cylinder.
2. The use of a downstream control plate in any case reduces the vortex shedding behind the square cylinder by reducing Strouhal number.
3. The optimum cases that decreases the fluid forces on a square cylinder in a laminar flow found in this research is by using a vertical upstream control plate with h/W=0.5 and S/W=3 and a horizontal downstream control plate with width W and placed in the range of X/W=0 to 0.3 and 0.5 to 1.3.

Conclusion

5. As Reynolds number increases, the drag coefficient on the cylinder decreases for all cases.
6. Using a combination of an upstream and downstream control plates reduces the lift and drag coefficients on the cylinder for all Reynolds number.

THANK YOU