# Finite Volume Analysis of Resolute Rowing Shell With a Time Variant Inlet Velocity Boundary Condition

Ben Koenig, 2.290

# 2.29 Framework Solver

## Adapted from Example 6, cylinder cross flow

-TVD Scheme
-Incremental non rotational

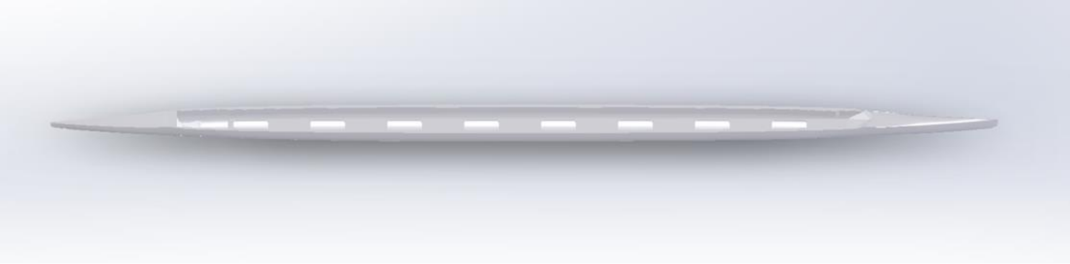
```
if ~isfield(app, 'Nx'), app.Nx =1251; end
if ~isfield(app, 'Ny'), app.Ny = 126; end
if ~isfield(app, 'T'), app.T = 20; end
if ~isfield(app, 'dt'), app.dt = 0.00075; end
if ~isfield(app, 'PlotIntrvl'), app.PlotIntrvl = .05/3/app.dt; end
if ~isfield(app, 'nu'), app.nu = 0.002; end

app.SetupScript = 'RowingSetup';
app.PlotScript = 'RowingPlots';
app.RunName = 'Flow_Past_Hull';
app.updateBcs=1;
app.NonRot=1;
solver = 1;
```

$$\frac{L}{\eta} = O(Re^{\frac{3}{4}})$$

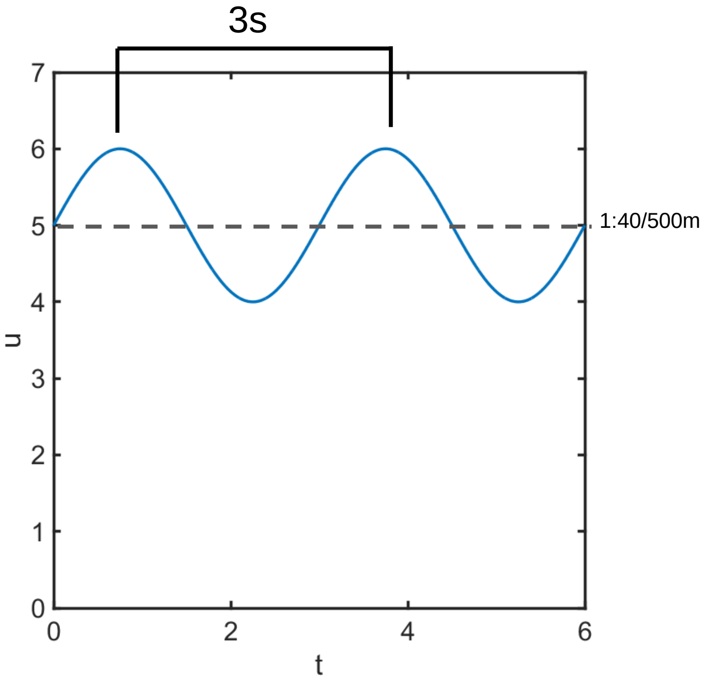
$\nu = 8 * 10^{-7}$ ⟶ $\sim 40x\ (Nx, Ny, Nt)$

$\sim 7\ years$

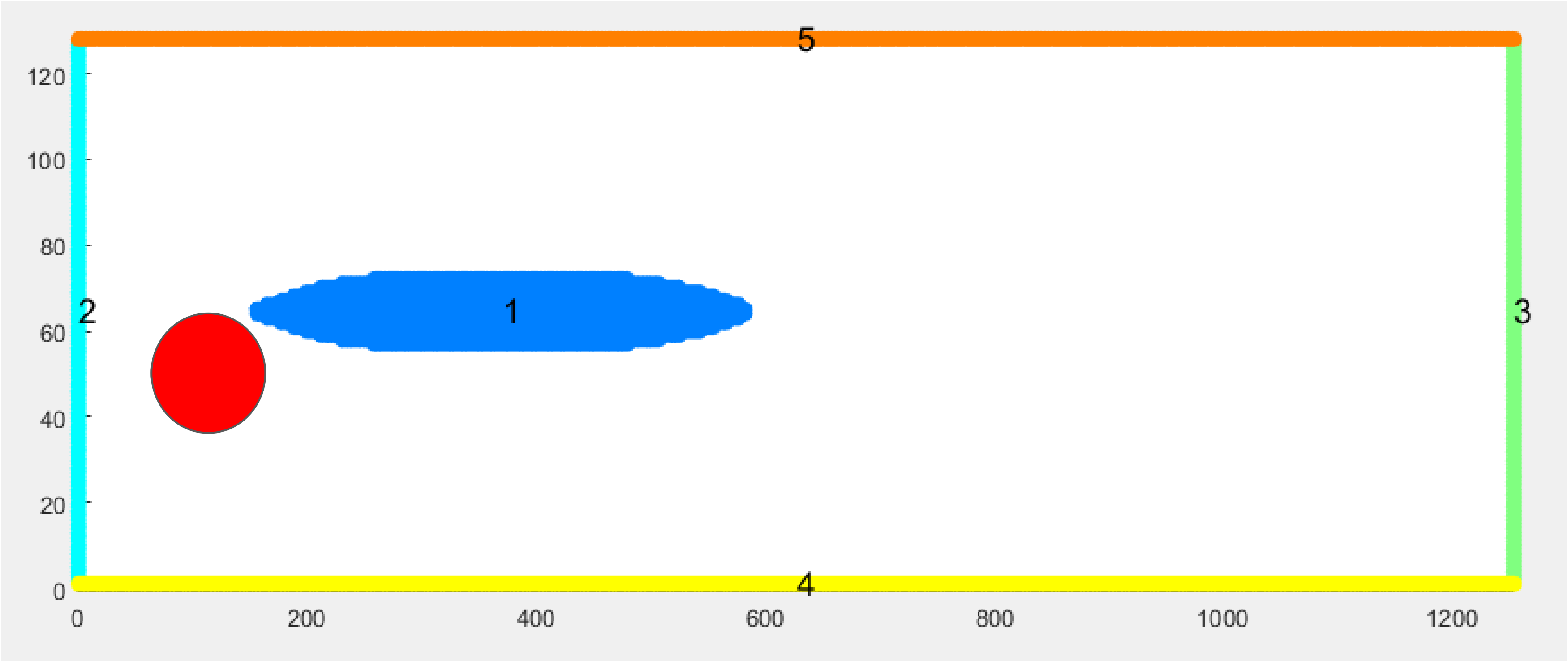
# Mask, Inlet Velocity BC



https://grabcad.com/library/resolute-midweight-8-1

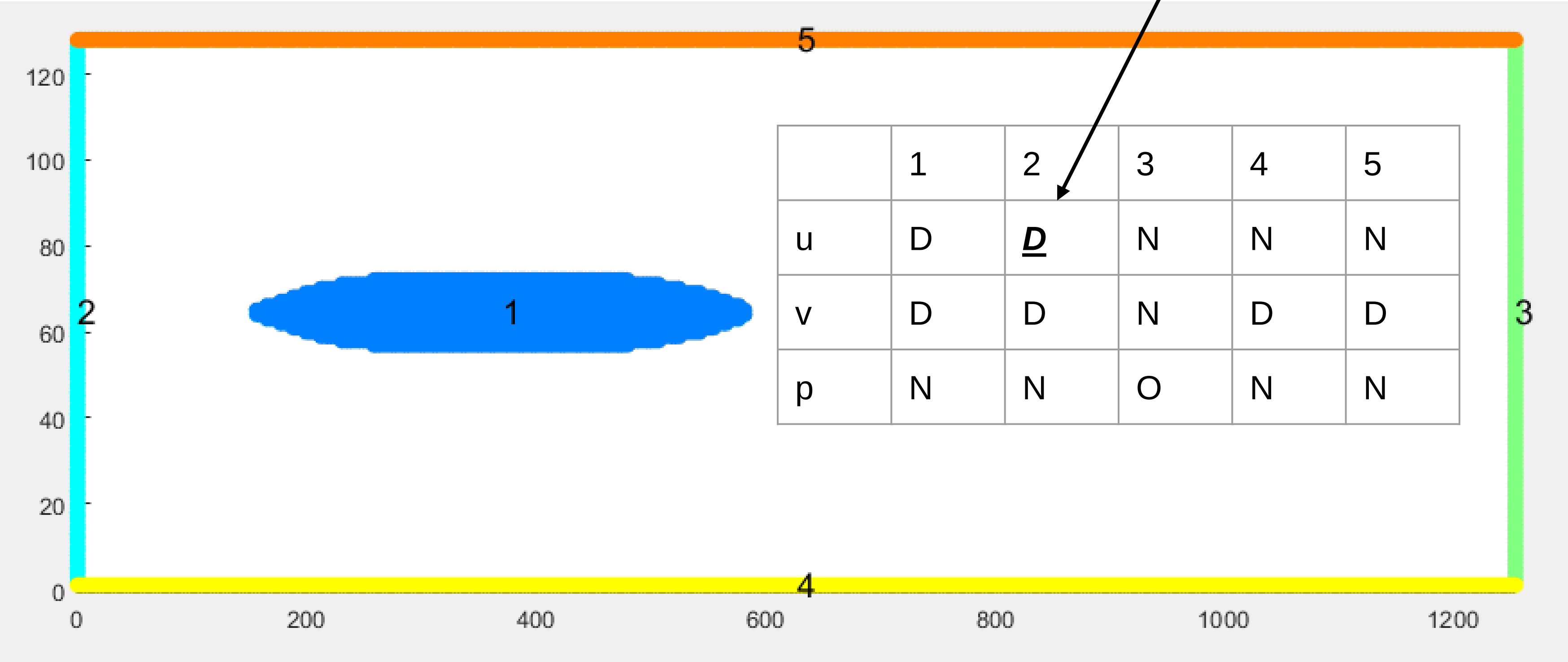


# Initial Conditions



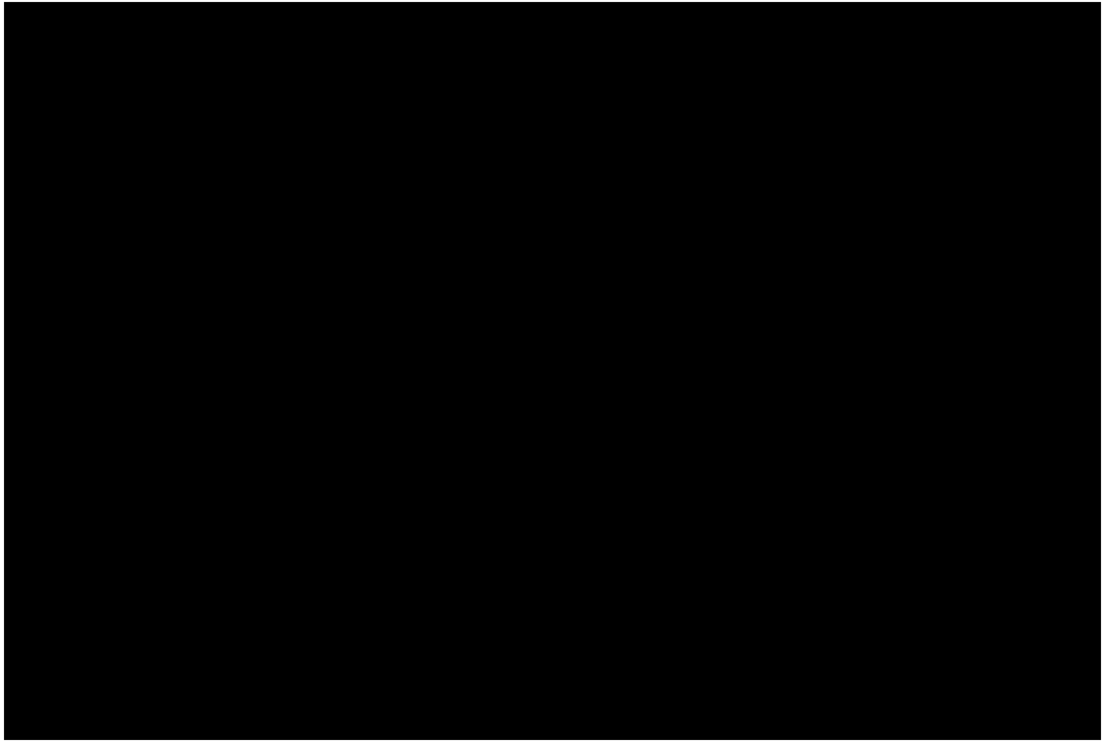
# Boundary Conditions

Ramp into sinusoid

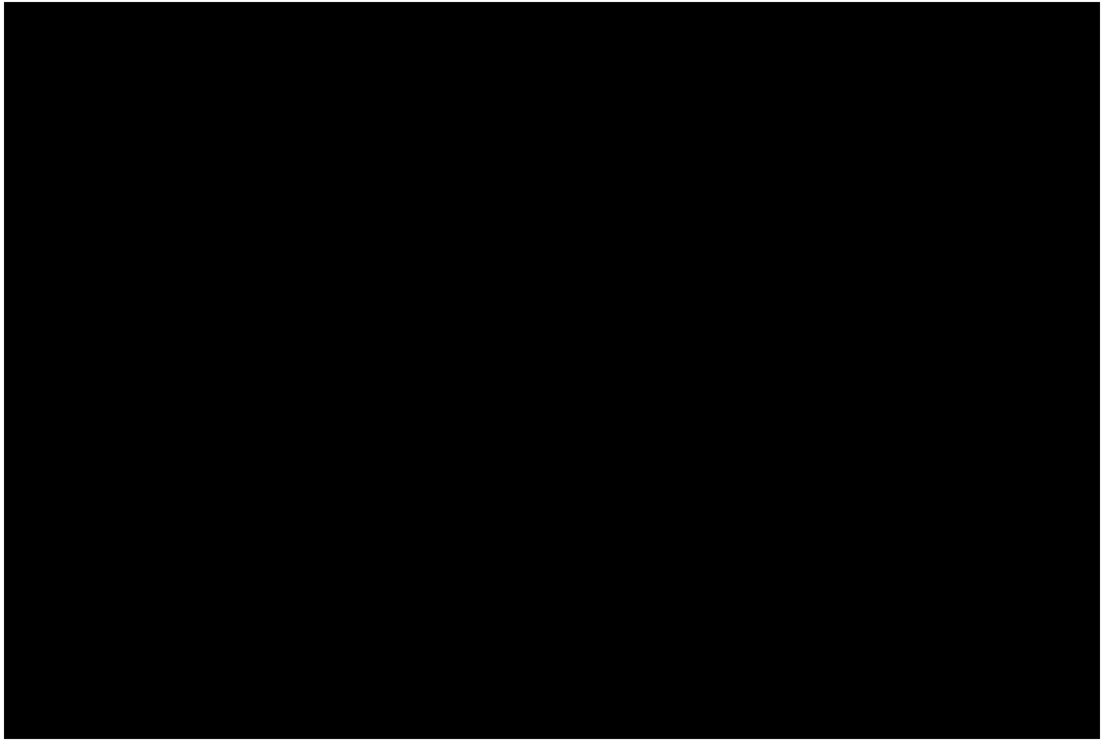



| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| u | D | ***<u>D</u>*** | N | N | N |
| v | D | D | N | D | D |
| p | N | N | O | N | N |

# Behavior With Constant Velocity BC



# Behavior With Sinusoidal Velocity BC

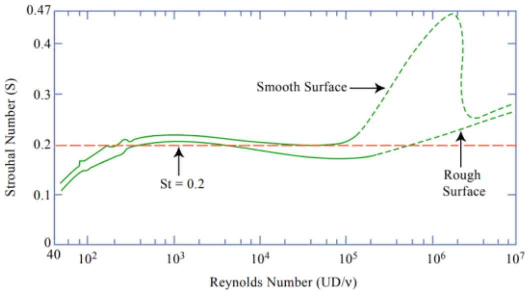


# Vorticity Comparison

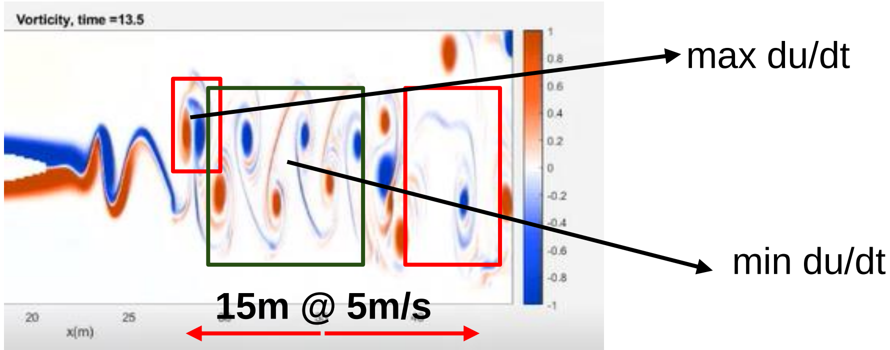
$$S_t = \frac{f_s * D}{U}$$

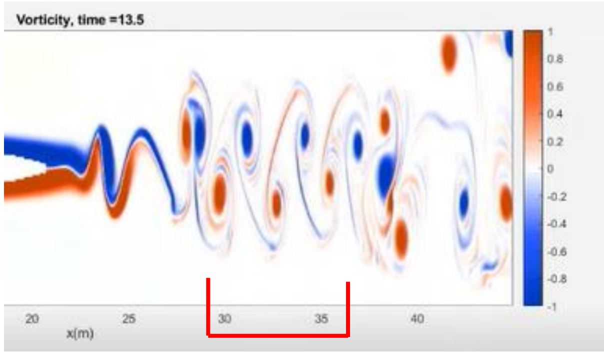
$$f_s = 1.67Hz$$

(BC invariant)




*Sinusoidal BC*

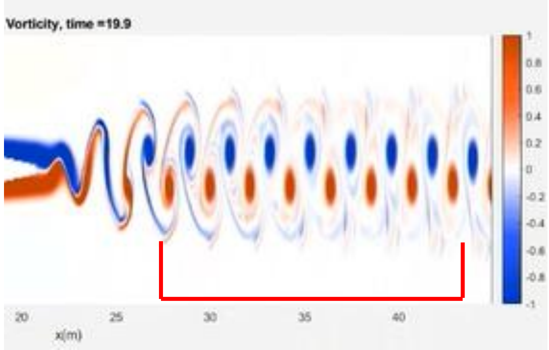



3 cycles in 7m (1.4s)

**2.1Hz**

*Constant BC*

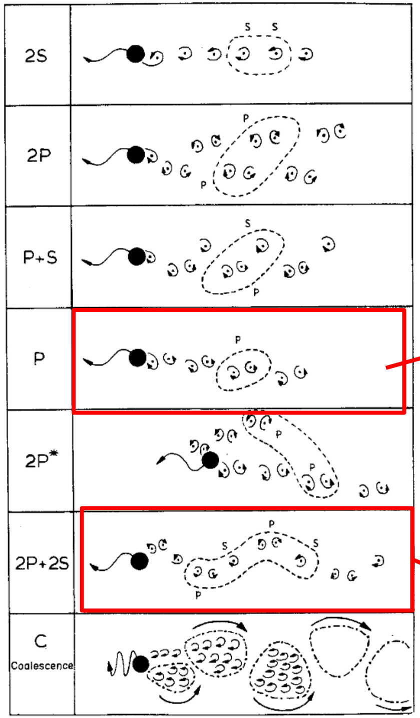



7 cycles in 17.5m (3.5s)

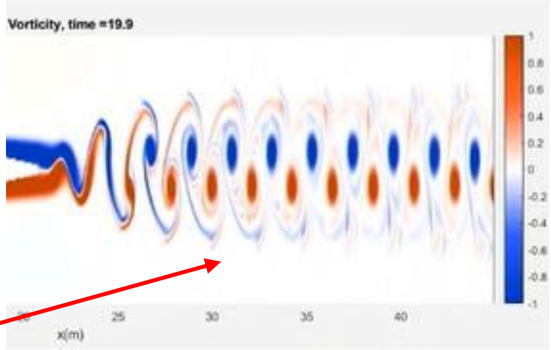
**2Hz**

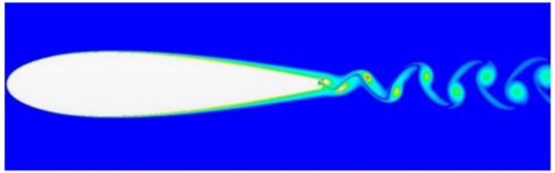
# Comparison to Literature

$$\frac{f_e}{f_s} = 0.21$$



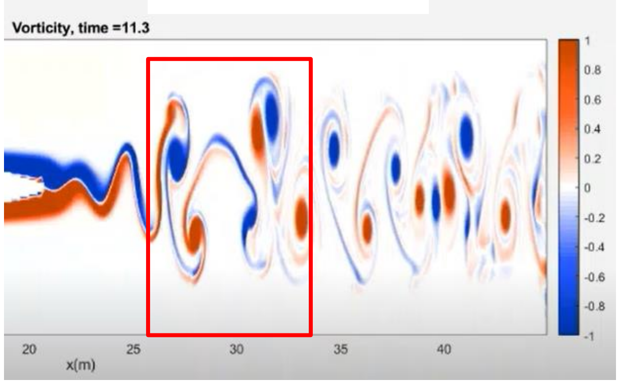

[4]

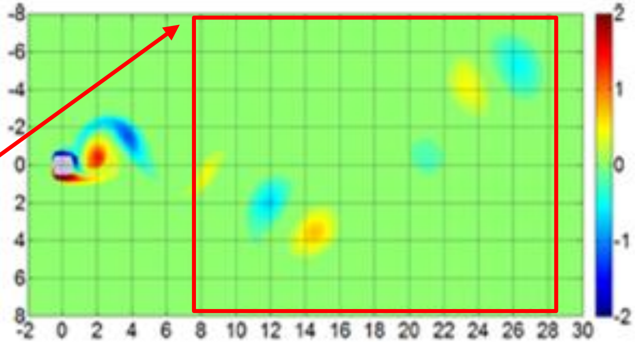


[2]

Re>10^6

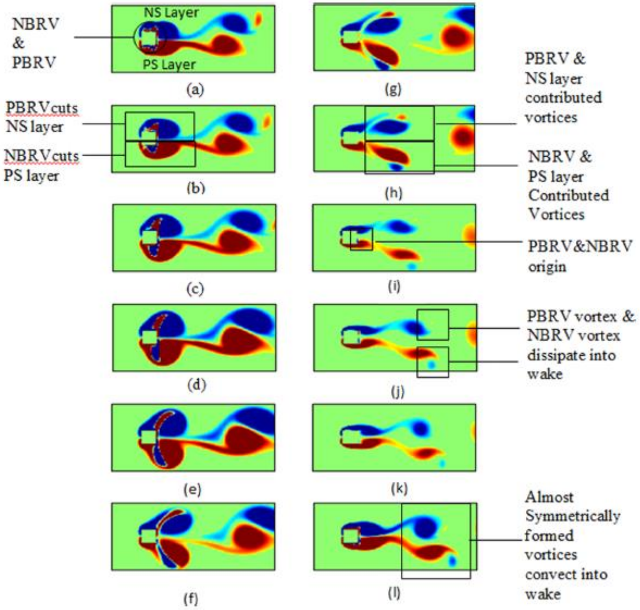


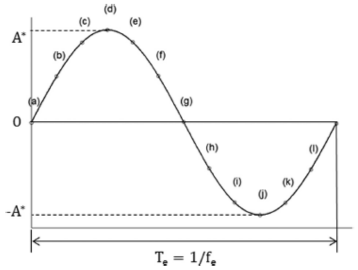



[1]

$$\frac{f_e}{f_s} = 0.4, Re = 100$$

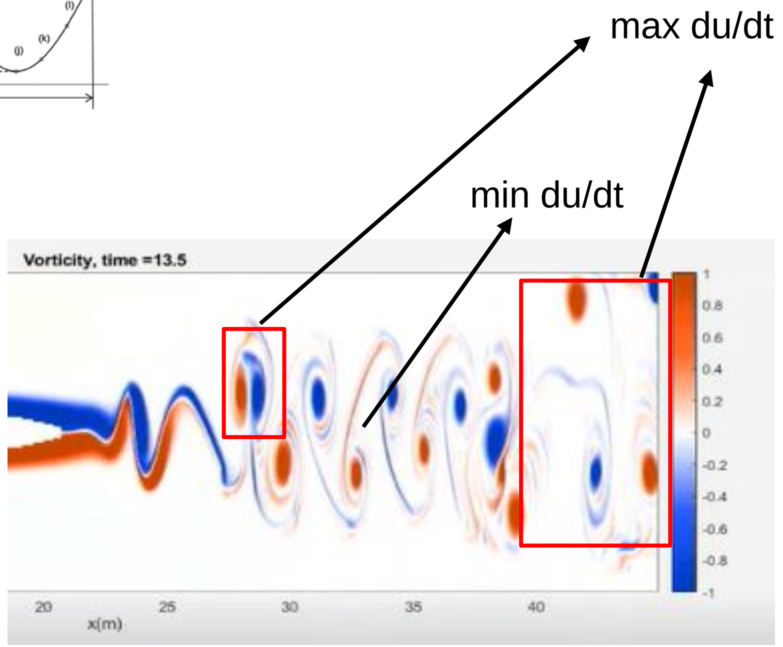
# Comparison to Literature



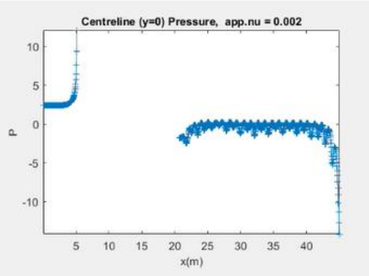

[1]

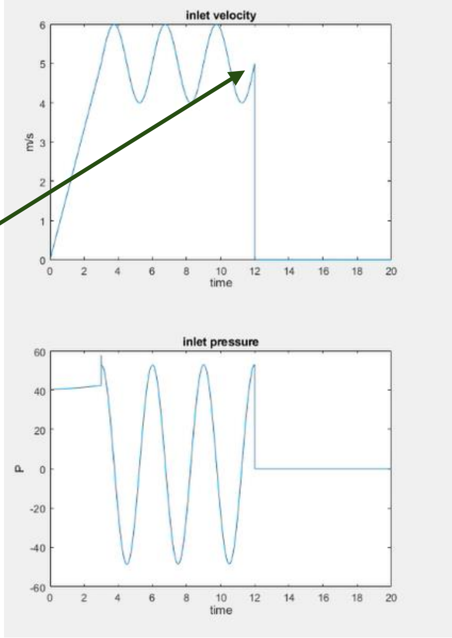
$$\frac{f_e}{f_s} = 0.6, Re = 100$$

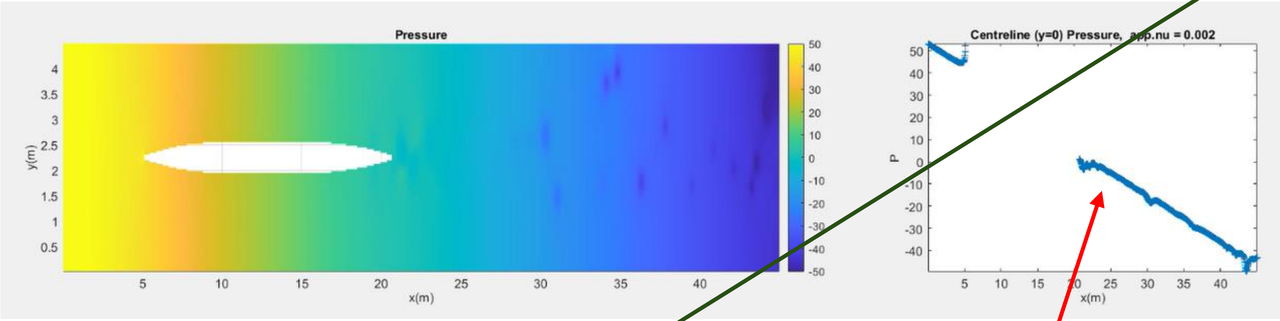


# Pressure Issue

constant BC




Incompressible + mass conservation at each finite volume: any boundary velocity change must immediately propagate to entire domain, requiring a large pressure gradient

$$\rho \frac{\partial \vec{V}}{\partial t} + \rho \left(\vec{V} \cdot \nabla\right) \vec{V} = -\nabla p + \mu \nabla^2 \vec{V} + \rho \vec{g}$$

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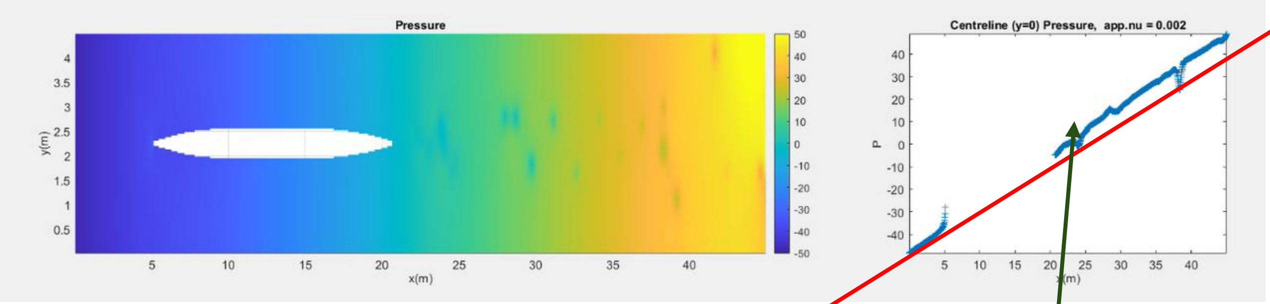


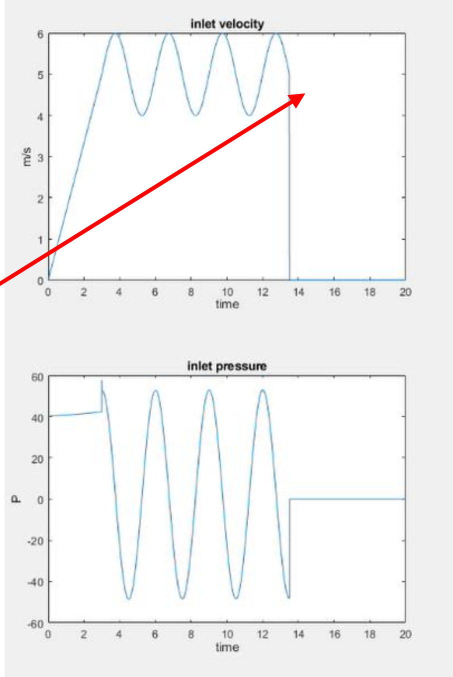


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$$\rho \frac{\partial \vec{V}}{\partial t} + \rho \left( \vec{V} \cdot \nabla \right) \vec{V} = -\nabla p + \mu \nabla^2 \vec{V} + \rho \vec{g}$$

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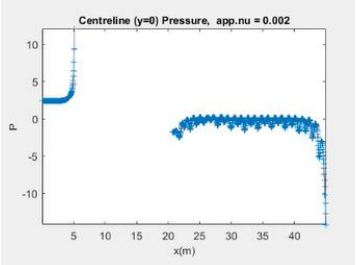


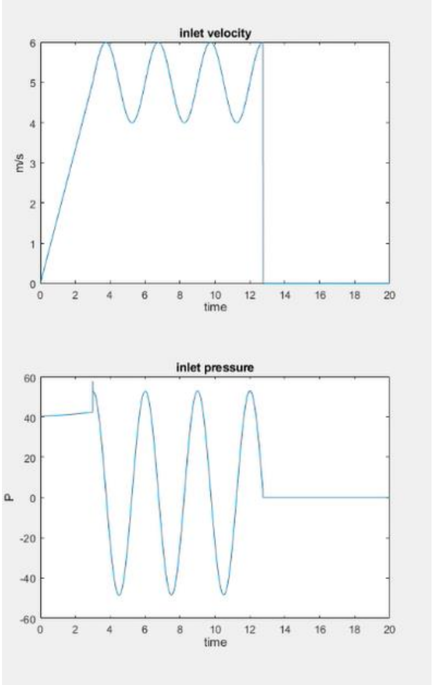


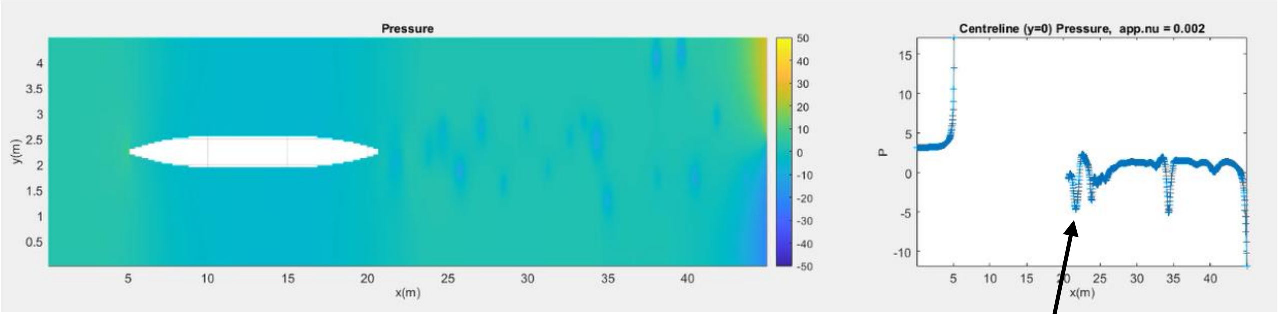


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# Conclusion

- Unexpectedly large but physically meaningful pressure gradients

- Vortex generation and shedding for constant BC behaves in an expected manner and matches up to existing literature, frequency ratio for time dependent BC lower than most existing literature

- Drag analysis, vary Re?

# Acknowledgements

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# References

[1]Krishnan, H., Agrawal, A., Sharma, A., and Sheridan, J., 2016, “Near-Body Vorticity Dynamics of a Square Cylinder Subjected to an Inline Pulsatile Free Stream Flow,” Physics of Fluids, 28(9), p. 093605.

[2]Hu, J., Wang, Z., Zhao, W., Sun, S., Sun, C., and Guo, C., 2020, “Numerical Simulation on Vortex Shedding from a Hydrofoil in Steady Flow,” Journal of Marine Science and Engineering, 8(3), p. 195.

[3]“Readings | Design Principles for Ocean Vehicles (13.42) | Mechanical Engineering | MIT OpenCourseWare” [Online]. Available: https://ocw.mit.edu/courses/mechanical-engineering/2-22-design-principles-for-ocean-vehicles-13-42-spring-2005/readings/. [Accessed: 12-May-2020].

[4]Williamson, C. H. K., and Roshko, A., 1988, “Vortex Formation in the Wake of an Oscillating Cylinder,” Journal of Fluids and Structures, 2(4), pp. 355–381.