CFD using OpenFOAM
Lecture 8: Solution to Complex Geometry Problems in OpenFOAM

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Outline

Recap of Lecture 7

Complex Geometry Flows

Flow over circular cylinder

Course Summary

- Mass Conservation (Continuity) : 1 Equation
- Momentum Conservation : U, V, and W

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- Finite Volume Discretisation :
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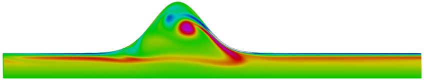
Recap: Flow Governing Laws, Discretisation & Solution Method

- Mass Conservation (Continuity) : 1 Equation
- Momentum Conservation : U, V, and W
- Finite Volume Discretisation :
- Challenges Faced (Decoupling, Non-linearity) & Solution Methodology
- Flow Behavior : Steady & Transient, Laminar & Turbulent
- Solvers : icoFoam, simpleFoam, pisoFoam etc.

- In real world scenarios, fluid flow occurs in complex geometries i.e, one which cannot be defined by cuboidal geometry.

Blood Flow in Aneurysm



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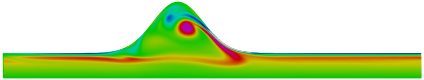
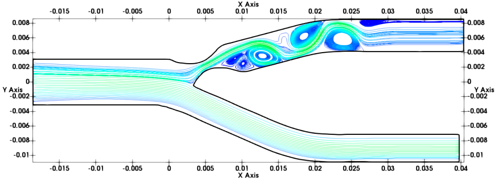


Blood Flow in Carotid Bifurcation



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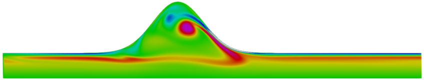

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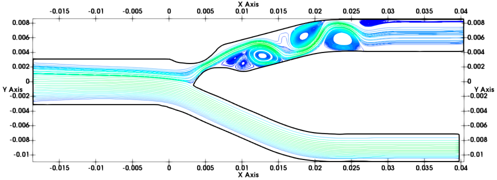
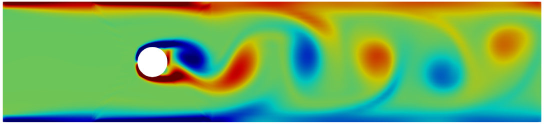


Vortex shedding behind circular cylinder



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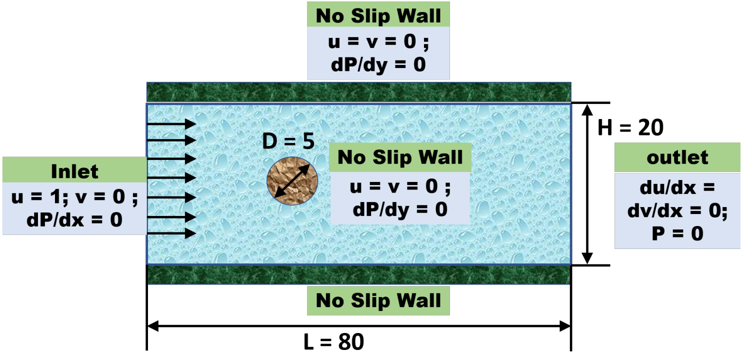
3. Setting up flow parameters in 'constant/transportProperties' file.
4. Setting up start and end time along with post-processing functions in 'system/controlDict' file.

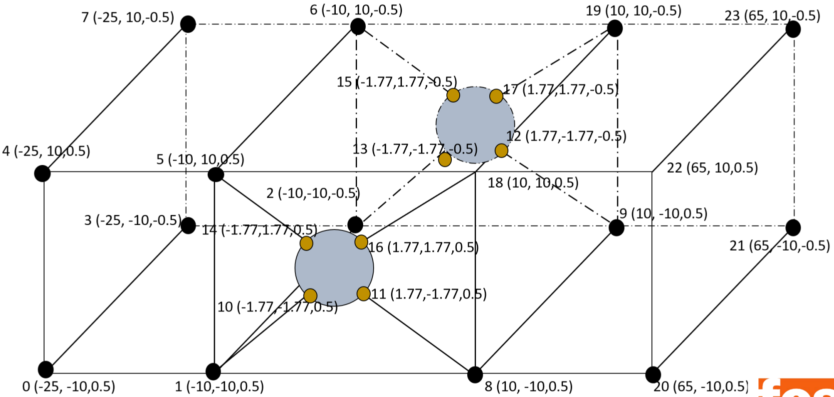
Illustrative Example : Flow over cylinder

- Consider flow over circular cylinder confined inside a channel as shown :



- A Cartesian grid cannot be employed using in-built discretisation scheme.

- The geometry is divided into 6 different blocks as shown (along with vertex coordinates)[2]:



- arcs and blocks are defined as below: (system/blockMeshDict)

```
edges
(
    arc 10 11 (   0 -2.5  0.5)
    arc 12 13 (   0 -2.5 -0.5)
    arc 14 10 (-2.5    0  0.5)
    arc 15 13 (-2.5    0 -0.5)
    arc 14 16 (   0  2.5  0.5)
    arc 15 17 (   0  2.5 -0.5)
    arc 16 11 ( 2.5    0  0.5)
    arc 17 12 ( 2.5    0 -0.5)
);
```

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    arc 15 17 (   0  2.5 -0.5)
    arc 16 11 ( 2.5    0  0.5)
    arc 17 12 ( 2.5    0 -0.5)
);
```

```
blocks
(
    // before cylinder
    hex ( 0  1  2  3  4  5  6  7) ( 60 1 30) simpleGrading (1 1 1)

    // cylinder
    hex ( 1  8  9  2 10 11 12 13) (30 1 30) simpleGrading (1 1 1) // bottom
    hex ( 1 10 13  2  5 14 15  6) (30 1 30) simpleGrading (1 1 1) // left
    hex (14 16 17 15  5 18 19  6) (30 1 30) simpleGrading (1 1 1) // top
    hex (11  8  9 12 16 18 19 17) (30 1 30) simpleGrading (1 1 1) // right

    // after cylinder
    hex ( 8 20 21  9 18 22 23 19) (180 1 30) simpleGrading (1 1 1)
);
```

Go to ‘0/U’ and ‘0/P’

```
boundaryField
{
    inlet
    {
        type            fixedValue;
        value           uniform (1.0 0 0);
    }
    outlet
    {
        type        zeroGradient;
    }
    wall
    {
        type        fixedValue;
        value       uniform (0 0 0);
    }
    obstacle
    {
        type        fixedValue;
        value       uniform (0 0 0);
    }
    frontAndBack
    {
        type        empty;
    }
}
```

Go to '0/U' and '0/P'

```
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{
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        value           uniform (1.0 0 0);
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```

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boundaryField
{
    inlet
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    outlet
    {
        type            fixedValue;
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    obstacle
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- The main objective is to calculate lift and drag co-efficients on cylinder.
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Setting-up post-processing parameters

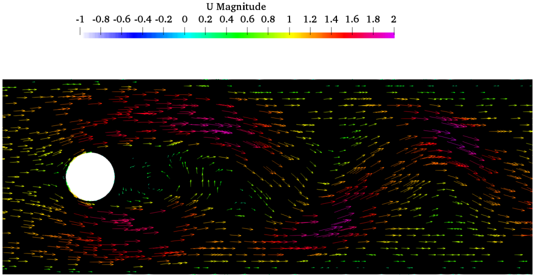
- The main objective is to calculate lift and drag co-efficients on cylinder.
- This is achieved by adding forceCeffs monitor in 'system/controlDict' file.

```
functions
{
    forceCoeffs
    {
    type          forceCoeffs;
    libs ( "libforces.so" );
    writeControl timeStep;
    writeInterval 1;

    patches       ( "obstacle" );
    pName         p;
    UName         U;
    rho           rhoInf;   // Indicates incompressible
    log           true;
    rhoInf        1;        // Redundant for incompressible
    liftDir       (0 1 0);  // Lift Direction
    dragDir       (1 0 0);  // Drag Direction
    CofR          (0.0 0.0 0.0);  // Axle midpoint on ground
    pitchAxis     (0 0 1);
    magUInf       1.0;  // Velocity
    lRef          5.0;     // Wheelbase length
    Aref          5.0;    // Cross section Area
    }
}
```

- After completing the set-up, run 'blockMesh' and 'icoFoam' to obtain the solution.

velocity vectors (2D glyphs in paraFoam)



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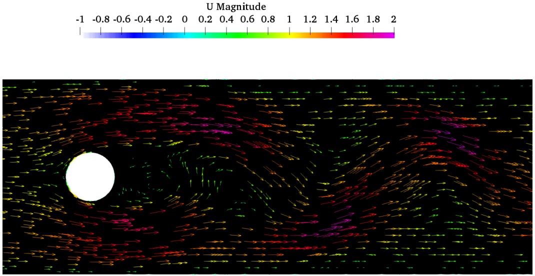
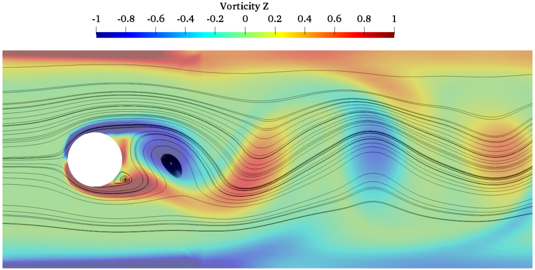
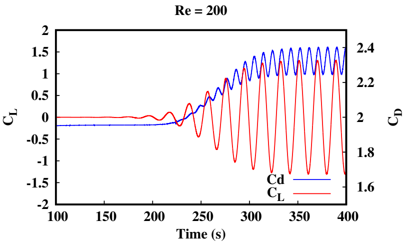


Streamlines (stream-tracer in paraFoam)



Variation of lift and drag

- The variation of lift and drag co-efficients on cylinder is as follows:



- Observations
  1. Periodic steady state is obtained after t = 240 units.
  2. Mean lift is zero while mean drag is around 2.

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This completes the short course on CFD using OpenFOAM. For more complex cases and tutorials, one may refer `https://cfd.fossee.in/home` .

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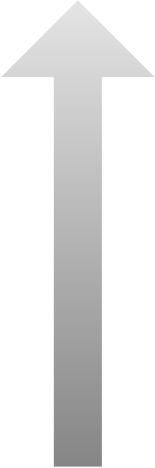

Introduction to CFD & OpenFOAM as CFD tool : What is CFD → Why to study → importance of OpenFOAM

Governing Laws in CFD and Discretisation

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OpenFOAM solution Methodology → various solvers and their capability

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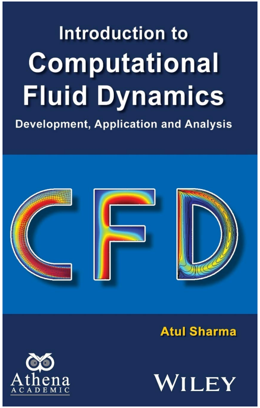
Summary of Course

- Illustrative examples for simple & complex geometry
- OpenFOAM solution Methodology → various solvers and their capability
- Governing Laws in CFD and Discretisation
- Introduction to CFD & OpenFOAM as CFD tool : What is CFD → Why to study → importance of OpenFOAM

References

1. Sharma, A. (2016). Introduction to computational fluid dynamics: development, application and analysis. John Wiley & Sons.
2. https://github.com/AsmaaHADANE/Youtube-Tutorials/blob/master/flow_around_cylinder.zip
3. https://www.openfoam.com/



Thank you for listening!

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