ME 412 – CFD_HT LAB PROJECT

Title – Study of laminar flow and heat transfer in a square channel with 30 deg inline angled baffle turbulators using OpenFOAM.

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Contents to be covered…

- Background
- Modelling and Methodology
- Results and Validation

Background

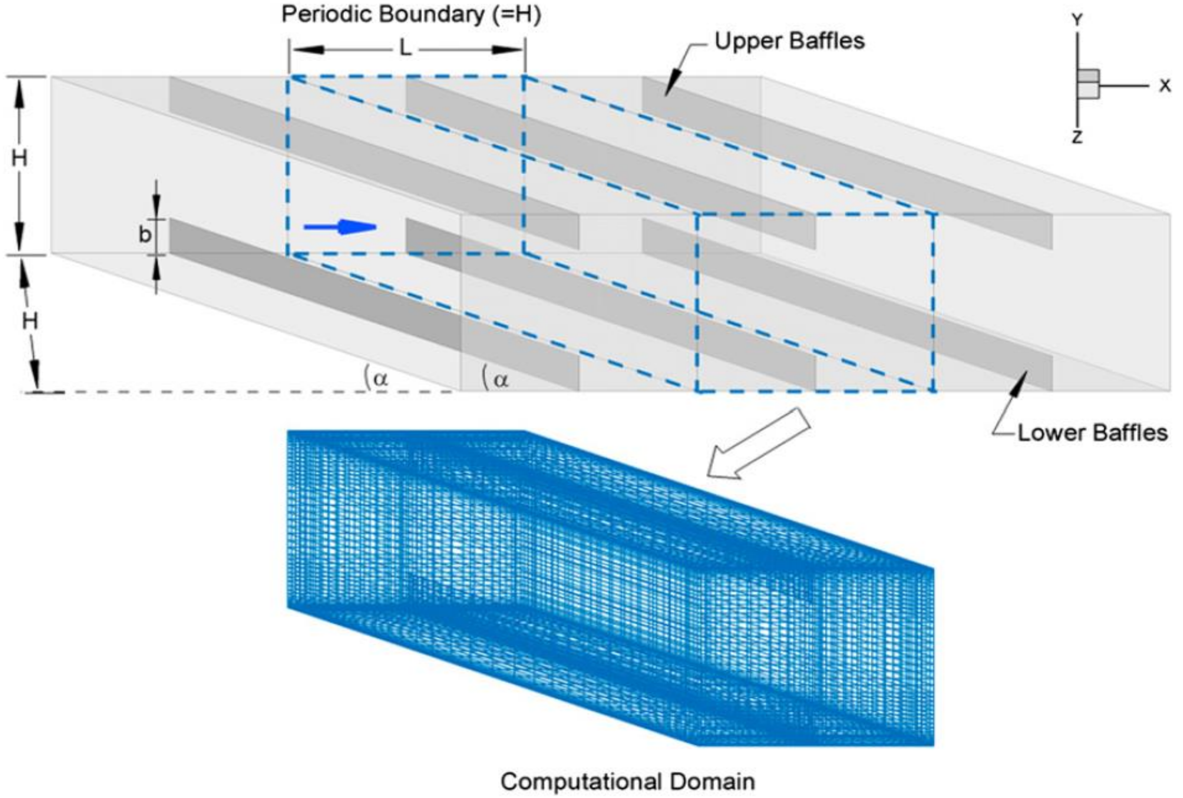
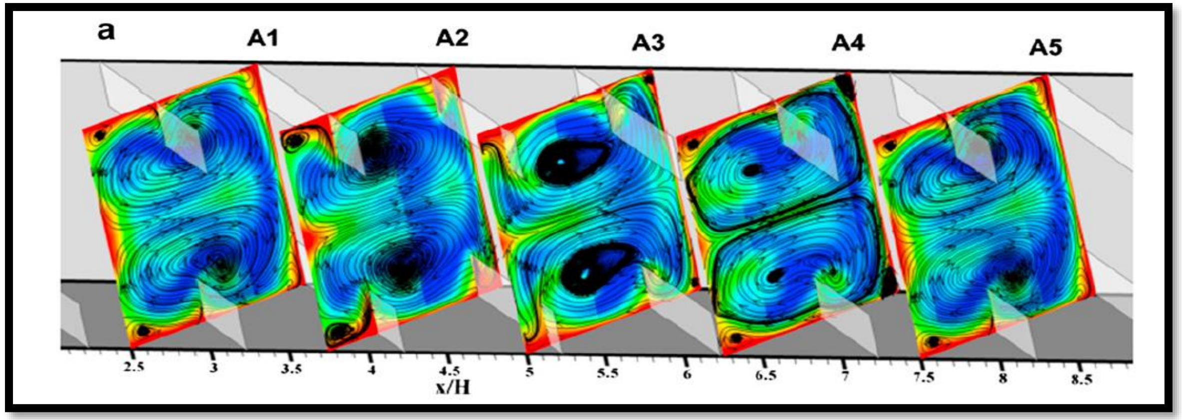


Fig. 1. Channel geometry and computational domain of periodic flow.



Objective

1. Effects of different geometry on flow behaviors in the channel.
2. Investigate heat transfer behaviors in a three-dimensional isothermal wall square channel fitted with 30-angled baffles.
3. Generate a pair of streamwise counter-rotating vortex (P-vortex) flows through the tested channel.

Figure1: *Streamline plot & Heat transfer behavior (right) and Channel Geometry (left)*

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Validate Present work with OpenFOAM Simulation Software

Modelling And Methodology

Approach

Multiblock Meshing → Merging/ Baffle Modelling → 2D Geometry Modelling with Baffles → 3D Geometry Modeling with Baffles

- ✓ Created multiple blocks in OpenFOAM.
- ✓ Merged and Meshed multi blocks.
- ✓ Created a single baffle with 2D multiblock.
- ✓ Created two 90 deg inline baffles with 2D multiblock.
- ✓ Created two 90 deg inline baffles with 3D multiblock.
- ✓ Created 30 deg line inline baffles with 3D block.

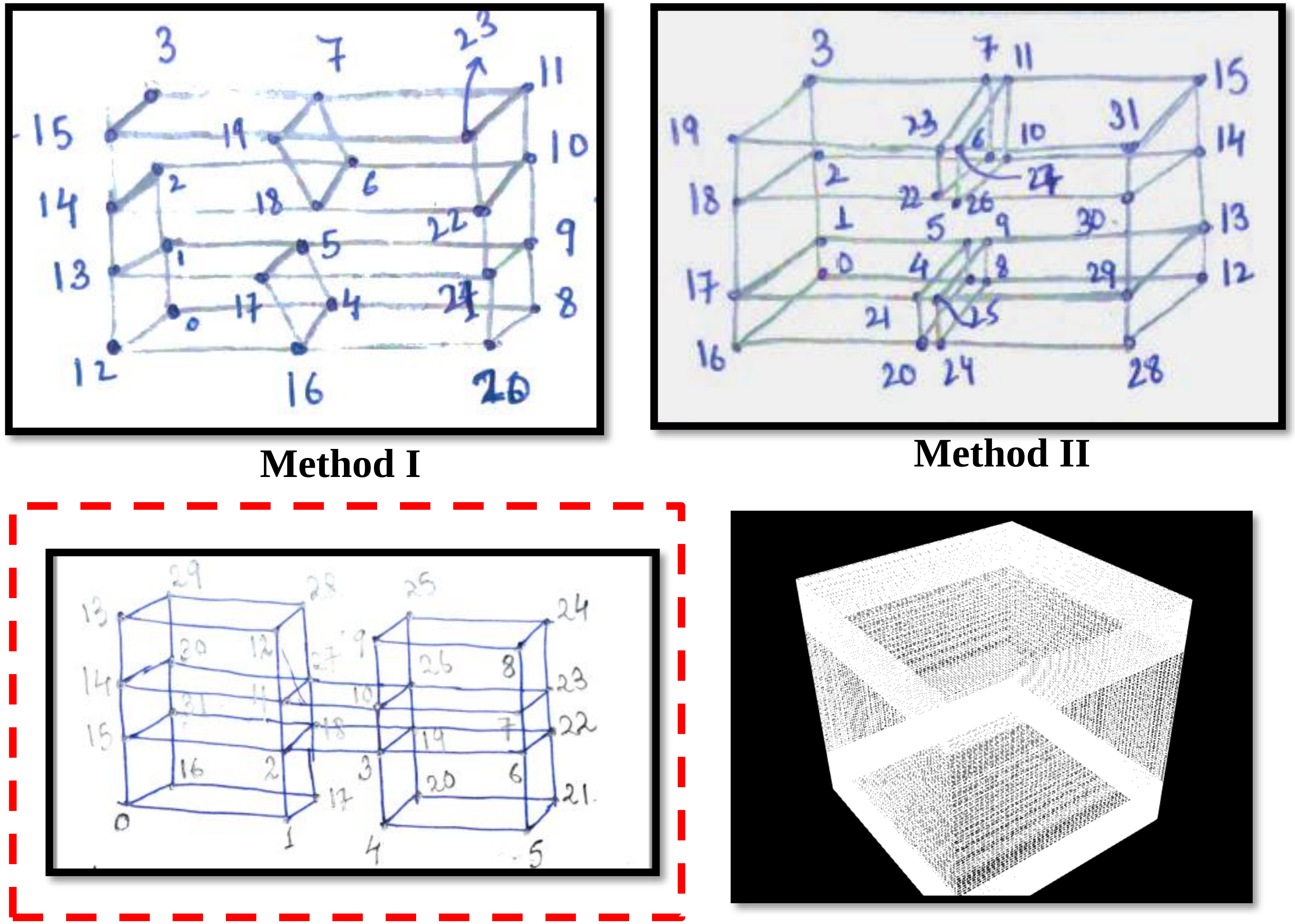
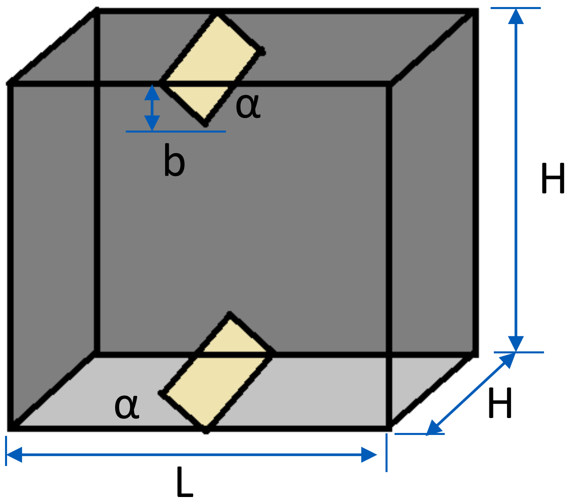


***Figure 2**: Square channel created by Multiblock Meshing and Merging Method.*

Method III is most suitable for creating baffles without defining any additional source code.

Modeling and Meshing



H = Height of Channel = 0.05m
L = Length of Channel = 0.05 (i.e., L=H)
Where, L= H, 1.5H or 2H.
Also, L/H = Pitch ratio (PR) = 1.0 ,1.5, 2.0
b = Baffle Height
Where b/H = blockage ratio (BR) = 0.1,0.2,0.3.
α = Baffle angle – 30 deg

Total Mesh Count is around ~96000

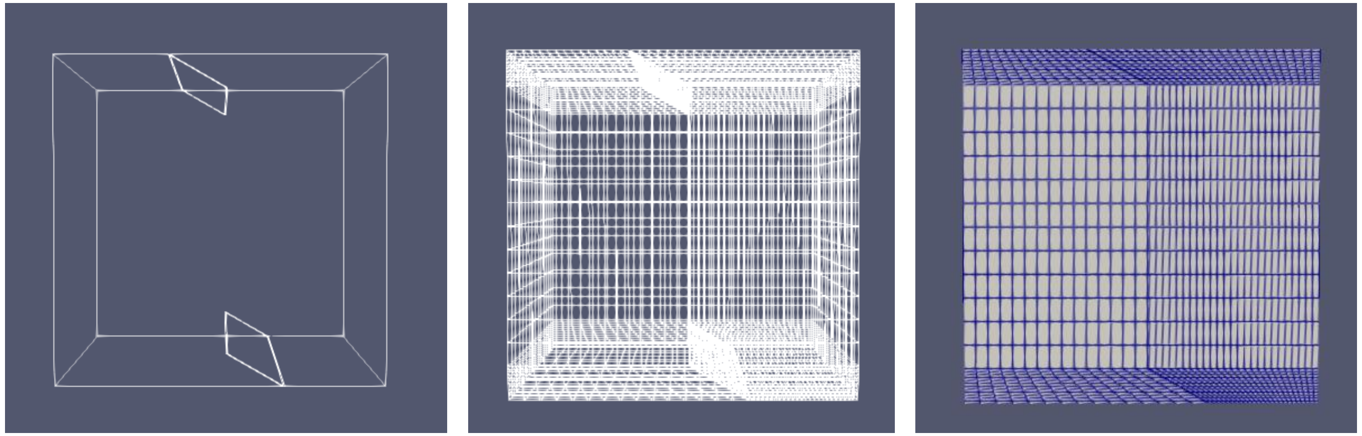


Figure 3: *Square channel with 30 deg inline angled baffle turbulators with b/H ratio 0.1 for PR 1*

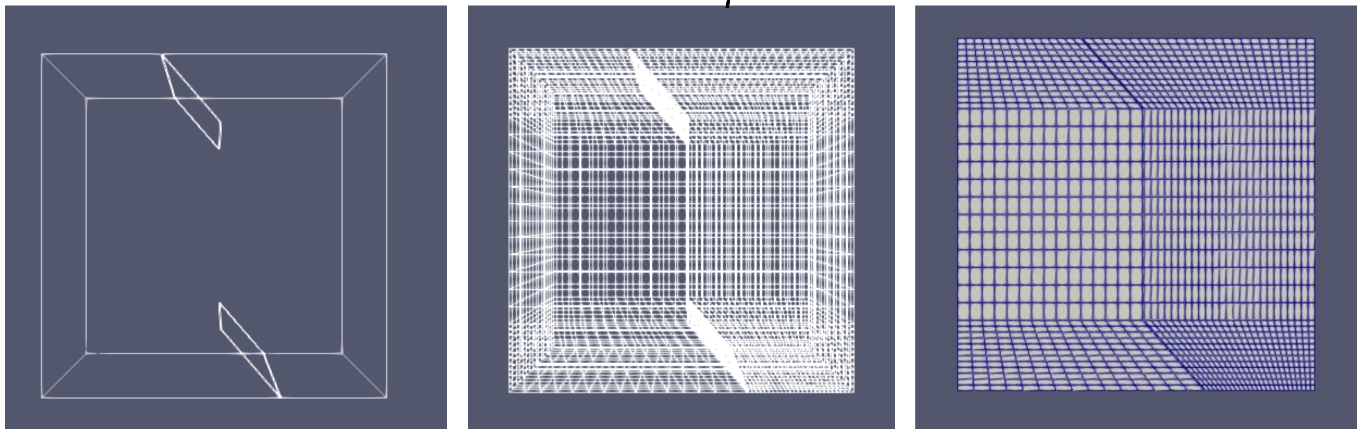


Figure 4: *Square channel with 30 deg inline angled baffle turbulators with b/H ratio =0.2 for PR 1*

Methodology

- ✓ Simulation for Flow through the channel was performed for checking the flow &heat transfer behavior for different geometry.
- ✓ Simulation running time – 1000 s with 0.001-time steps.
- ✓ ***buoyantSimpleFoam*** solver is used.
- ✓ Turbulence Property - Laminar
- ✓ Inlet Velocity – 0.316 m/s
- ✓ Density of fluid- 0.836 kg/m^3
- ✓ Kinematic viscosity of fluid – 1.568 e-5m^2/s

```
boundary
(
    outlet
    {
        type cyclic;
        neighbourPatch  inlet;
        faces
        (
            (15  0 16 31)
            (14 15 31 30)
            (13 14 30 29)
        );
    }

    inlet
    {
        type cyclic;
        neighbourPatch  outlet;
        faces
        (
            ( 5  6 22 21)
            ( 6  7 23 22)
            ( 7  8 24 23)
        );
    }
    walls
    {
        type wall;
        faces
        (
            ( 1  0 16 17)
            ( 2  1 17 18)
            ( 3  2 18 19)
            ( 4  3 19 20)
            ( 5  4 20 21)
            ( 9  8 24 25)
            (10  9 25 26)
            (11 10 26 27)
            (12 11 27 28)
            (13 12 28 29)
        );
    }
    frontBack
    {
        type empty;
        faces
        (
            ( 0 15  2  1)
            (15 14 11  2)
            (14 13 12 11)
            ( 2 11 10  3)
            ( 4  3  6  5)
            ( 3 10  7  6)
            (10  9  8  7)

            (16 17 18 31)
            (31 18 27 30)
            (30 27 28 29)
            (18 19 26 27)
            (20 21 22 19)
            (19 22 23 26)
            (26 23 24 25)
        );
    }
);
```

blockMeshDict File

```
dimensions      [0 1 -1 0 0 0 0];

internalField   uniform (0.316 0 0);

boundaryField
{
    #includeEtc "caseDicts/setConstraintTypes"

    walls
    {
        type            noSlip;

    }
    inlet
    {
        type            cyclic;
        value           uniform (0.316 0 0);
    }
    outlet
    {
        type            cyclic;

    }
    frontBack
    {
        type            empty;
    }

}
```

U file

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Thermophysical Properties & other parameters

```
dimensions      [1 -1 -2 0 0 0 0];

internalField   uniform 101325;

boundaryField
{
    #includeEtc "caseDicts/setConstraintTypes"

    walls
    {
        type            fixedFluxPressure;
        gradient        uniform 0;
        value           uniform 101325;
    }
    inlet
    {
        type            cyclic;
        gradient        uniform 0;
        value           uniform 101325;
    }
    outlet
    {
        type            cyclic;
        value           uniform 101325;
    }
    frontBack
    {
        type            empty;
    }
```

P_pgh file

```
internalField   uniform 300;

boundaryField
{
    walls
    {
        type            fixedValue;
        value           uniform 310;
    }
    inlet
    {
        type            cyclic;
        value           uniform 300;
    }
    outlet
    {
        type            cyclic;
        value           uniform 300;
    }
    frontBack
    {
        type            empty;
    }
```

T file

```
thermoType
{
    type            heRhoThermo;
    mixture         pureMixture;
    transport       const;
    thermo          hConst;
    equationOfState perfectGas;
    specie          specie;
    energy          sensibleEnthalpy;
}

mixture
{
    specie
    {
        molWeight       28.96;
    }
    thermodynamics
    {
        Cp              1004.9;
        Hf              0;
    }
    transport
    {
        mu              1.846e-05;
        Pr              0.707;
    }
}
```

Thermo physical Properties file

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Results and Validation

Flow Behaviors in Channel

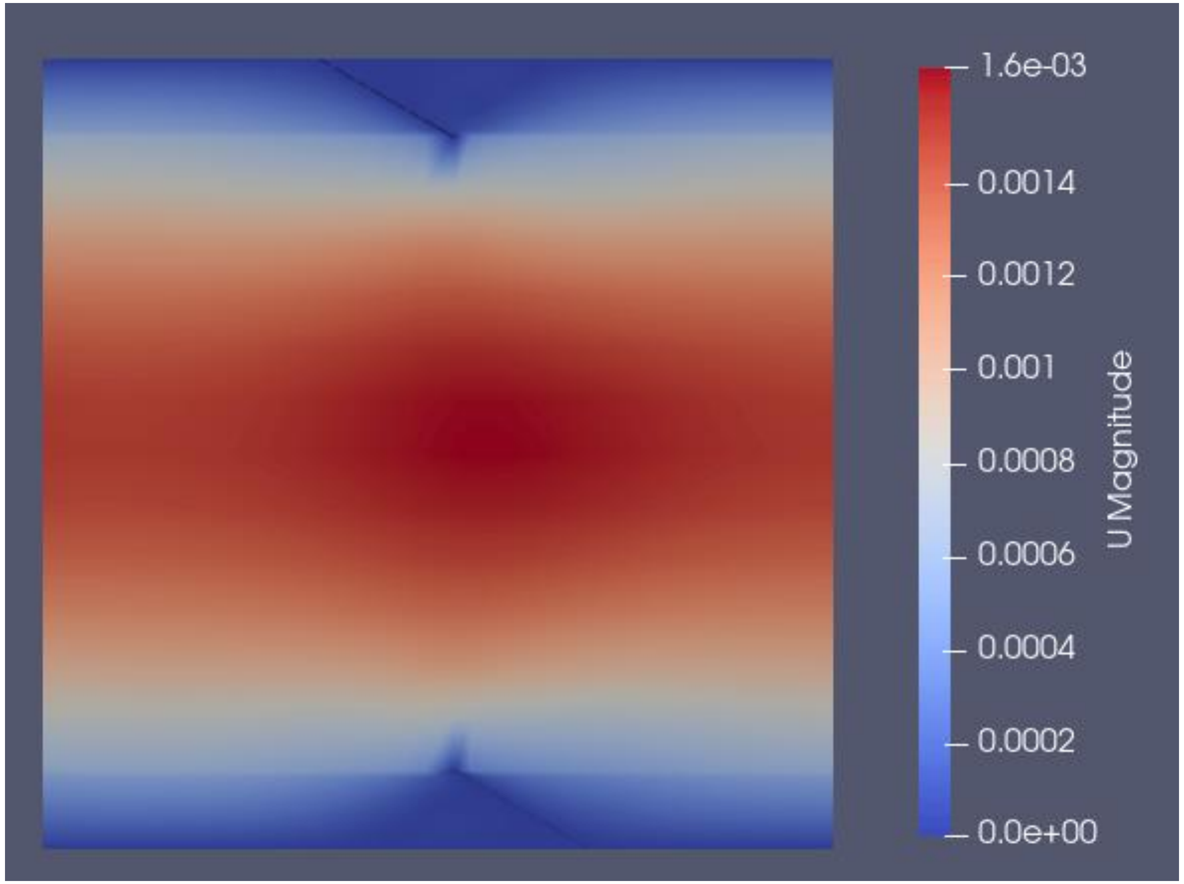

Figure 5: *Velocity contour and velocity Profile plotted for 30 deg baffle with b/H=0.1*

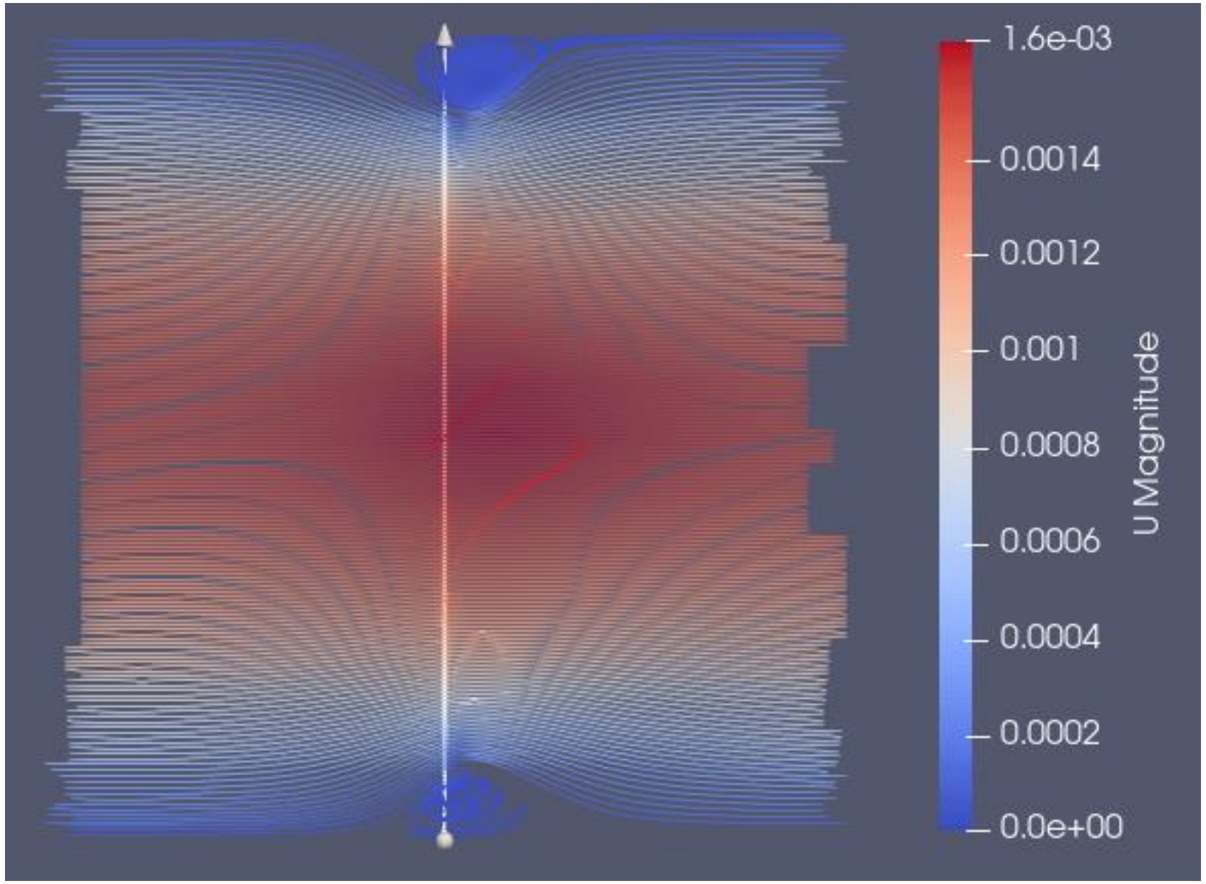

Figure 6: *Streamline Contour for 30 deg baffle with b/H=0.1*

Continue …

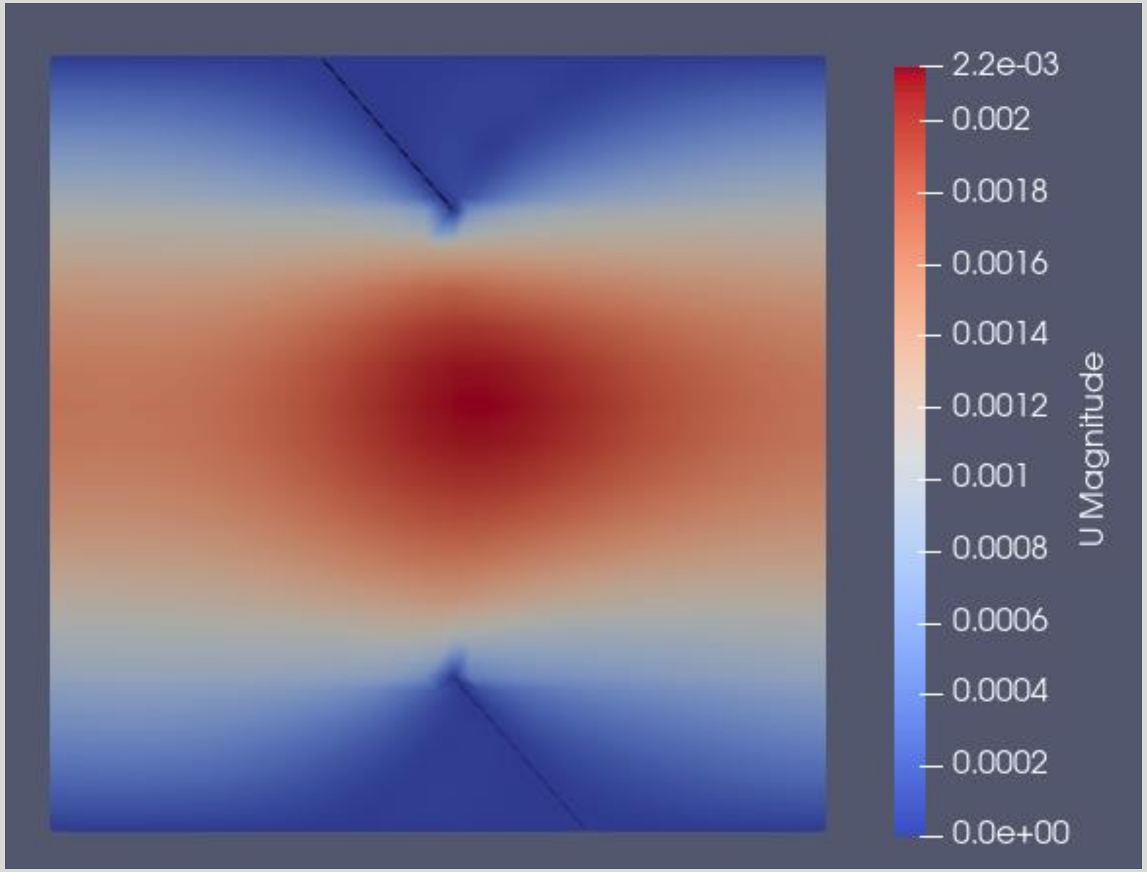

Figure 7: *Velocity contour and velocity Profile plotted for 30 deg baffle with b/H=0.2*

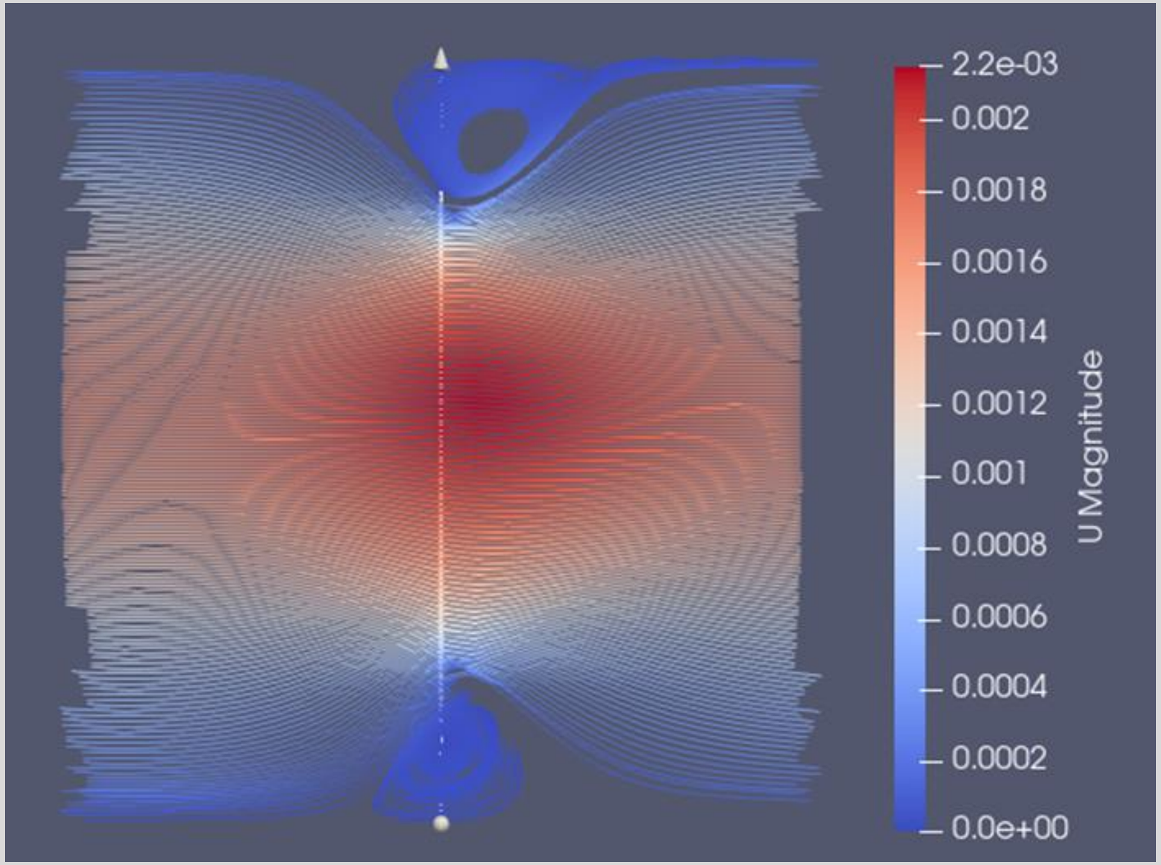

Figure 8: *Streamline Contour for 30 deg baffle with b/H=0.2*

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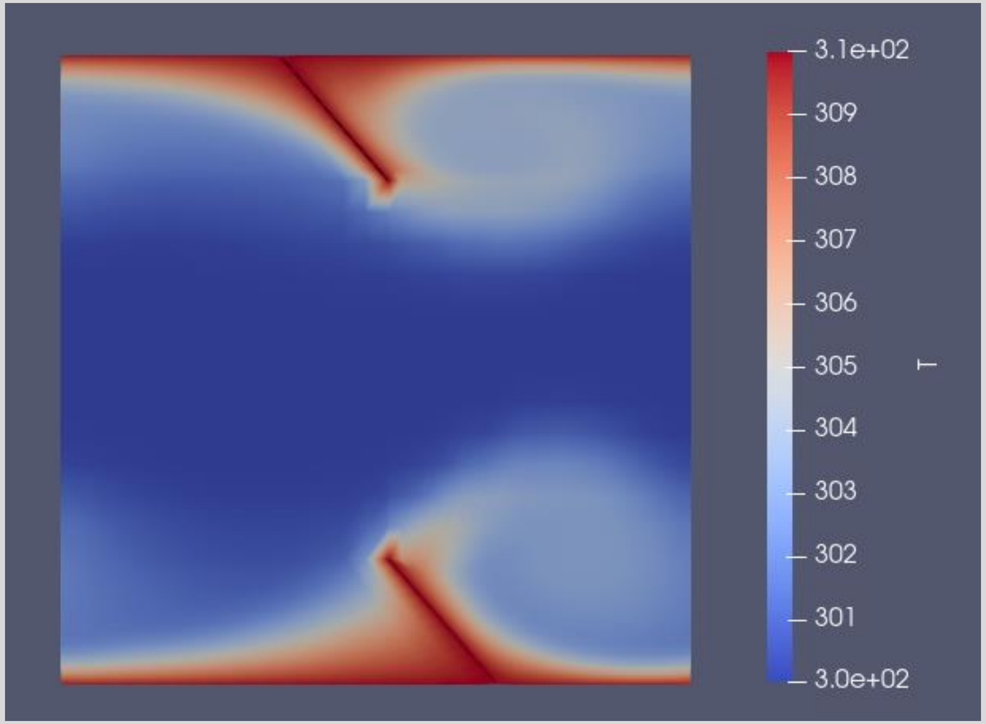
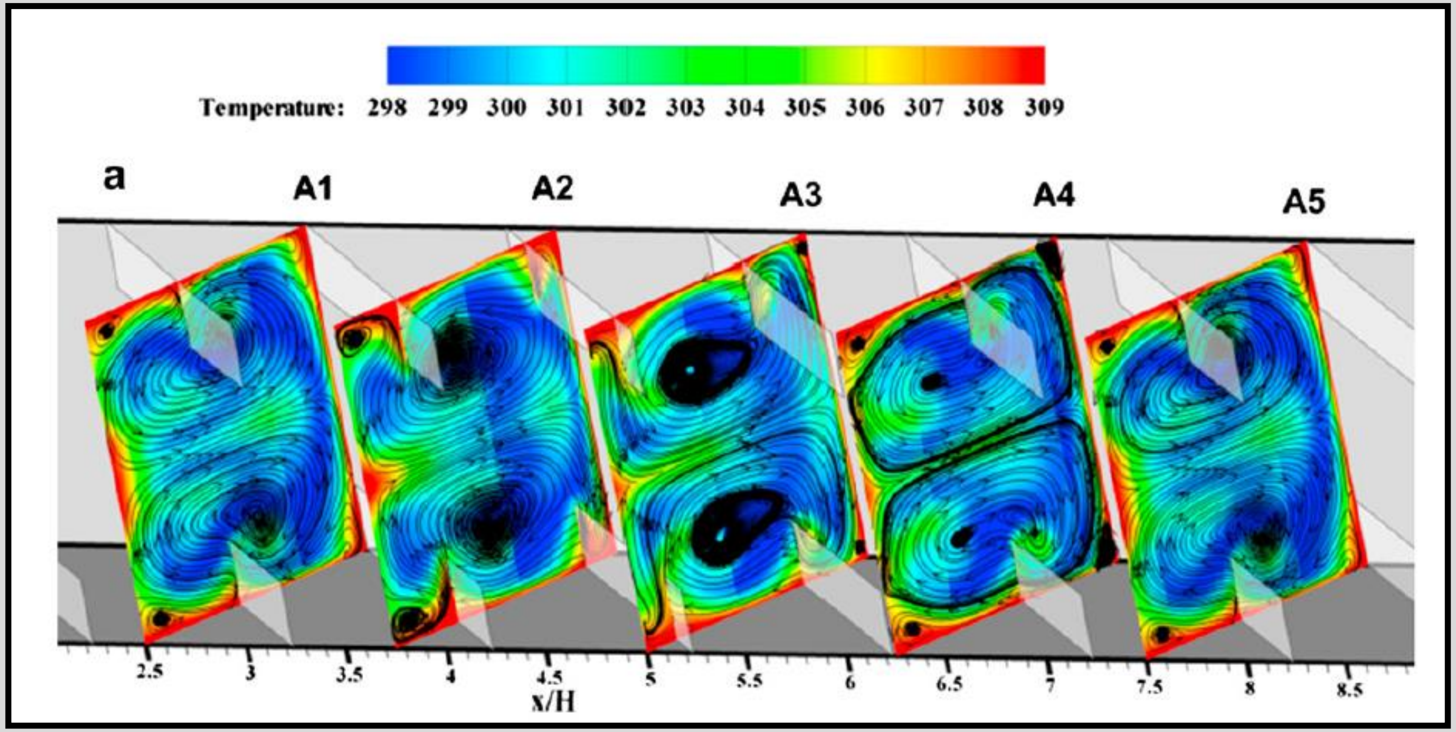
- ✓ Objective 1 : Effect of BR ratio on the Flow behaviors of the square channels, Increase in BR leads to larger vortex formation

Heat Transfer behaviour in Channels





✓ Objective 2: Temperature plot almost like the reference paper with 0.6% to 1% deviation.

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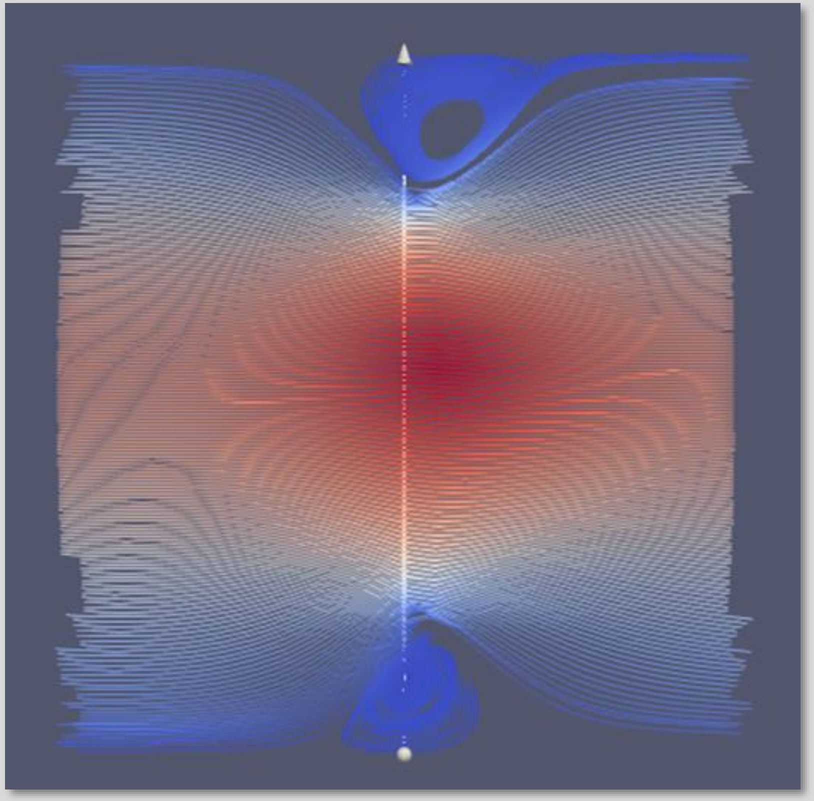
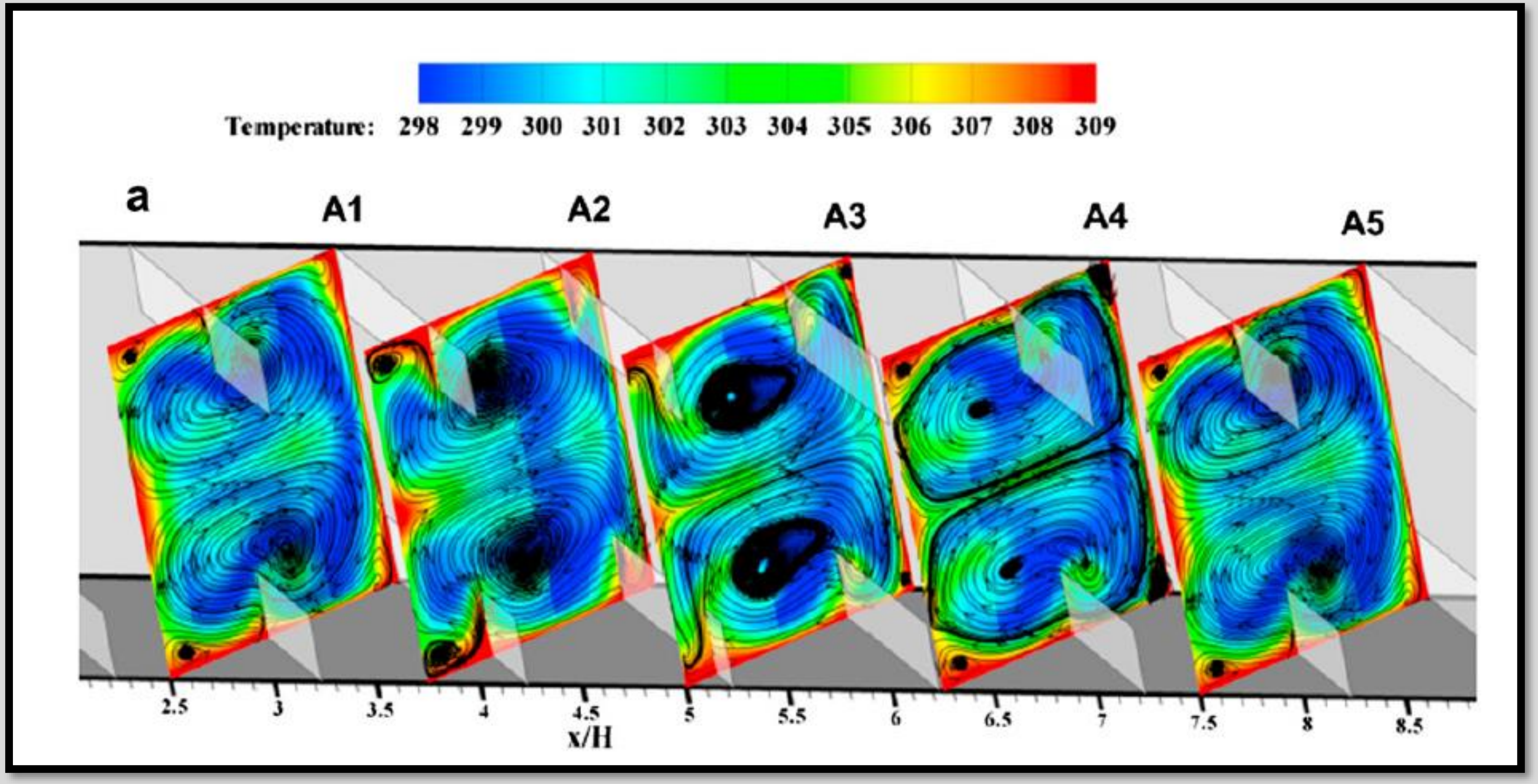
Pair of Vortex Formation in the Channel





✓ Objective 3 : Pair of streamwise counter-rotating vortex (P-vortex) flows through the channel can be seen.

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