SKILL-LYNC

Simulation of Flow through a pipe in OpenFoam

Content Sr No. Topic 1 Introduction Analytical Solution 2 Assumed values 3 Steps to solve for Analytical Solution 4 Analytical Solution Simulation 5 Automation 5.1 Code for creating co-ordinate 5.2 Code for creating blockMeshDict 6 Simulation Files 6.1 blockMeshDict 6.2 pressure...

CFD MATLAB

Piyush Dandagawhal
updated on 19 Jul 2021

comment Share Project

Project Details

Content

Analytical Solution

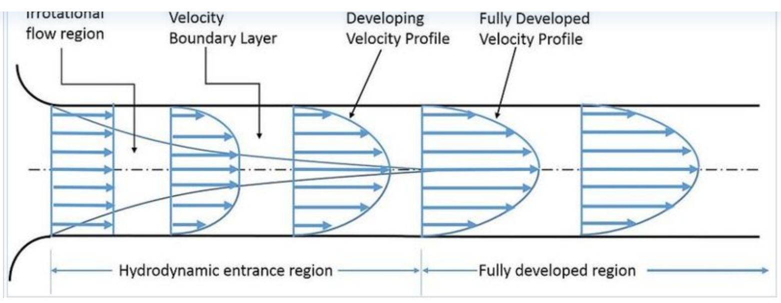
1) Introduction: Understanding flow through pipe and comparing the analytical results with Simulations and validating them using OpenFoam.

For this we employ the help of Hagen-Poiseuille's Equation and Reynold number formula to evaluate the analytical solution.

2) Given and assumed values:

Sr No.	Properties	Values
1	Diameter of pipe(assumed)	*20mm*
2	Kinematic Viscosity	$0.8926 \cdot 10^{-6} N \cdot sm^{-2}$
3	Density of water	*1000* $K\frac{g}{m^3}$
4	Reynolds Number	*2100*

3) For our current probelm we make an assumption and use the diameter as an assumed value. The methodology of the problem is given below.


Irrotational flow region
Velocity Boundary Layer
Developing Velocity Profile
Fully Developed Velocity Profile
Hydrodynamic entrance region
Fully developed region

The hydrodynamic entrence length is given by: $0.05 \cdot Re \cdot D$ for Laminar flow.

using this we obtain the entry length. Le.

The length of the whole pipe is greater than Entry length. I.e Le < L.

Step 2) The velocity that is obtained analytically can be expressed using the Reynold's number, which is given by.

$$Re = \frac{v \cdot D}{\nu}$$

Reynolds number for Lan=minar flow is 2100 for water.

Step 3) Use the length of pipe to find the pressure difference accross the pipe.

Using Hagen–Poiseuille equation to find the Pressure Difference: $\frac{32 \cdot L \cdot \nu \cdot v}{D^2}$ using the Length obtained from above method we find the pressure difference accross the pipe.

The kinamatic pressure difference is given by: $\frac{\triangle p}{\rho}$

$\rho = 1000$ Density of water.

Step 4) Finding the shear across the wedge profile. Shear gives an idea of how the flow is occuring accross the cross-section of the pipe. The shear gives the profile of flow of the fluis through the pipe.

The equation is given by: $\tau = \frac{2 \cdot \mu \cdot v(\max)}{r}$

4) Solution of Analytical solution.

Using all these steps we can obtain the values for analytical solution of flow through a pipe.

Sr no No.	**Properties**	**Values**
1	Le	*2.1m*
2	L	*2.5m*
3	Velocity(average)	*0.0935 m/s*
4	Velocity (maximum)	*0.1870m/s*
5	Pressure Drop	*16.6430 Pa*
6	Kinematioc Pressure Drop	*0.0166 Pa*
7	Shear Stress	*0.033 Pa*

The above process show the analytical method to evaluate the flow throught a pipe.

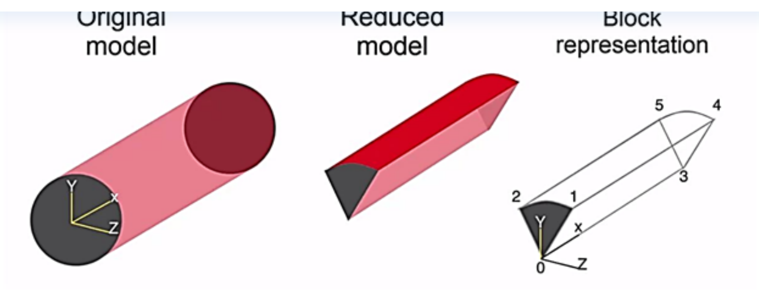
As far as the simulation and validation is concerned, it is Given below:

Simulation

The simulation method involves the use of OpenFoam and using MATLAB to automate the blockMeshDict file.

Using the values obtained from above like Diameter, Length of the pipe and the angle of the wedge.

Angle of the wedge: As the simulation is axisymmetric it will be easier if we take as



as the wedge is what will be used for simulation it is necessay to provide appropriate values to create a blockMesh file. For that the below code will automate the process.

5) Automation:

1) Code that calculates the co-ordinate points.

```
function [points_t, points_b, x_arc, y_arc, zl] = new_bmd(ang, l, r);
%a function that reurns the co-ordinate points and co-ordinate of arc.

    %inputs

    zo = 0;
    zl = l;
    %creating the arrays for x, y co-ordinates
    x = linspace(0, r, 10);
    y = linspace(0, r, 10);

    %origin points
    xo = x(1);
    yo = y(1);

    %The points at the edge of wedge.
    xr = r*sind(ang);
    yr = r*cosd(ang);

    %Finding the points of the arc.
    ang_1 = linspace(0, ang, ang);
    for i = 1:length(ang_1)
        if ang_1(i) == 0
            x_arc = r*sind(ang_1(i));
            y_arc = r*cosd(ang_1(i));
        end
    end

    x_arc = x_arc;
    y_arc = y_arc;

    xl = -xr;
    yl = yr;

    %array that compiles the x, y, z co-ordinates
    a = [xo, yo, zo, xr, yr, zo, xl, yl, zo];
    b = [xo, yo, zl, xr, yr, zl, xl, yl, zl];


    arc = zeros(3, 3);
    arc_f = zeros(3,3);

    %Converting the points into an array and the length of the wedge is
    %along x-axis.
    for p = 1:length(a)
        arc(p) = a(p);
    end
    points_t = zeros(3, 3);
    points_t(1, :) = arc(3, :);
    points_t(2, :) = arc(2, :);
    points_t(3, :) = arc(1, :);

    for q = 1:length(b)
        arc_f(q) = b(q);
    end
    points_b = zeros(3, 3);

    points_b(1, :) = arc_f(3, :);
```

```
piy = fopen('C:UsersatharvaDesktop/blockMeshDict.txt', 'wt');
[points_t, points_b, x_arc, y_arc, zl] = new_bmd(3, 2.5, 0.01);

h = ["/*--------------------------------*- C++ -*----------------------------------*";
  "  =========                 |";
  "  \      /  F ield         | OpenFOAM: The Open Source CFD Toolbox";
  "   \    /   O peration     | Website:  https://openfoam.org";
  "    \  /    A nd           | Version:  8";
  "     \/     M anipulation  |";
"*---------------------------------------------------------------------------*/";
"FoamFile";
"{";
"    version     2.0;";
"    format      ascii;";
"    class       dictionary;";
"    object      blockMeshDict;";
"}";
"// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //";

"convertToMeters 1;";

"vertices"];


for i = 1:length(h)
    fprintf(piy, '%sn', h(i));
end
fprintf(piy, '(n');



for j = 1:3
    fprintf(piy, 't(%d %d %d)n', points_t(1:3, j)');
end
fprintf(piy, 'n');
for k = 1:3
    fprintf(piy, 't(%d %d %d)n', points_b(1:3, k)');
end
fprintf(piy, ');nn');
fprintf(piy, 'blocksn(n');
fprintf(piy, 'thex (%d %d %d %d %d %d %d %d) (500 20 1) simpleGrading (1 0.1 1)n);n', [0 3 5
fprintf(piy, 'edgesn(ntarc 1 2 (%d %d %d)ntarc 4 5 (%d %d %d)n);nn', [x_arc y_arc 0 zl y_arc
fprintf(piy, 'boundaryn(ntinletnt{ntttype patch;nttfacesntt(nttt(%d %d %d %d)ntt);nt}n', [0 1
fprintf(piy, 'toutletnt{ntttype patch;nttfacesntt(nttt(%d %d %d %d)ntt);nt}n', [3 5 4 3]);
fprintf(piy, 'ttopnt{ntttype wall;nttfacesntt(nttt(%d %d %d %d)ntt);nt}n', [1 4 5 2]);
fprintf(piy, 'tfrontnt{ntttype wedge;nttfacesntt(nttt(%d %d %d %d)ntt);nt}n', [0 3 4 1]);
fprintf(piy, 'tbacknt{ntttype wedge;nttfacesntt(nttt(%d %d %d %d)ntt);nt}n', [0 2 5 3]);
fprintf(piy, 'taxisnt{ntttype empty;nttfacesntt(nttt(%d %d %d %d)ntt);nt}n);n', [0 3 3 0]);
fprintf(piy, 'mergePatchPairsn(n);n');
fprintf(piy, '%s', "// ***********************************************************************
```

6) Setting up simulation in OpenFoam:

Using the blockMesh file obtained from automation will get the geometry, but there are various other tweaks need to be made to other files for better flow simulation.

The Files that are updated are:

6.1)blockMeshDict
```
/*--------------------------------*- C++ -*--------------------------------
  =========                 |
  \      /  F ield         | OpenFOAM: The Open Source CFD Toolbox
   \    /   O peration     | Website:  https://openfoam.org
    \  /    A nd           | Version:  8
     \/     M anipulation  |
*---------------------------------------------------------------------------
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    object      blockMeshDict;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
convertToMeters 1;
vertices
```

```
        (0 9.986295e-03 -5.233596e-04)

        (2.500000e+00 0 0)
        (2.500000e+00 9.986295e-03 5.233596e-04)
        (2.500000e+00 9.986295e-03 -5.233596e-04)
);

blocks
(
        hex (0 3 5 2 0 3 4 1) (500 20 1) simpleGrading (1 0.1 1)
);
edges
(
        arc 1 2 (0 1.000000e-02 0)
        arc 4 5 (2.500000e+00 1.000000e-02 0)
);

boundary
(
        inlet
        {
                type patch;
                faces
                (
                        (0 1 2 0)
                );
        }
        outlet
        {
                type patch;
                faces
                (
                        (3 5 4 3)
                );
        }
        top
        {
                type wall;
                faces
                (
                        (1 4 5 2)
                );
        }
        front
        {
                type wedge;
                faces
                (
                        (0 3 4 1)
                );
        }
        back
        {
                type wedge;
                faces
                (
                        (0 2 5 3)
                );
        }
        axis
        {
                type empty;
                faces
                (
                        (0 3 3 0)
                );
        }
);
mergePatchPairs
(
);
// ***************************************************************************
```

6.2)pressure

```
/*--------------------------------*- C++ -*-------------------------------------
  =========                 |
  \      /  F ield         | OpenFOAM: The Open Source CFD Toolbox
   \    /   O peration     | Website:  https://openfoam.org
```

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       volScalarField;
    object      p;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

dimensions      [0 2 -2 0 0 0 0];

internalField   uniform 0;

boundaryField
{
    inlet
    {
        type            zeroGradient;
    }

    outlet
    {
        type            fixedValue;
        value            uniform 0.0166;
    }

    top
    {
        type            zeroGradient;
    }

    front
    {
        type            wedge;
    }
    back
    {
        type            wedge;
    }
    axis
    {
        type            empty;
    }
}

// ************************************************************************
```

6.3)Velocity

```
/*--------------------------------*- C++ -*----------------------------------
  =========                 |
  \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox
   \\    /   O peration     | Website:  https://openfoam.org
    \\  /    A nd           | Version:  8
     \\/     M anipulation  |
*---------------------------------------------------------------------------
FoamFile
{
    version     2.0;
    format      ascii;
    class       volVectorField;
    object      U;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

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

internalField   uniform (0.0935 0 0);

boundaryField
{
    inlet
    {
        type            fixedValue;
        value            uniform (0.0935 0 0);
    }

    outlet
    {
        type            zeroGradient;
```

SKILL LYNC

```
    top
    {
        type            fixedValue;
        value            uniform (0 0 0);

    }

    axis
    {
        type            empty;
    }

    front
    {
        type            wedge;
    }
    back
    {
        type            wedge;
    }
}

// *************************************************************************
```

6.4)Transport properties

```
/*--------------------------------*- C++ -*----------------------------------
  =========                 |
  \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox
   \\    /   O peration     | Website:  https://openfoam.org
    \\  /    A nd           | Version:  8
     \\/     M anipulation  |
*---------------------------------------------------------------------------
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "constant";
    object      transportProperties;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

nu              [0 2 -1 0 0 0 0] 0.8926e-6;


// *************************************************************************
```

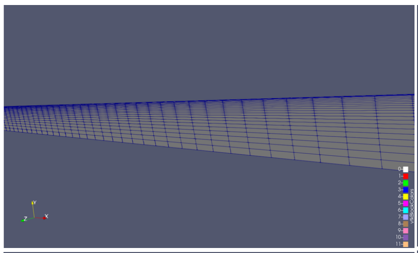
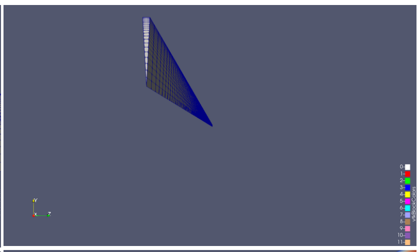
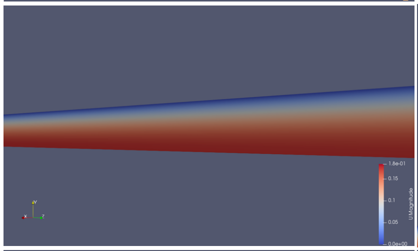
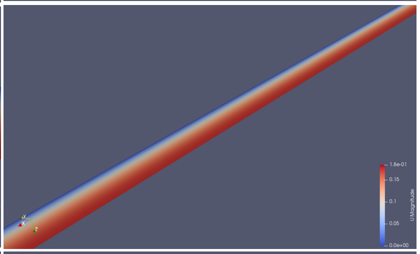
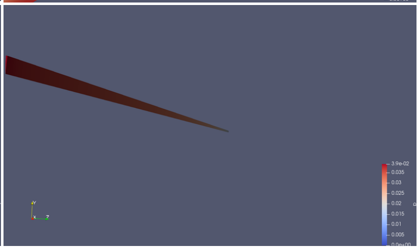
6.5)ControlDict

```
/*--------------------------------*- C++ -*----------------------------------
  =========                 |
  \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox
   \\    /   O peration     | Website:  https://openfoam.org
    \\  /    A nd           | Version:  8
     \\/     M anipulation  |
*---------------------------------------------------------------------------
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    location    "system";
    object      controlDict;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

application     icoFoam;

startFrom       startTime;

startTime       0;

stopAt          endTime;

endTime         50;

deltaT          0.01;

writeControl    timeStep;

writeInterval   20;
```

```
writePrecision  6;

writeCompression off;

timeFormat      general;

timePrecision   6;

runTimeModifiable true;


// ************************************************************************
```

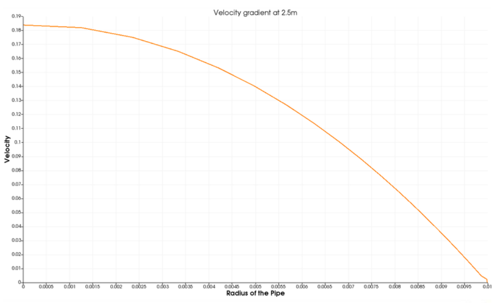
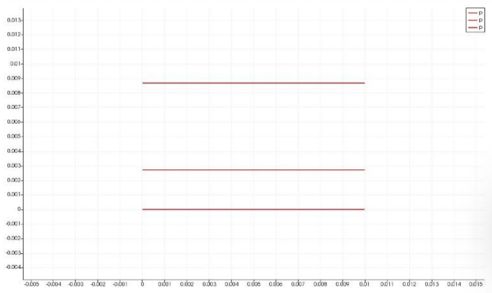
----

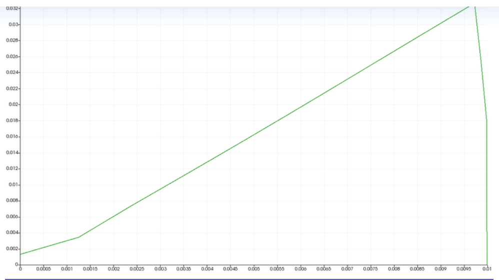
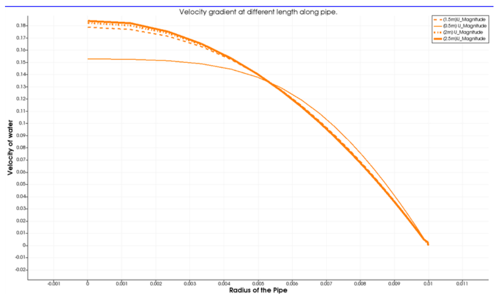
7) Preview as Simulation result

blockMesh (Preview)		
Velocity		
Pressure		

----

8) Results of Simulation:

	Analytical Solution	Simulation Result
Velocity	Velocity(avg) 0.0935m/s Velocity(Max) 0.1870m/s	
Pressure	0.0166 Pa	
Shear	0.0233 Pa	

		
Velocity at different lengths	Understanding the change in velocity at different lengths along the pipe.	

----

9) Comments on the result:

The simulation shows how the velocity and pressure will change along the length of the pipe. As we also see the shear stress accross the radius of the wedge. The variations of velocity shows that the fluid(water) is reaching the steady state as it approaches the outlet. The precise location is 2.1m from origin as it is the entrance length of the pipe.

Furthermore, as The comparision shows that there is indeed the unsteadyness which occurs due to the entrance. The shear distribution shows that there is a larger magnitude of shear at the wall (Which is obvious because of boundary condition phenomenon(no slip)).

10) Conclusion:

It is hence proven that the pressure difference governed by the Hagen-Poiseuille's equation is valid in the simulation. And provides as complete understanding of the flow inside the pipe.

Leave a comment

Other comments...