Numerical Fluid Mechanics II

Summer Semester 2016

Deliverable Task 1: Laminar Backward-Facing Step

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1. Introduction

Backward-Facing step is a benchmark of CFD (Computational Fluid Dynamics). The aim of the task is to simulate the Laminar Backward-Facing step on OpenFoam using SimpleFoam solver.

2. Convergence study

Taking various mesh size in account with Reynolds number of “Re = 100”, the convergence of the Recirculation length tabled as follows,

S.No	Mesh size (channel 1)	Mesh size (channel 2)	Recirculation length – Lr (m)
1	50 x 5	50 x 10	0.2776
2	100 x 10	100 x 20	0.3758
3	200 x 20	200 x 40	0.4228
4	300 x 30	300 x 60	0.4497
5	400 x 40	400 x 80	0.4604
6	500 x 50	500 x 100	0.4648
7	600 x 60	600 x 120	0.4668
8	**700 x 70**	**700 x 140**	**0.4671**
9	800 x 80	800 x 160	0.4651
10	900 x 90	900 x 180	0.4639
11	1000 x 100	1000 x 200	0.4641

Table 1: Recirculation length (Lr) for various mesh size

From the table, it's inferred that recirculation lengths (Lr) haven't changed much after the mesh sizes following **700 x 70** in channel 1 and **700 x 140** in channel 2. For this reason, the mesh size is chosen as it gives the maximum recirculation length

3. Run simple Foam efficiently

With the chosen mesh, new simulations are simulated by changing the relaxation factors. The results of these simulations are tabulated as follows:

S.No	Mesh size 1	Mesh size 2	Relaxation on U	Relaxation on P	No of iterations
1	700 x 70	700 x 140	0.6	0.4	5774
2	**700 x 70**	**700 x 140**	**0.8**	**0.4**	**3225**
3	700 x 70	700 x 140	0.75	0.25	3848
4	700 x 70	700 x 140	0.73	0.27	4096
5	700 x 70	700 x 140	0.7	0.3	4536
6	700 x 70	700 x 140	0.75	0.35	3856

Table 2: List of Relaxation factors

From the above table, we can choose relaxation factors as P = 0.4 N/m^2 and U=0.8m/s. due to less number of iterations.

4. Results and interpretations at "Re = 100"

4.1 Velocity Streamlines

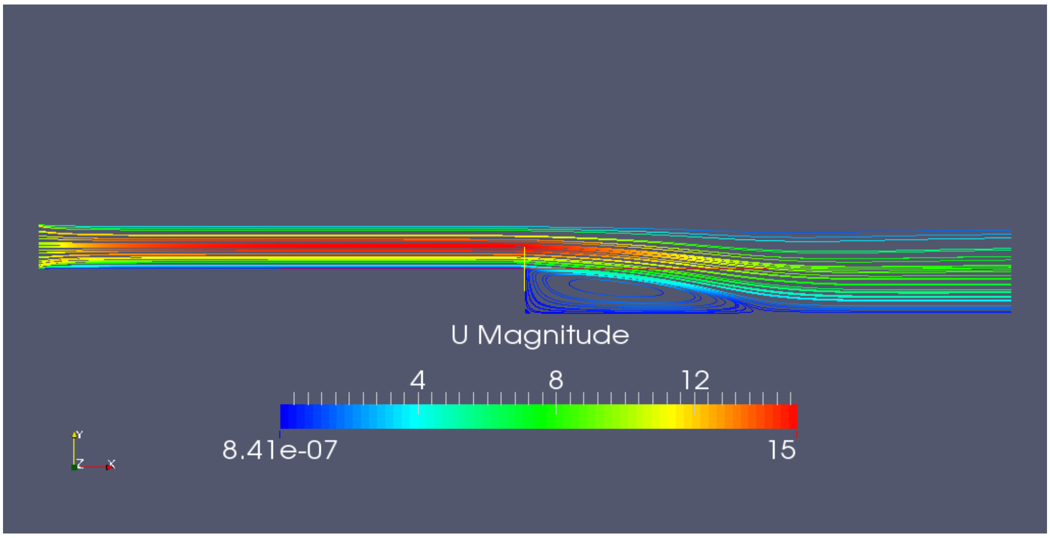

Figure 1: Velocity streamlines

The above simulation explains the velocity streamlines .The boundary layer is formed at the entrance of the channel 1 which further increases the velocity at the center channel resulting in a parabolic velocity profile .When the flow reaches the step, a recirculation and eddy are formed at the bottom of the step which created by low pressure region. This recirculation changes the direction of the flow towards the bottom of the channel. This recirculation tends to create another low pressure region in the upper channel which again leads to recirculation.

4.2. Velocity profile (u) at x = -0.5 D

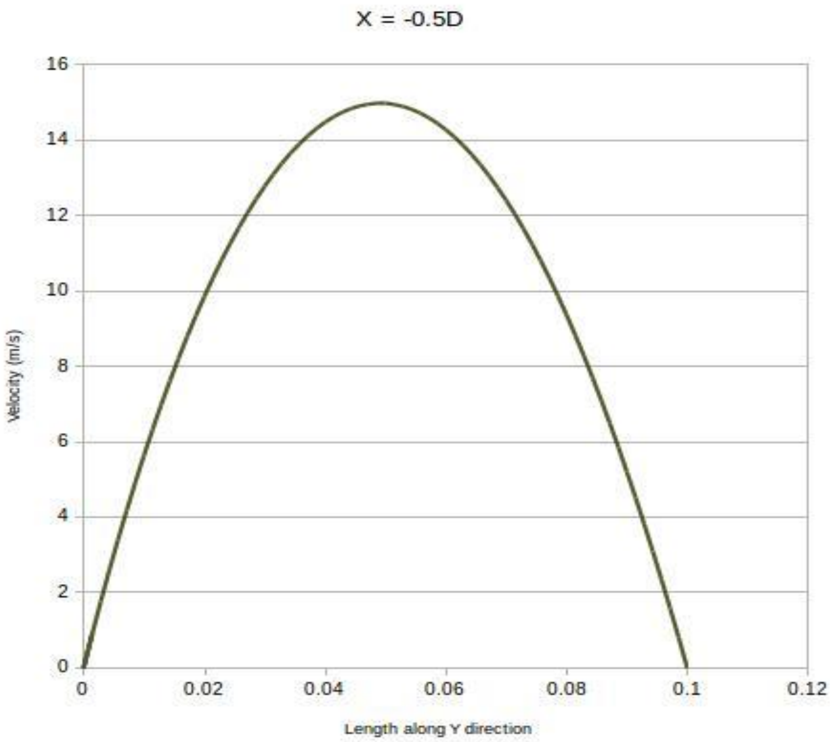

Figure 2: u at x = -0.5D

The above figure shows the velocity profile at $x = -0.5D$. We can see that the profile is parabolic and symmetric about the mid of the entrance channel. Also the peak velocity of $14.976 m/s$ has been reached. Hence the flow is fully developed.

4.3 Velocity profile (u) at x = D

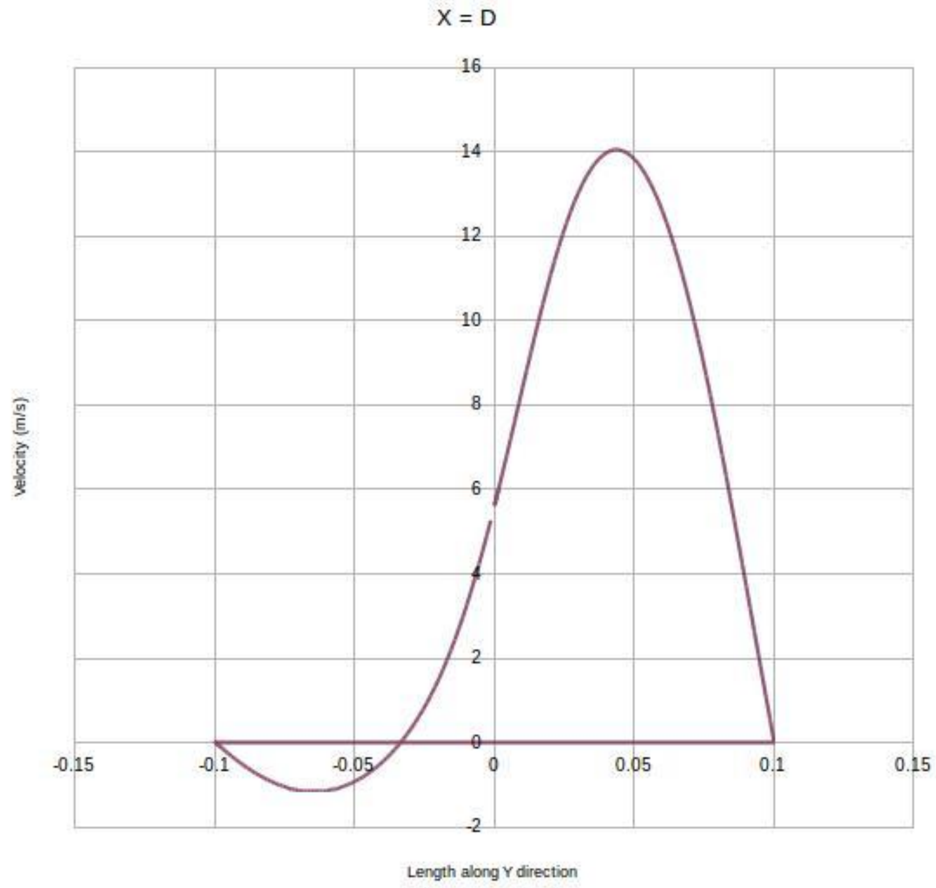

Figure 3: *u* at *x* = *D*

Figure 3, shows the velocity profile at x = D. The velocity reaches a negative value of 1.1714 m/s along y-axis(at base of channel).This is due to formation of recirculation region which is due to the low pressure region at the step.Then the velocity gradually increases and follows a parabolic profile and reaches 0 m/s at the top wall.

4.4 Velocity profile (u) at x = 9.5 D

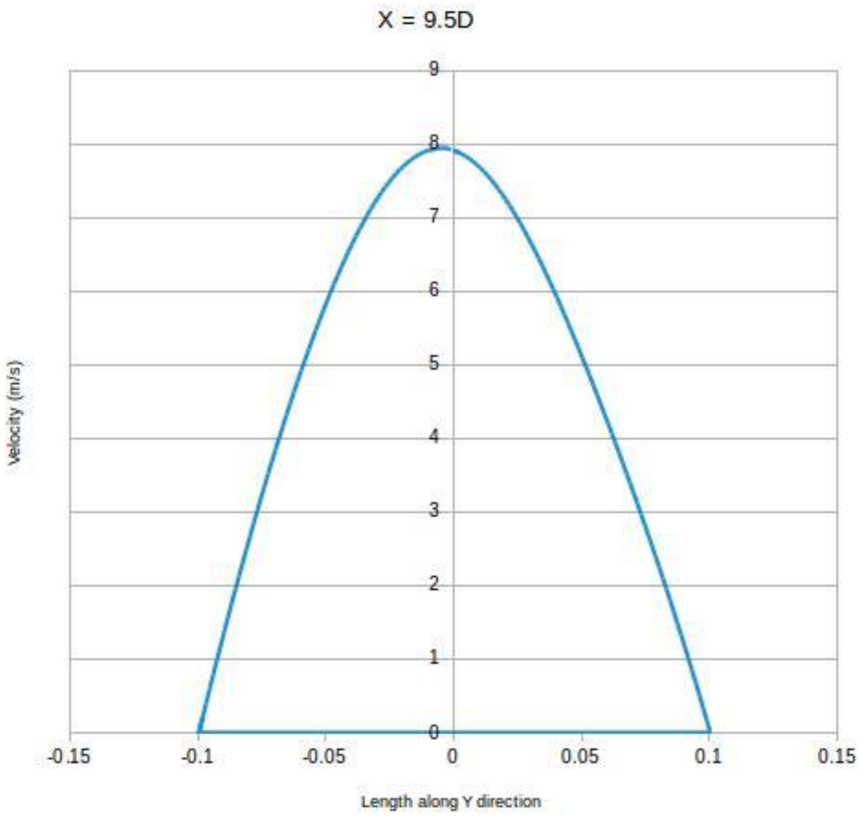

Figure 4: u at $x = 9.5D$

Above is the velocity profile at $x = 9.5D$. We can see that the profile symmetric with respect to the channel mid-height with peak velocity (u) of 7.920*m/s*.

5. Reynolds Number dependencies:

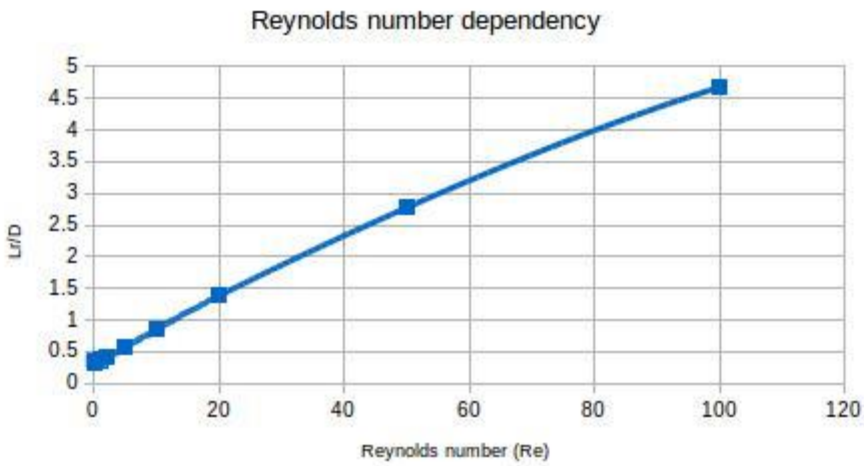

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Figure 5: Reynolds number dependency

The above plots shows the change of L_r /D with respect to different Re. We can see that as the Re increases the L_r/D also increases. This is because the Re increases when the velocity of the fluid increases and as the velocity increase the fluid length of the recirculation region also increases.

6. Conclusion:

In this task, we have modelled and simulated backward facing step using simpleFoam solver. The various mesh sizes are studied and we have chosen 700 x 70 for the entrance channel and 700 x 140 for the second channel.

Secondly we have studied the various effects of pressure and velocity relaxation factors and the best combination is chosen depending on the small number of iterations.

Then the various velocity profiles are simulated by changing the positions. The flow is fully developed before the backstep is reached. After the backstep, a recirculation region is developed due to low pressure region and finally is fully developed again before the outlet. Finally, the effects of Reynolds number are studied. As the Reynolds number is increases recirculation region also increases.