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Computational Investigation of Subsonic Flow over Backward-Facing Step

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ABSTRACT

The present study is to investigate the behavior of airflow over backward-facing step geometry for various velocities using CFD. Even though backward-facing step has simple geometry but it contains many flow regimes related to practical engineering. It's considered that the flow shows a strong two-dimensional behavior, on the plane of symmetry. The main objective of the analysis is to calculate pressure coefficient along length of backward facing step at various airflow velocities and calculation of reattachment point in terms of expansion ratio. Study of airflow over backward-facing step suggests that flow is recirculating and highly unsteady.

KEY WORDS: Subsonic flow, separated flow, RNG k- ε model, pressure coefficient, reattachment point.

1. INTRODUCTION

Early twentieth century was the beginning to the extensive research on separated flows. Separated flows are common in several engineering applications such as aircraft wings, turbine and compressor blades, buildings, suddenly expanding pipes, combustors, etc. Though flow over backward-facing step is complex and composed of many regions of different flow regimes it has been correctly investigated by using appropriate turbulence models. Also this study develops fuel efficient designs to reduce consumption of the rapidly-depleting non-renewable resource and minimize greenhouse gas emission. The main applications include the automobile and aircraft industries. In an aerodynamic perspective, drag is considered as one of the major reason for inefficient fuel consumption. There are several types of drag, but in this paper, the focus will be on the pressure drag created by the separated flows and the ways to minimize it. Analysis is carried out for three different Reynolds number. The parameter used for changing Reynolds number is airflow velocity. The three different velocities used for analysis are 20 m/s, 25 m/s and 30 m/s and their corresponding Reynolds number are $8.6x10^5$, $10.8x10^5$ and $12.9x10^5$.

Work Flow chart:

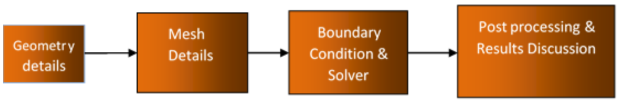


Figure.1. Work Flow chart

Geometry details: The actual dimension of the model was tabulated and is drafted by using CATIA V5 modeling software.

Table.1. Geometry details

Dimensions (in mm)	
Length	700
Width	300
Height	70
Thickness	4

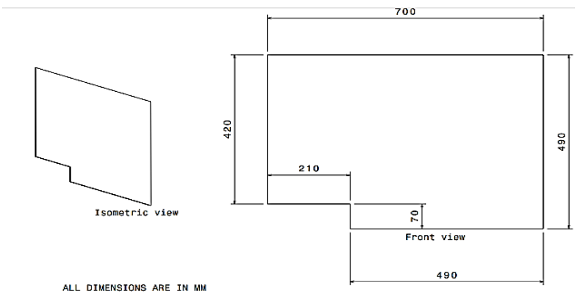


Figure.2. Geometry details

Mesh details:

Dimensions of the domain:

Height = 490mm

Length = 700mm

Mesh Details:

Number of nodes =10981

Number of cells =1055

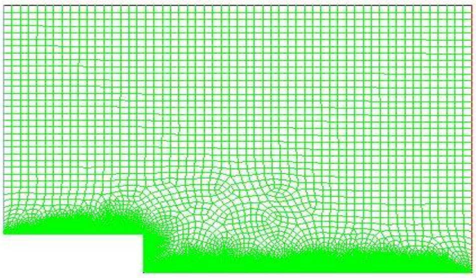


Figure.3. Mesh details

Quality of Mesh:

Minimum Orthogonal Quality = 0.253225

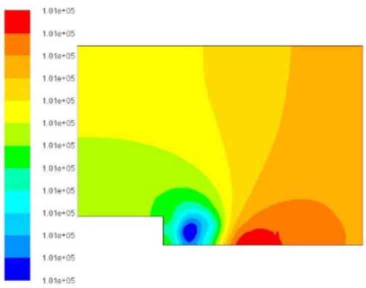
Maximum Aspect Ratio = 11.6

Flow solver & methodology:

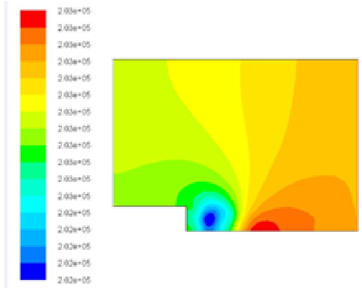
- The segregated solver is used with an implicit formulation
- second orders scheme for pressure terms
- QUICK scheme for convective derivative
- a second order upwind scheme for turbulent variables
- No transition model is implemented
- Residuals up to 10e-6
- Evaluated with RNG k- ε model

2. RESULTS AND DISCUSSION

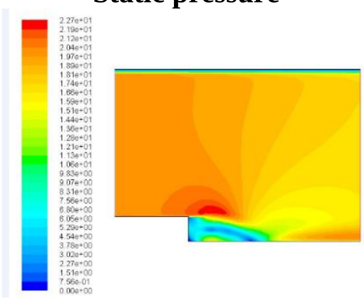
Analysis is carried out for three different Reynolds number. The reattachment point at various airflow velocities 20 m/s, 25 m/s and 30 m/s are obtained. Reattachment point(X/d) is defined as the average distance from the step edge to the flow reattachment position. At 20 m/s the reattachment point is 2.55d, at 25 m/s the reattachment point is 2.65d and at 30 m/s the reattachment point is 3.14d.



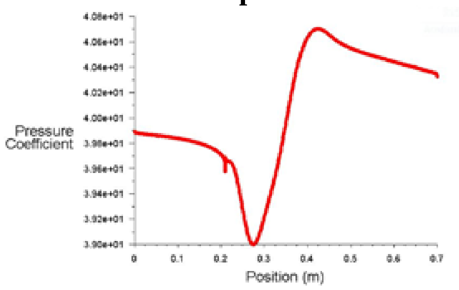
Static pressure



Absolute pressure

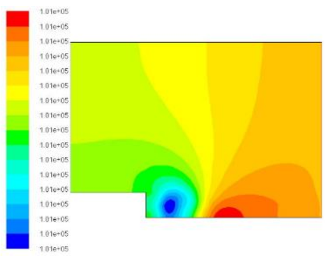


Velocity contour

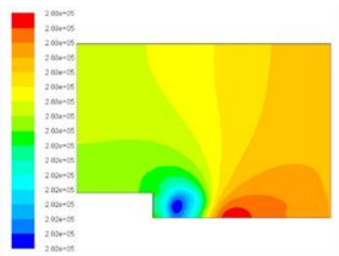


Pressure Coefficient

Figure.4. Pressure contours and Cp plot for 20m/s model



Static pressure



Absolute pressure

Velocity contour **Pressure Coefficient**

Figure.5. Pressure contours and Cp plot for 25 m/s model

Static pressure **Absolute pressure**

Velocity contour **Pressure Coefficient**

Figure.6. Pressure contours and Cp plot for 25 m/s model

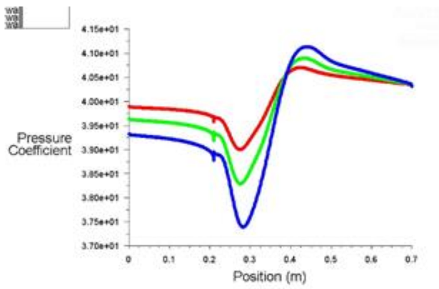


Figure.7. Comparison of Pressure Coefficient for various air velocity

3. CONCLUSIONS

Calculation of pressure coefficient along length of backward facing step at various velocities is done. Reattachment point in terms of expansion ratio is calculated at corresponding velocity. Through the results it was observed that when the velocity of air increases the reattachment point also increases in terms of expansion ratio(X/d). The obtained computational results will be verified experimentally.

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