Numerical investigation of flow though venturi for various angular positions of the butterfly valve

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Abstract— This work aims on analyzing the flow characteristics and pressure variation upon flow of air across the a venturi with a butterfly valve setup. The valve is placed before the converging end and after the diverging end of the venturi. The flow is analyzed for different angular positions of the butterfly valve. A series of analysis for both normal venturi flows without the valve arrangement and with the valve are carried out to arrive at a conclusion of the effect of introducing the valve. The analysis is carried out in commercial ANSYS software assuming a two-dimensional flow.

Keywords— Butterfly valve, venturi, flow velocity, turbulence

I. INTRODUCTION

Venturi as we know, serves for the conversion of the available high pressure at one end to achieve increased velocity at the other i.e., conversion of pressure head into kinetic energy head which implies increased velocity. It is typically found in a lot of mechanical arrangements, one of the notable applications being the automobile’s air-fuel mixing carburettor setup. This work aims on analyzing the effect of introducing obstacles in the form of butterfly valve in the flow path similar to that of the choke and throttle valves found in a simple carburetor and its effects on the flow characteristics are studied to arrive at better design decisions. The analysis is carried out assuming a two dimensional flow in commercial ANSYS software and its FLUENT module.

II. ANALYSIS SETUP

A. Geometry

The geometry is done with the help of Design Modeller that comes along with the Fluent module. The length of the entire venturi is assumed to be 1m. The constriction along the length i.e., the throat is assumed to be 50% of the original cross section.

Fig 1. geometry
B. Meshing

The meshing is made to be very fine with higher number of elements near the convergent-divergent sections and in the throat area. Here after meshing, there were 1,23,420 elements. However, when there is an obstruction that is introduced in the inlet, the area around the obstruction is also meshed to a fine size, as the flow properties tend to change there as well. The result of meshing produces about 98,024 elements.

![Fig 2 Mesh](image)

C. Setup

The setup is done with Double precision and the flow characteristics were set to be K-Epsilon. The inlet made to be velocity inlet with a velocity magnitude of 0.005799m/s operating at 1Bar pressure. This is to obtain a Reynold’s number value of 180\(^{[1]}\)

D. Results

The results are visualized in the form of graphs and contours. Typically, the graphs are plotted along the center line. From the results, the maximum and minimum values are identified such as the max velocity etc. in both cases when there is no obstruction and then there is an obstruction. The calculations are repeated for various angular positions of the valve and the most optimal location for positioning the valve is identified is each case.

### III. MATHEMATICAL MODELLING

The following assumptions are made for carrying out the calculations:

- The flow is incompressible in nature.
- There is no phase change that occurs during the passage through the tubes.
- The flow is irrotational.

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- There is no phase change that occurs during the passage through the tubes.
- The flow is irrotational.
- The fluid flow is subjected only to two forces – The downward gravitational force and the force due to the difference in pressure.
The inferences are made only after reaching the steady states. The following constants are used based on experimental procedures. $C_1 = 1.44$, $C_2 = 1.92$, $C_p = 0.09$, $\sigma_k = 1.0$, $\sigma_\epsilon = 1.3$. As the forces that occur are only the forces due to gravity and pressure, Euler’s equation comes into play. Thus we get,

$$\frac{dp}{\rho} + gdz + \nu dv = 0$$

Which is the Euler’s equation of motion. From the following the more specific Bernoulli’s equation can be obtained by integrating the obtained equation.

$$\int \frac{dp}{\rho} + \int gdz - \int \nu dv = \text{constant}$$

As the flow is incompressible, $\rho$ is constant thus we have,

$$\frac{p}{\rho} + gz + \frac{v^2}{2} = \text{constant}$$

$$\frac{p}{\rho}g + \frac{v^2}{2g} + z = \text{constant}$$

Thus the above equation obtained is the Bernoulli’s equation for fluid flow.

V. NORMAL VENTURI FLOW

Initially an analysis was carried out that reflected the normal flow through the venturi without any obstruction along the flow direction. The geometry was drawn, meshing was done and the setup including boundary conditions were set using the fluent module of the ANSYS workbench software and the results were plotted in the form of contours and charts.

The outlet velocity obtained was around $7.69503228e^{-003}$m/s. It was also observed that when the flow velocity supplied at the inlet was high, reversed flow occurred along the outlet region due to the insufficient pressure difference causing an issue. However, this can be overcame by extending the length of the outlet flow path/channel.

VI. VENTURI FLOW WITH OBSTRUCTION

In a real world carburetor however, there are butterfly valves placed both in the inlet at the outlet. The butterfly valve in the inlet functions as a choke and the butterfly valve in the outlet functions as a throttle. The choke helps in cold starting conditions by drawing extra fuel thus providing an extra heat required to overcome the initial starting trouble. The throttle
valve however helps in facilitating acceleration by allowing more fuel-air mixture to reach the combustion chamber. This was carried out as an analysis and the results were studied.

A. Choke valve fully open

(i) THROTTLE VALVE FULLY OPEN

(ii) THROTTLE VALVE AT 45°

(ii) THROTTLE VALVE FULLY CLOSED
B. **Choke valve at 45°**

(i) **THROTTLE VALVE FULLY OPEN**

(ii) **THROTTLE VALVE AT 45°**

(iii) **THROTTLE VALVE FULLY CLOSED**
C. Choke valve fully closed

(i) THROTTLE VALVE FULLY OPEN

(ii) THROTTLE VALVE AT 45°

(iii) THROTTLE VALVE FULLY CLOSED
VII. CONCLUSION

When there were no obstacles in the flow passage, the flow through the constriction (throat) caused a velocity increase for a proportional decrease in velocity. But when both choke valve and throttle valve are introduced in the inlet and outlet, the outlet velocity decreased from 37.95% increase to 3.46% increase due to the venturi action. This shows that the butterfly valves nullify the purpose of using the venturi. However, in the case where no venturi at all, it resulted in a decrease in the available velocity which is undesirable. Hence presence of venturi stands to be useful in this regard. Although the maximum velocity appeared in the fully open condition of the Throttle valve in case of fully open & fully closed choke valve, it can be seen through the analysis that maximum velocity appeared in the fully closed condition of the throttle valve in the case where the choke is at 45°. However, it is to be noted that the difference in the velocities is very much negligible in all the cases.

REFERENCES


