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# CFD Analysis of Flow Through Venturi

[1]Jay Kumar, [2]Jaspreet Singh, [3]Harsh Kansal, [4]Gursimran Singh Narula, [5]Prabhjot Singh
[1,2,3,4]UG Students, School of Mechanical Engineering, Chitkara University, Punjab, India
[5]Assistant Professor, School of Mechanical Engineering, Chitkara University, Punjab, India

## Abstract
Venturi plays very Important Role in different field of engineering. Venturi has a number of industrial applications in which its design is important factor. One of the important factors that affect the fuel consumption is that design of venture of carburettor. The venturi of the carburettor is important that provides a necessary pressure drop in the carburettor device. There is a need to design the Venturi with an effective analytical tool or software. In this work, three parameters namely pressure drop and Velocity discharge nozzle angle of the Venturi will be analyzed using computational fluid dynamics. For this analysis CFD will be done using two softwares namely GAMBIT and FLUENT. The results obtained from the softwares will be analyzed for optimum design of a venturi.

## Keywords
CFD, Venturi, GAMBIT, FLUENT

## I. Introdution
A venturi creates a constriction within a pipe (classically an hourglass shape) that varies the flow characteristics of a fluid (either liquid or gas) travelling through the tube. As the fluid velocity in the throat is increased there is a consequential drop in pressure. A venturi can also be used to mix a fluid with air. If a pump forces the fluid through a tube connected to a system consisting of a venturi to increase the water speed (the diameter decreases), a short piece of tube with a small hole in it, and last a venturi that decreases speed (so the pipe gets wider again), air will be sucked in through the small hole because of changes in pressure. At the end of the system, a mixture of fluid and air will appear. The Venturi effect is a special case of Bernoulli's principle, in the case of fluid or air flow through a tube or pipe with a constriction in it [1].

### A. Venturi Effect
The Venturi effect is a jet effect; as with a funnel the velocity of the fluid increases as the cross sectional area decreases, with the static pressure correspondingly decreasing. According to the laws governing fluid dynamics, a fluid's velocity must increase as it passes through a constriction to satisfy the principle of continuity, while its pressure must decrease to satisfy the principle of conservation of mechanical energy. Thus any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction is negated by a drop in pressure.
When a fluid such as water flows through a tube that narrows to a smaller diameter, the partial restriction causes a higher pressure at the inlet than that at the narrow end. This pressure difference causes the fluid to accelerate toward the low pressure narrow section, in which it thus maintains a higher speed. The Venturi meter uses the direct relationship between pressure difference and fluid speeds to determine the volumetric flow rate [6].

### B. Venturi Tubes
The simplest apparatus, as shown in the photograph and diagram, is a tubular setup known as a Venturi tube or simply a venturi. Fluid flows through a length of pipe of varying diameter. To avoid undue drag, a Venturi tube typically has an entry cone of 30 degrees and an exit cone of 5 degrees.
Venturi tubes are available in various sizes from 100 mm to 813 mm with flow coefficient value of 0.984 for all diameter ratios. They are widely used due to low permanent pressure loss. They are more accurate over wide flow ranges than orifice plates or flow nozzles. However it not used where the Reynolds number is less than.

### C. Bernoulli's Principle
The Venturi effect is a special case of Bernoulli's principle, in the case of fluid or air flow through a tube or pipe with a constriction in it.
Bernoulli's principle can be derived from the principle of conservation of energy. This states that, in a steady flow, the sum of all forms of mechanical energy in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy and potential energy remain constant. Thus an increase in the speed of the fluid occurs proportionately with an increase in both its dynamic pressure and kinetic energy, and a decrease in its static pressure and potential energy. If the fluid is flowing out of a reservoir, the sum of all forms of energy is the same on all streamlines because in a reservoir the energy per unit volume (the sum of pressure and gravitational potential $\rho g h$) is the same everywhere [7].
Bernoulli's principle can also be derived directly from Newton's 2nd law. If a small volume of fluid is flowing horizontally from a region of high pressure to a region of low pressure, then there is more pressure behind than in front. This gives a net force on the volume, accelerating it along the streamline.
Fluid particles are subject only to pressure and their own weight. If a fluid is flowing horizontally and along a section of a streamline, where the speed increases it can only be because the fluid on that section has moved from a region of higher pressure to a region of lower pressure.

### D. Bernoulli's Equation
Energy is conserved in a closed system, that is, the sum of potential and kinetic energy at one location must equal the sum of the potential and kinetic energy at any another location in the system. If potential energy decreases at one location, the kinetic energy must proportionally increase at that location. The fluid now enters the throat of the Venturi with a new area A2, which is smaller than A1. In a closed system mass can be neither created nor destroyed (law of conservation of mass, simply, what goes in, must come out), and as such, the volumetric flow rate at area A1 must equal the volumetric flow rate at area A2. If the area at location A2 is smaller than A1, the fluid must travel faster to maintain the same volumetric flow rate. This increase in velocity results in a decrease in pressure which follows Bernoulli's equation.

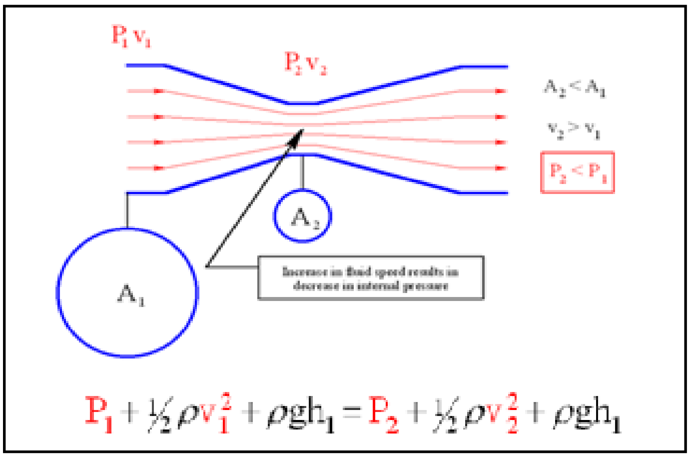


Fig. 1: Shows Venturi Tube

## II. Designing

In this a simple venturi as shown in fig 1 was taken and its various dimensions were measured. Then according to the measured dimensions a meshed structure of the venturi was drawn with the help of GAMBIT software. Then the meshed structure was exported as the .mesh file and was analyzed with proper boundary conditions using the software FLUENT and the results of this analysis were studied [1-2].

There are so many parameters to vary but in this case only the effect of the variation of angle on the flow across the venturi is studied.

The analysis was done for $\Theta = 30^0, 40^0, 45^0$ where $\Theta$ is the angle between the axis of the vertical axis of the body of the venturi.

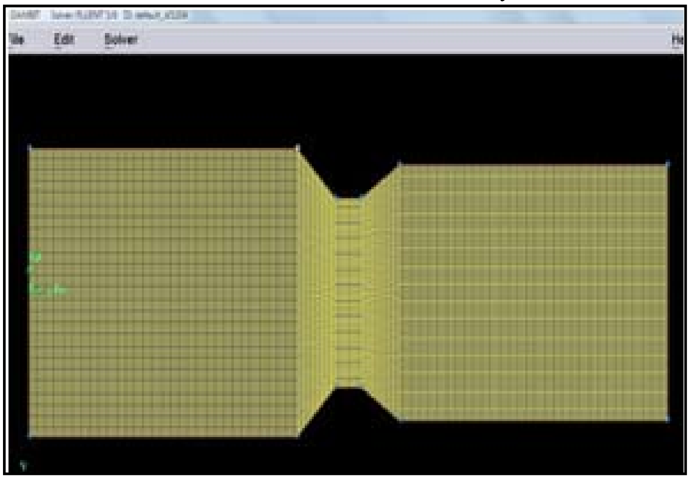

Fig. 2: Shows Geometry of Simple venturi in Gambit

### A. Specification of the Venturi

The model of the venturi as drawn in the GAMBIT software is shown in the fig. 2.

The various dimensions of the venturi are mentioned below.

Total length of venture tube = 150 mm
Inlet diameter = 52 mm
Throat diameter = 34 mm
Outlet diameter = 46 mm
Length of throat = 6 mm
Length of the inlet part = 63 mm
Length of the outlet part = 63 mm
Angle of fuel discharge nozzle with the vertical axis of venturi = $\Theta$

## III. Results and Discussions

The inlet air was assumed to enter the venturi at normal temperature and the pressure was taken to be 1 atm. The following are results of the analysis of the venture for different angles of the throttle plate.

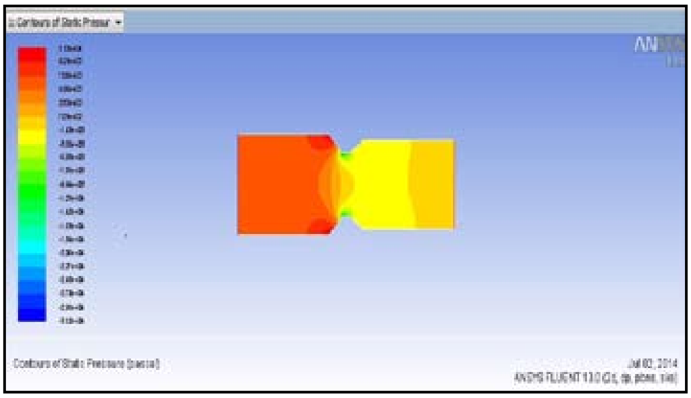

Fig. 3: Shows the Static Pressure Contour for Venturi Nozzle Angle of $45^0$

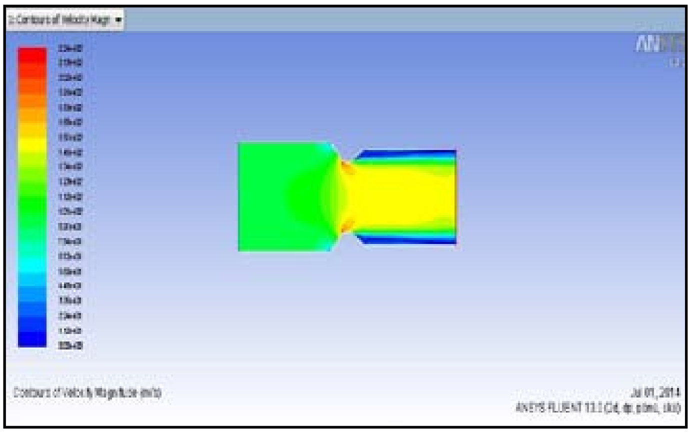

Fig. 4: Shows the Velocity Contour for Venturi Throat Angle of $45^0$

Fig. 3 shows the statics pressure view for $45^0$ throttle plate

From fig. 3 it is clear that when the throttle plate is $45^0$ open, there is less amount of air flow through the inlet valve and hence the mixture is somewhat richer than the other cases. In this case the pressure at the throat of the venturi is around 93000 Pascal.

In fig. 4, when the throttle plate is open, the mixture is slightly leaner than in case of 450 opened throttle plate condition. In this case the pressure at the throat of the venturi is found to be around 91000 Pascal.

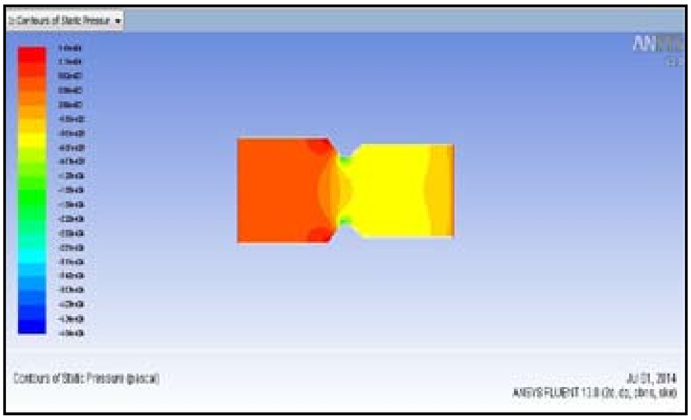

Fig. 5: Shows the Static Pressure Contour for Venturi Nozzle Angle of $40^0$

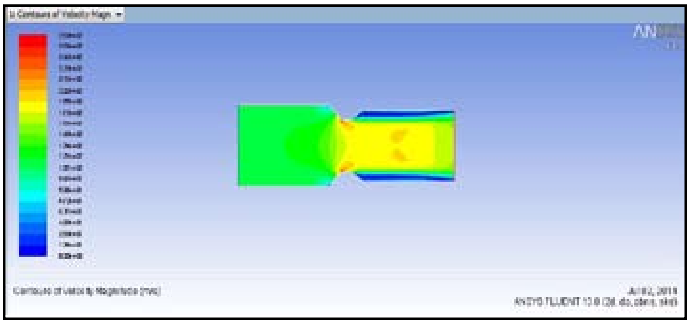

Fig. 6: Shows the Velocity Contour for Venturi Throat Angle of $40^0$

From fig. 6, when the throttle plate is $40^0$ open, there is be more amount of air flow through the inlet of the venturi. So the mixture will be leaner. In this case the pressure at the throat is found to be 87000 Pascal.

From fig 6, when the throttle plate is open, there will be maximum amount of air flow through the inlet of the venturi. In this case the pressure at the throat is found to be 85000 Pascal.

From the analysis done the throat pressure was found to be 90000 Pascal. Then by taking the previous boundary conditions and the throat pressure as 90000 Pascal, the flow of fuel through the fuel discharge nozzle as 10 m/s.

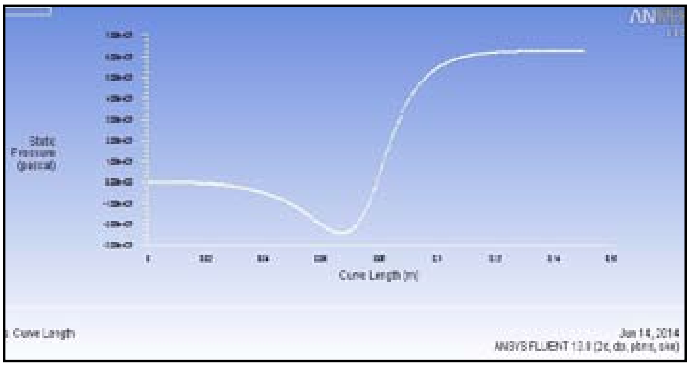


Fig. 7: Graph Showing Variation of Throat Pressure

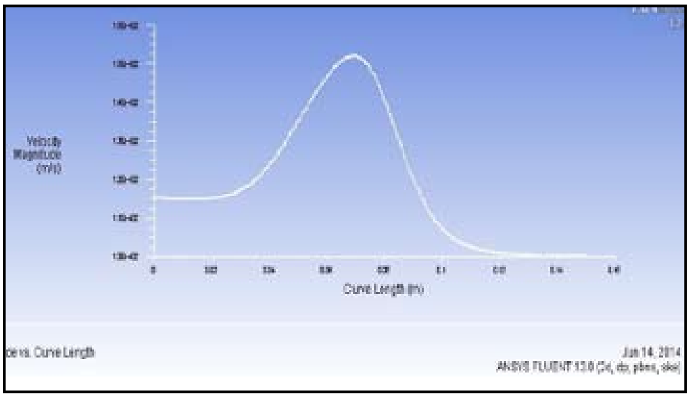


Fig. 8: Graph Showing Variation of Velocity Magnitude (m/s)

It is clear from both the figures that the velocity is maximum at the throat of the venturi as shown in fig. 8 whereas the pressure is the minimum at the venturi as shown in fig. 7, shows a uniform distribution of pressure and fig. 8 shows that the velocity also uniformly increases from the inlet of the venturi towards the throat.

The following pictures show the results obtained from the analysis of the carburettor with help of FLUENT.

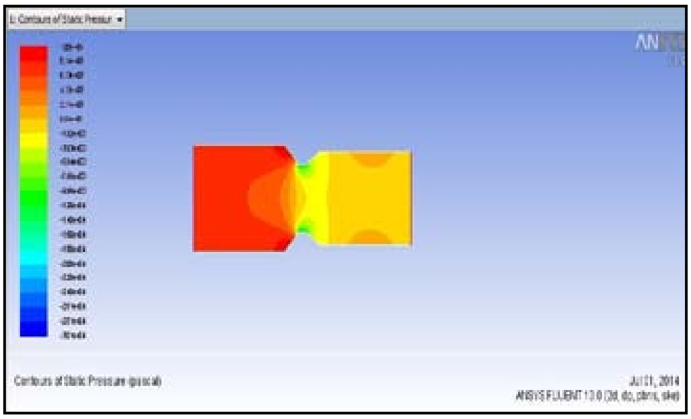


Fig. 9: Shows the Static Pressure Contour for Venturi Nozzle Angle of $30^0$

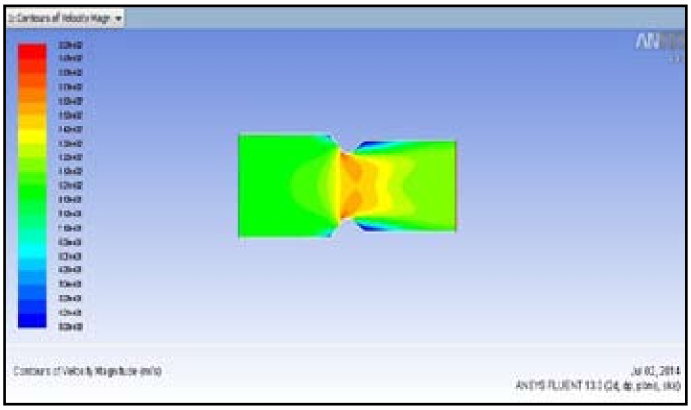

Fig. 10: Shows the Velocity Contour for Venturi of $30^0$

Fig. 9 shows the static pressure contour for fuel discharge nozzle angle of $30^0$ and fig. 10 shows the velocity contour for fuel discharge nozzle angle of $30^0$. It is clear from both the figures that the velocity is maximum at the throat of the venturi as shown in fig. 10 whereas the pressure is the minimum at the venturi of the carburettor as shown in fig. 9 shows that the pressure is not distributed uniformly throughout the body of the venturi and the distribution is also same in case of velocity as shown in fig. 10.

## IV. Conclusion

From the above analysis the conclusions obtained are

1. When the flow inside the venturi was analyzed for different angles, it was found that the pressure at the throat of the venturi decreased with the increase in opening of the throttle plate. Because when the throttle plate opening increases then the flow of air through the venture increases. But as obtained from the analysis above the pressure at the throat the throat also decreases with increase in opening of the throttle plate so the flow of air from the float chamber into the throat increases.
2. When analyzed for venturi nozzle angle of 300, it was observed that the pressure distribution inside the body of the carburettor venture is quite uniform which leads to a better atomization and vaporization of the fuel inside the carburettor body. But in other cases like where the fuel discharge nozzle angle was 300, 400 or 450, the pressure distribution is quite non-uniform inside the venturi. So it is concluded that for operated engine the optimum air discharge nozzle angle is 300.

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Harsh Kansal is an enrolled student in School of Mechanical Engineering at Chitkara University, Punjab, India. He was Exchange Student for a semester at Chung Ang University, Seoul, Korea. His areas of interest are Solid Mechanics, Manufacturing Techniques and Computational Fluid Dynamics.

Mr. Prabhjot Singh is Assistant Professor in School of Mechanical Engineering, Chitkara University, Punjab. His area of interest is Industrial Production for betterment of society that maximizes the innovation. He emphasizes on bridging the gap between industries and engineering institution for entrepreneur engineers. He also filed a patent in the field of production.

Jay Kumar is an enrolled student in School of Mechanical Engineering at Chitkara University, Rajpura, Punjab. His areas of interest are Computational Fluid Dynamics, Designing, Reverse Engineering, 3-D Scanning and Thermodynamics.

Jaspreet Singh, he is an enrolled student in School of Mechanical Engineering at Chitkara University, Rajpura, Punjab. His areas of interest are Computational Fluid Dynamics, Designing, Reverse Engineering and Thermodynamics.

**Gursimran Singh Narula,** he is an enrolled student in School of Mechanical Engineering at Chitkara University, Rajpura, Punjab. His areas of interest are Computational Fluid Dynamics, Designing and Thermodynamics.