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Investigation of Mass Flow Rate in Venturimeter Using CFD Analysis

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ABSTRACT
Venturimeter is a device which is used for measuring rate of flow of fluid flowing through pipes. The application of these are found in Aviation, Automotive,chemical, petro chemical industries, etc. In automotive industry venturimeter is used to measure the fuel and air distribution in carburetor. In this work dynamic flow analysis is to be carried by varying inlet diameter of venturimeter such as 25mm, 30mm and 35mm. Theoretical calculations are to be done for mass flow rate of air. The obtained theoretical values are to be compared with ANSYSvalues. By varying the inlet pressure the mass flow rates of Al2O3, water and air passing through various diameters of Venturimeter are to be calculated. In this work Unigraphics software is used for modeling of venturimeters with inlet diameters of 25 mm, 30mm and 35mm. FEA software ANSYS is used for calculating mass flow rate values for venturimeters.
Keywords: Automotive, carburetor, chemical, mass flow rate, venturimeter.

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I. INTRODUCTION

A venturimeter is a device used for measuring the rate of a flow of a fluid flowing through a pipe.It is based on the principle of Bernoulli's equation. Inside of the venturimeter pressure difference is created by reducing the cross-sectional area of the flow passage. The pressure difference is measured by using a differential U-tube manometer. This pressure difference helps in the determination of rate of flow of fluid or discharge through the pipe line. As the inlet area of the venturimeter is large than at the throat, the velocity at the throat increases resulting in decrease of pressure. By this, a pressure difference is created between the inlet and the throat of the venturimeter.The Venturimeter tubes in general are made of titanium, cast iron, steel for higher lines sizes. For smaller line sizes they are made of glass, acrylic, rulon etc. The Venturimeter 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 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. The Venturimeter 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 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.

II. THEORETICAL MASS FLOW RATE CALCULATIONSINVENTURIMETER

The appropriate obstruction meter for designing the Air restrictor would be Venturimeter with Cd (~0.85), which is greater than the Cd (~0.65) of Orifice meter. Because in 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 a drop in pressure negates any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction. An equation for the drop in pressure due to the Venturimeter effectmay be derived from a combination of Bernoulli's principle and the continuity equation.

Mass Flow Rate Calculation of Air Passing Through Venturimeter of 25 mm, 30 mm and 35 mm Diameter Keeping Pressure Constant:

The mass flow rate (m) through Venturimeter is given by [1] = $\frac{A*P}{\sqrt{T}} * \sqrt{\frac{\gamma}{R}} * \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}}$ …… (1)

Total atmospheric pressure (P) of air = 101325 Pa
Atmospheric temperature (T)= 300K
Inlet diameter of venturimeter (d) = 25 mm
Specific heat ratio of air (γ) = 1.4
Gas constant (R) = 286 J/KgK
Area of inlet (A) =$\left(\frac{\pi}{4}\right) d^2$ = 0.00049 m^2
Mass flow rate ($\dot{m}$) = $\frac{A*P}{\sqrt{T}} * \sqrt{\frac{\gamma}{R}} * \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}}$
= 0.00033Kg/s
For inlet diameter of venturimeter (d) = 30 mm
Specific heat ratio of air (γ) = 1.4
Mass flow rate ($\dot{m}$) =$\frac{A*P}{\sqrt{T}} * \sqrt{\frac{\gamma}{R}} * \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}}$
= 0.00047 Kg/s

For inlet diameter of venturimeter (d) = 35 mm
Mass flow rate ($\dot{m}$) = $\frac{A*P}{\sqrt{T}} * \sqrt{\frac{\gamma}{R}} * \left(\frac{\gamma+1}{2}\right)^{-\frac{\gamma+1}{2(\gamma-1)}}$
= 0.00065 Kg/s

Mass flow rate of Al_2O_3, Air and water when passing through Venturimeter of different diameters and by varying the pressure are calculated and tabulated in Table 1throughTable 3. From Table 1 it is observed when Al_2O_3 flows through Venturimeter by varying the pressure the difference gets increased between consecutive diameters. It is observed from Table. 2 when waterflows through Venturimeter by varying the pressure the difference get increased between consecutive diameters. When Airflows through Venturimeter by varying the pressure the difference is getting increased gradually between consecutive diameters has been shown in Table. 3. Comparing the three tables the mass flow rate is higher when working fluid is Al_2O_3 passing through the Venturimeter of various diameters by varying the pressure.

Table.1: Mass Flow Rate of Al_2O_3at Different Pressures.

TOTAL ATMOSPHERIC PRESSURE (Pa)	THEORETICAL MASS FLOW RATE (kg/s)		
	25mm	30mm	35mm
101325	0.1218	0.1740	0.2386
101825	0.1224	0.1749	0.2398
102325	0.1231	0.1757	0.2410
102825	0.1236	0.1766	0.2422

Table. 2: Mass Flow Rate of Waterat Different Pressures.

TOTAL ATMOSPHERIC PRESSURE (Pa)	THEORETICAL MASS FLOW RATE (kg/s)		
	25mm	30mm	35mm
101325	0.1157	0.1659	0.2265
101825	0.1163	0.1671	0.2275
102325	0.1165	0.1672	0.2288
102825	0.1170	0.1673	0.2292

Table. 3: Mass Flow Rate of Airat Different Pressures.

TOTAL ATMOSPHERIC PRESSURE (Pa)	THEORETICAL MASS FLOW RATE (kg/s)		
	25mm	30mm	35mm
101325	0.1152	0.1646	0.2257
101825	0.1157	0.1654	0.2268
102325	0.1163	0.1662	0.2279
102825	0.1169	0.1670	0.2290

III. ANALYSIS OF VENTURIMETER

NX, also known as NX Unigraphics or usually just u-g, is an advanced CAD/CAM/CAE software package used for modeling the Venturimeter. This software was developed by Siemens PLM software. The three dimensional model of Venturimeter is shown in Fig. 1The meshed model of Venturimeter is shown in Fig. 2. The static pressure and net mass flow rate in the Venturimeter of 25 mm, 30 mm and 35 mm diameters are calculated when air is passing through it are shown in Fig. 3through Fig. 8. Table 4 shows the comparison mass flow rate values between theoretical and analysis software ANSYS results. From Table 4 it is observed that theoretical and ANSYS values are almost equal. Also it is observed that when area of inlet venturimeter is increasing the mass flow rate increases.

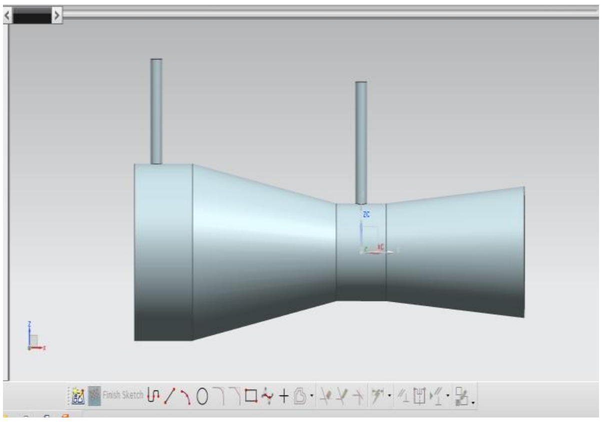

Fig. 1: 3D Model of Venturimeter

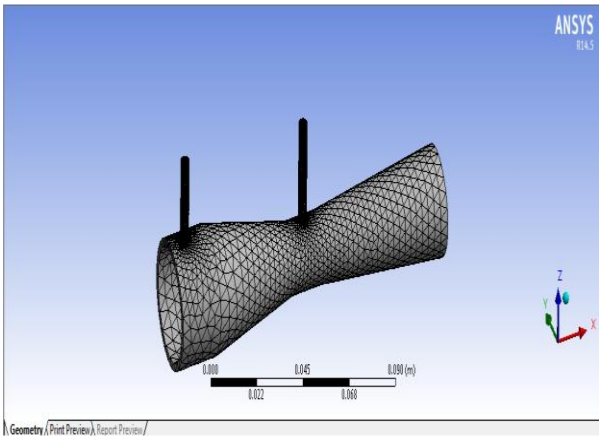

Fig. 2: Mesh Model of Venturimeter

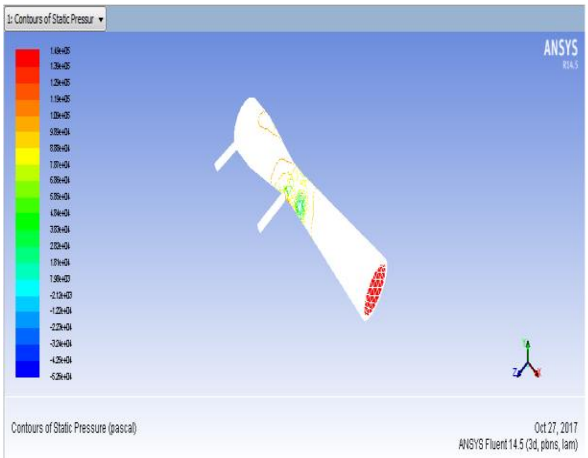

Fig. 3: Static Pressure in Venturimeter of Diameter (25mm)

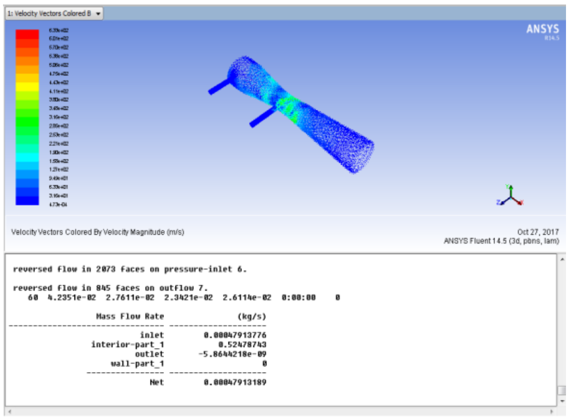

Fig. 4: Net Mass Flow Rate through Venturimeter of Diameter (25mm**)**

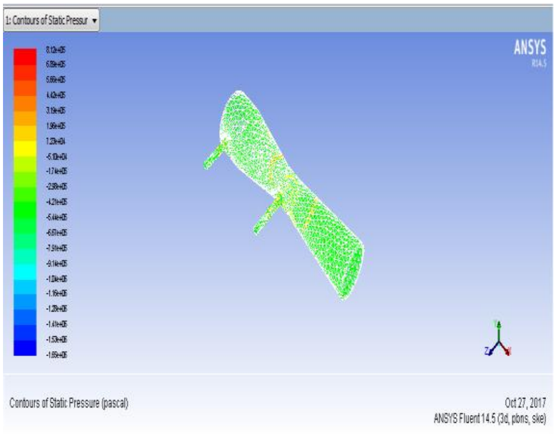

Fig. 5: Static Pressure in Venturimeter of Diameter (30 mm)

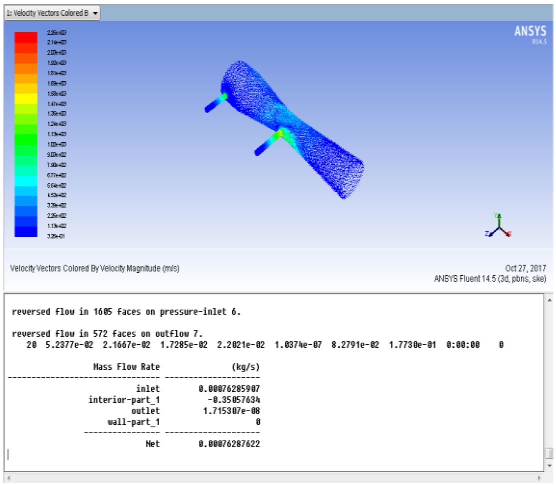

Fig 6: Net Mass Flow Rate through Venturimeter of Diameter (30 mm**)**

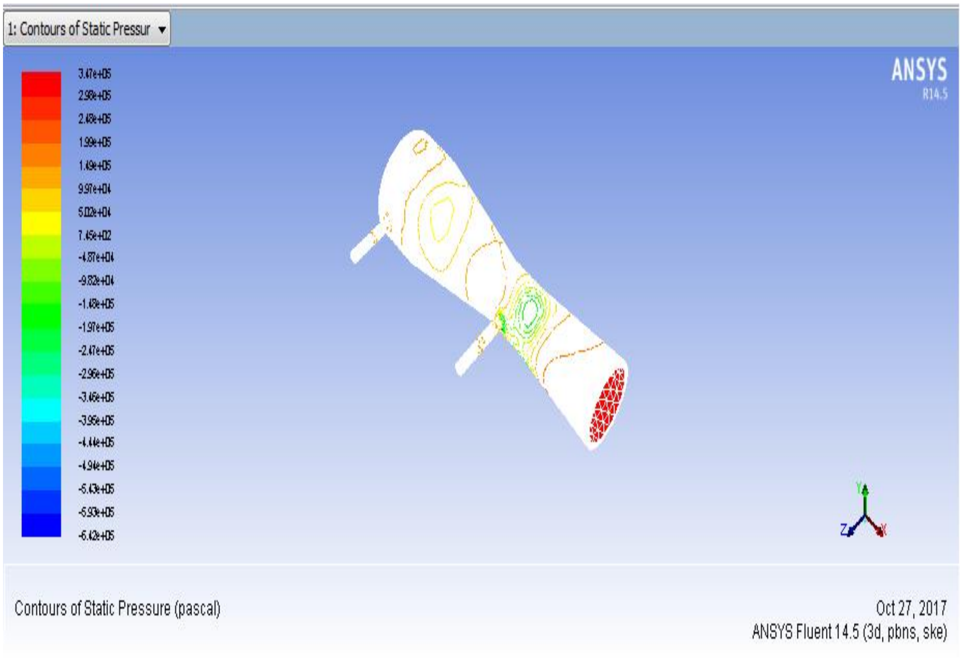

Fig.7: Static Pressure in Venturimeter of Diameter (35mm)

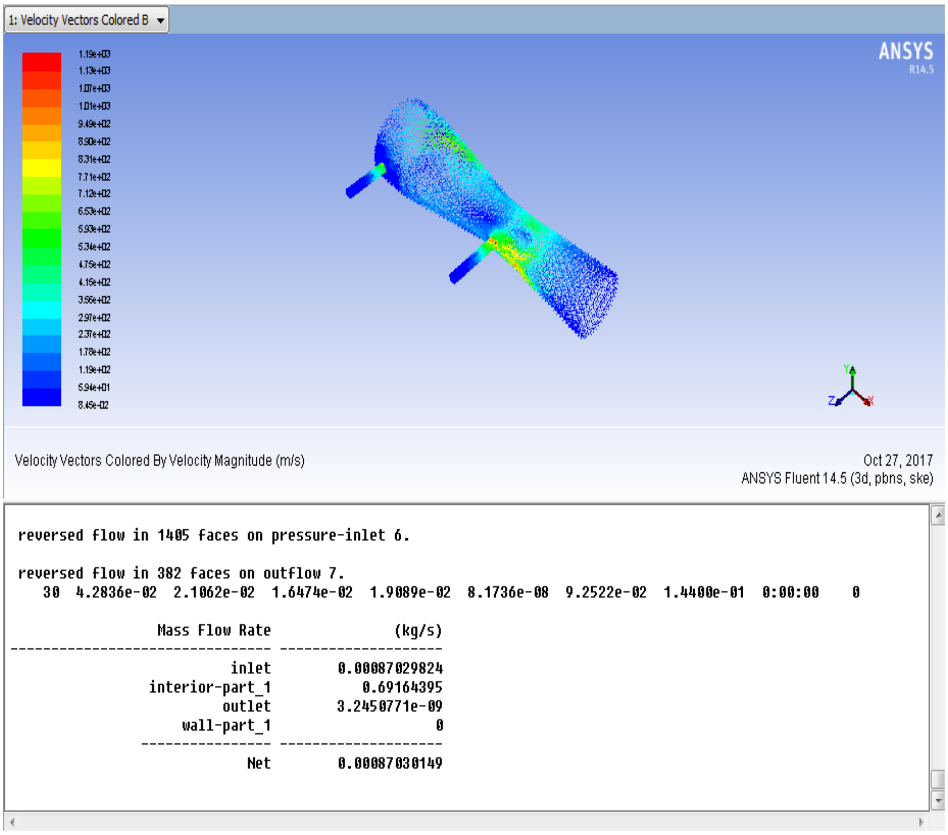

Fig 8: Net Mass Flow Rate through Venturimeter of Diameter (35 mm**)**

IV. CONCLUSIONS

In this work theoretical calculations are done for mass flow rate of Air passing through Venturimeter of different diameters keeping pressure as constant. From air flow analysis of different venturimeters, results produce different mass flow rate and 35 mm inlet venturimeter produced maximum amount of mass flow rate with minimum engine pull. From the calculations it is concluded that mass flow rate for air is minimum at 25mm diameteri.e. 0.1169 kg/s and maximum at 35mm diameteri.e. 0.2290 kg/s. Mass flow rate for water is minimum at 25mm diameter i.e. 0.1170and maximum at 35mm diameter i.e. 0.2292. Mass flow rate for AL_2O_3 is minimum at 25mm diameter i.e. 0.1236 and maximum at 35mm diameter i.e. 0.2422.It is also concluded that among the above three types of flows AL_2O_3(nano fluid) gives maximum flow rate.

Table. 4: Comparison of MassFlow Rate betweenTheoretical and ANSYSValues

Venturimeter Diameter (mm)	Theoretical Results(Kg/s)	ANSYS Results (Kg/s)
25	0.00033	0.00047
30	0.00047	0.00076
35	0.00065	0.00087

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