CFD Analysis of Flow through Venturi in Carburetor

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Abstract

Modern passenger vehicles with gasoline engines are equipped with various compensation devices for the supply of the air-fuel mixture. Even so, the fuel consumption is high due to many factors. One of the important factors that affect fuel consumption is the design of the carburetor. The carburetor venturi is important because it provides a necessary pressure drop across the carburetor device. Since various SI engine alternative fuels such as LPG, CNG are used in today's vehicles to reduce pollution and fuel consumption. Also for better economy and uniform fuel air supply, it is necessary to design the carburetor with an efficient analytical tool or software. In this work, the parameters namely pressure drop and speed, carburetor throttle angle will be analyzed using computational fluid dynamics. For this analysis, CFD will be performed using ANSYS software. The results obtained from the software will be analyzed for an optimal design of a carburetor.
Keywords: CNG, FLUENT, LPG, ANSYS, THROTTLE.

I. INTRODUCTION

A venturi creates a constriction in a pipe (typically hourglass shaped) which varies the flow characteristics of a fluid (liquid or gas) passing through the tube. As the velocity of the fluid in the throat increases, there is a consequent pressure drop. 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 speed of the water (the diameter decreases), a small piece of tube with a small hole, and finally a venturi which decreases the speed (so the hose widens again), air will be sucked through the small hole due to the pressure changes [1].

Large volumes of small engines (two wheels) are sold in India every year. Its emissions represent a significant percentage of total pollutants in India. As the automotive industry has demonstrated, significant emission reductions are technologically possible, especially with the use of electronic fuel injection. However, mainly due to cost constraints, small engine manufacturers rely on inexpensive small carburetors to generate the fuel mixture for their engines. Thus, a better understanding of the carburetor or of performance and modeling could lead to better control of the fuel mixture and reduced emissions from small engines [2].

The performance of a spark engine is mainly dependent on three variables namely air intake, fuel injection and spark ignition. The air intake system delivers oxygenated air to an engine's combustion chamber, where timely fuel injection and spark occurs to generate power for the vehicle. A proper air intake system delivers the required amount of clean air to the engine depending on the engine load, to provide power and better gas mileage during operation. The design of the air intake system requires optimizing air flow, reducing the inertia of moving parts to improve response and reduce losses. For ideal air flow, the intake system should increase the speed of the air until it enters the combustion chamber, while minimizing turbulence and restricting the flow. The earliest automobile intake systems were simple air intakes connected directly to carburetors where air and fuel were mixed. These systems posed problems of inefficient combustion, sluggish response and increased pollution. These are now replaced by the modern intake system with rapid response throttle coupled to electronically controlled fuel injection [3].

INTERNAL COMBUSTION ENGINES

The motor is a device that transforms one form of energy into another form. Thermal energy is a device that transforms the chemical energy in a fuel into another form of energy and uses that energy for useful work. The internal combustion engine is a device in which the combustion of the working fluid takes place inside the engine, e.g. gasoline or diesel engine.

A) SI Engine The SI engine is known as the spark ignition engine. In the case of such engines, the cycle is completed in 4 piston strokes, namely suction, compression, power and exhaust.

Suction: Suction strokes begin when the piston is at top dead center. At this time, the intake valve is opened while the exhaust valve is closed. As the piston moves to bottom dead center, suction is created and the air-fuel mixture is drawn into the cylinder..

Compression: When the piston returns from bottom dead center to top dead center, the load sucked in during the intake stroke is compressed. During this race, both valves are open. At the end, the mixture is ignited with the help of a spark plug. Due to ignition, the chemical energy of the fuel is converted into thermal energy, and the temperature rises to around 20000 C.

Expansion: : During this stroke, both valves remain in the closed position and energy is also produced.

Exhaust: During this stroke, the intake valve remains in the closed position while the exhaust valve remains open. The piston moves from bottom dead center to top dead center and sweeps the burnt gases out of the cylinder. In recent times, gaseous fuels are gaining in importance as cleaner fuels for the production of electricity through internal combustion engines; the power generation package comprising both reciprocating engines and gas turbine machines. Complete combustion with minimal emissions is the key characteristic of gaseous fuels and this characteristic is currently exploited worldwide for the purpose of electricity generation. Among the clean sources of fuel for power generation, natural gas has been exploited largely due to its high availability in specific locations. Likewise, there is also an impetus for the use of gas generated from industrial and municipal waste, namely diluted natural gas biogas and landfill gas. Unlike the production of gas from biological / organic waste by a biological conversion process, which is limited to non-loganiaceous material, the thermo chemical conversion pathway (also called gasification) can process any solid organic material. The biomass range includes agro-residues such as rice husks, sugar cane waste and biogas in compact or briquette form. The resulting gas, known as producer gas, can be used to power a compression ignition (CI) engine in dual fuel mode or a positive ignition (SI) engine in gas only mode. The exploitation of biomass energy via gasification is not only economical, but also respectful of the environment [4]. All carburetors work according to the Bernoulli principle which states that the speed of a fluid increases when the pressure drops. Within a certain range of speed and pressure, the speed increases with the pressure drop. However, this linear relationship only holds within a certain range. The carburetor should accelerate from rest to a certain speed. It depends on the air flow required by the engine speed and the throttle adjustment. According to Bernoulli's theorem, the air circulating in the neck of the carburetor will be at a pressure lower than atmospheric pressure, and related to the speed [5].

FACTORS AFFECTING CARBURETION

The various factors affecting the carburizing process are
1. Engine speed
2. Fuel vaporization characteristics
3. Incoming air temperature
4. Carburetor design

Since the motors are of the high speed type, there is very little time available for the preparation of the mixture. So, to have high quality carburetion, the air speed at the fuel injection point must be increased. To do this, a venturi is provided in the path of the air. The presence of highly volatile hydrocarbons in the fuel also ensures high quality carburetion. The pressure and temperature of the surrounding air also affect the carburizing process. A higher atmospheric air temperature increases the vaporization of the fuel and therefore a more homogeneous mixture is produced. The design of the carburetor, its intake system and the combustion chamber also affects the even distribution of the mixture between the different cylinders of the engine.

PRINCIPLE OF CARBURETION

Air and gasoline are drawn into the cylinder due to the suction pressure created by the downward movement of the piston. In the carburetor, the air passing through the combustion chamber captures the fuel discharged through a fine orifice in a tube called the carburetor nozzle. The fuel discharge rate depends on the pressure difference between the float chamber and the carburetor venturi neck and the surface of the tube outlet. In order for the fuel to be highly atomized, the suction effect should be strong, and the nozzle outlet should be relatively small. To produce strong suction, a restriction is usually provided in the carburetor pipe bringing air to the engine. This restriction is called throat. In this groove, due to the increase in air speed, the pressure is decreased and suction is created. The venturi tube has a narrower path in the center so that the path through the air will travel is reduced. Since the same amount of air must travel, it must pass through the path of the tube, so that the air velocity at the venturi is increased and suction is created.

Usually the fuel discharge jet is located at the point where suction is maximum. This is therefore positioned just below the throat of the venturi. The fuel spray from the fuel discharge jet and air are mixed at this point on the throat and a combustible mixture is formed. The maximum amount of fuel is atomized and some vaporizes. Due to the increased air velocity at the throat, fuel vaporization becomes easier.

II. LITERATURE SURVEY

P.Rajitha, Dr. k Subramanyan, kalapala Prasad [1] study that the flow inside the venturi was analyzed with two different fluids, it was found that the pressure at the throat of the venturi decreased with the increase of the opening of the throttle valve. Because when the opening of the throttle valve increases, the air flow through the firm increases. But as obtained from the analysis, the pressure at the throat also decreases as the opening of the throttle plate increases, so that the air flow from the float chamber into the throat increases.

Arvind.T, Swaminathan M.R [2] studies this redesigned carburetor body in which two throttle bodies replace the conventional throttle body. Analyzes of the modified model have shown that the design of the venturi provides a more symmetrical and organized flow downstream of the carburetor. This simple design change has the potential to improve the distribution of the mixture downstream of the carburetor without major changes in the design of the carburetor.

Kriti Gupta, Saumya Sharma [3] investigates that from this article, the amount of air entering the engine is controlled by the throttle valve. Rectangular, rhombus and triangular were considered and their models were designed for analysis. Taking into account the different conditions to which the throttle body is subjected, the different inlet and outlet boundary conditions were calculated in this work. The nature of the flow through the valve was analyzed and the different regions formed in the air flow field were investigated.

Shivkumar biradar, Ebinezar, Raj Reddy [4] study that from this article, CFD simulations are carried out to validate the FLUX analysis inside the gas carburetor of the producer. The results show a good understanding of the details of the flow and paved the way for optimization of the geometric design to achieve good mixing efficiency.

Ami A. Patel, [5] investigates that from this paper the Velocity speed line has a uniform aerodynamic shape by comparing the existing flat-plate throttle to the design of the aerodynamic throttle, the mixture of l The air-fuel is also uniform, reduces the unborn fuel ratio and increases the efficiency of the carburetor.

Jennifer S. Thompson, oubay Hassan, David cars well [6] studies that the use of premiers for the correct supply of the fuel mixture and the supply of the correct amount of excess air results in a reduction of the oxides of nitrogen (NO). Based on this, a goal-oriented optimization was undertaken which suggested minor modifications to the premixed geometry that will improve the completeness of the mixture between air and natural gas while achieving the correct fuel / oxidizer ratio for combustion cleaner.

Timothy A. Shedd, Diego A. Arias [7] study that the results of CFD simulations were used to understand the effect of different obstacles in the flow on the overall discharge coefficient and the static pressure at the end of the tube. fuel. This result indicated that an overall discharge coefficient can be used to correct mass flow, while a localized correction factor can be determined from three-dimensional CFD simulations to estimate the static pressure at locations of interest in the complex venturi.

Janusz Wojtkowiak, Czeslaw Oleskowicz [8] study that experimental and numerical studies of the flow characteristics of butterfly control valves, flow fields and pressure distributions have been performed.

M. Balaji, K. amal Satheesh [9] study that the formulated throttling parameters were calculated using flow equations and were modeled. The throttle body with a rectangular shaft profile showed better flow characteristics with minimal backflow and reduced turbulence downstream of the butterfly valve, thus being the best choice.

ChangChun Xu, HaengMuk Cho [10] study what makes the car comfortable and quiet, in order to completely burn air and fuel in the engine; the author can adjust the throttle to achieve this result. Therefore, in this article, the author can simulate the turbulence program to find the optimal installation of the throttle body to reduce noise and exhaust emissions.

III. Problem Statement

[1] As there are problem with engine efficiency and fuel economy of engines. Normal engine gives only 2025% efficiency .So increase in efficiency and fuel economy there should be some modification in system. To study the effects of varying Throttle position of carburetor in venturi nozzle jet of carburetor using CFD analysis.

[2] During Air fuel mixture will pass from venturi that time cavity of stream line flow will produced so definitely it will affect Fuel economy, so it will recover by design of carburetor.

IV. Objectives

[1] If to get Exact Air fuel mixture, to improve volumetric and thermal efficiency.

[2] For better fuel economy get throttle angle position for venturi.

[3] To avoid Cavity of stream line flow in venturi.

[4] Pressure Drop and velocity Discharge nozzle angle of the Venturi will be analyzed using Computational Fluid Dynamics.

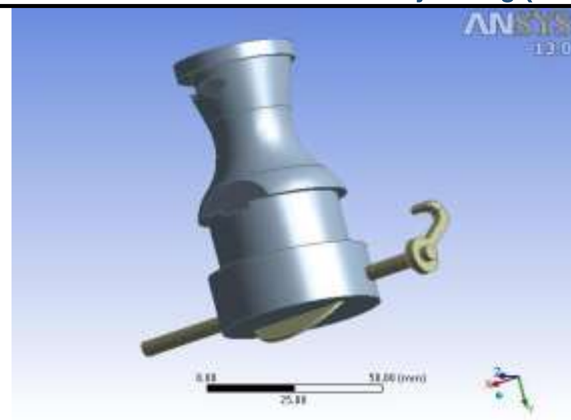
V. CARBURETOR MODEL

5.1 Specification of the Model Carburetor

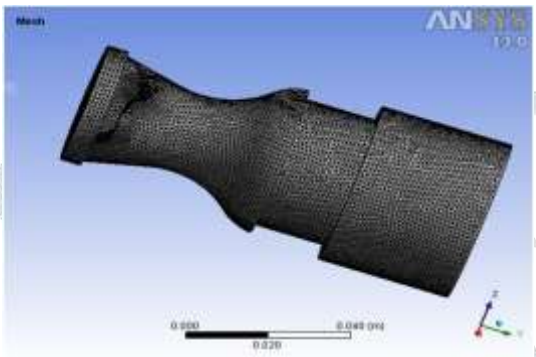
The model of the carburetor as drawn in the Solidwork software. Detail dimension of the carburetor inside volume i.e Flow path

Total length of carburetor = 100 mm
Inlet diameter = 35 mm
Throat diameter = 25 mm
Outlet diameter = 46 mm
Length of throat = 5 mm
Length of the inlet part = 51mm
Length of the outlet part = 51 mm
Nozzle inlet diameter = 1.5 mm

Actual model of carburetor



Cavity of carburetor



Meshing of cavity of carburetor

VI. THEORETICAL AIR FUEL RATIO

For calculating the theoretical air fuel ratio we have three sections
Section 1-1 at inlet
Section 2-2 near the throttle i.e. on the right side of throttle towards throat &
Section 3-3 at throat

For 10 degree throttle position:-

We know that at 1-1 Pressure is equal to atmospheric pressure i.e. P_1=1.013e5 Pa & we get pressure at 2-2 from simulation i.e. P_2=101402 Pa

Applying the steady flow energy equation to sections 1-1 & 2-2 per unit mass flow of air:

$$q - w = (h_2 - h_1) + \frac{1}{2}\left(C_2^2 - C_1^2\right)$$

Here, q and w are the heat and work transfers from the entrance to the section 2-2 and h and C stand for enthalpy and velocity respectively. If we assume reversible adiabatic conditions, and there is no work transfer, q=0, w=0, and if approach velocity C1≈0 we get

$$C_2 = \sqrt{2(h_1 - h_2)}$$

Assuming air to be a perfect gas, we get

$$C_2 = \sqrt{2c_p(T_1 - T_2)} \quad \text{……………………………….(1)}$$

But the process from inlet to throttle is isenthalpic therefore we get

$(P1/P2) = (\rho 1/\rho 2)^n$…………………………………………………………….(2)

We also know that

$\rho_1 = \frac{P1}{RT1}$

$\rho_2 = \frac{P2}{RT2}$………………………………………………………………………………….(A)

Where T_1=Temp at inlet= 300K

T_2=Temp neat the throttle R = 287 J/kgK

n=1.1

Put this in equation 2, We get

T2=300.1K

Put T1 & T2 in equation 1we get

C2=14.72 m/s From equation A we get

ρ_1=1.1765Kg/m^3

Therefore theoretical mass flow rate of air is $m_a = \rho_2 a_2 C_2$

Where a_2 is area at throttle a_2=0.001703 m^2

m_a=0.02953

But we know that

$\dot{m}_a = 901.8 A_3 \ldots$

Where

A_3=area of throat

$A_3 = \frac{\pi d_3^2}{4}$

d_3= 24.40mm= 0.02440m= Diameter of throat

$A_3 = \frac{\pi d_3^2}{4} = (3.1416 * 0.02440^2/4)$

A_3= 0.00046759 m^2

Therefore

$$\dot{m}_a = 901.8 A_3 \sqrt{\left(\frac{p_3}{p_1}\right)^{1.43} - \left(\frac{p_3}{p_1}\right)^{1.71}}$$

0.02953=901.8*0.00046759* $\sqrt{\left(\frac{p_3}{p_1}\right)^{1.43} - \left(\frac{p_3}{p_1}\right)^{1.71}}$

In this equation P_3 is unknown which is pressure at throat

Therefore by solving this we get

P_3=0.65e5Pa

Therefore mass flow rate of fuel is calculated from this pressure value at throat

$$\dot{m}_f = \rho_f A_f C_f$$

$$= A_f\sqrt{2\rho_f(p_1 - p_3 - \rho_f gz)}$$

where A_f is the exit area of the fuel jet in m^2 & ρ_f is the density of the fuel in kg/m^3, C_f is the velocity of the fuel at the exit of the fuel nozzle (fuel jet), and z is the depth of the jet exit below the level of fuel in the float bowl. This quantity must always be above zero otherwise fuel will flow out of the jet at all times. The value of z is usually of the order of 10 mm d_F = Nozzle exit diameter = 1.5mm= 0.015 m ρ_f= 719.7Kg/m^3

P_1=1.01325e5 Pa P_3=0.65e5 Pa

$A_f = \frac{\pi d_f^2}{4}$= 1.7672e-4 m^2

$$\dot{m}_f = \rho_f A_f C_f$$

$$= A_f\sqrt{2\rho_f(p_1 - p_3 - \rho_f gz)}$$

$\dot{m}_f$= 1.7672e-6*$\sqrt{2 * 719.7 * (1.013e5 - 0.85e5 - 719.7 * 9.81 * 0.01)}$

$\dot{m}_f$ = 0.003498

Air fuel ratio= m_a / m_f

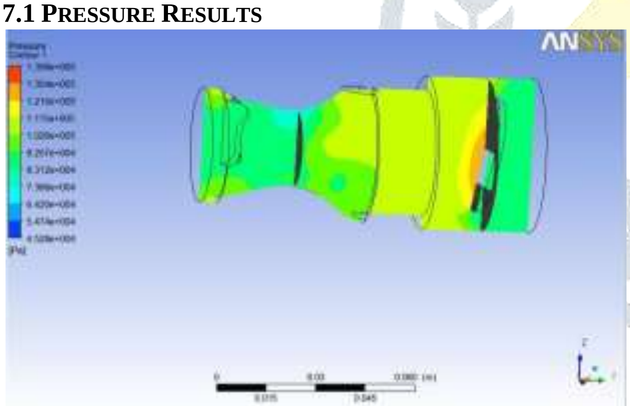
= 0.02953/0.003498

A/F= 8.44

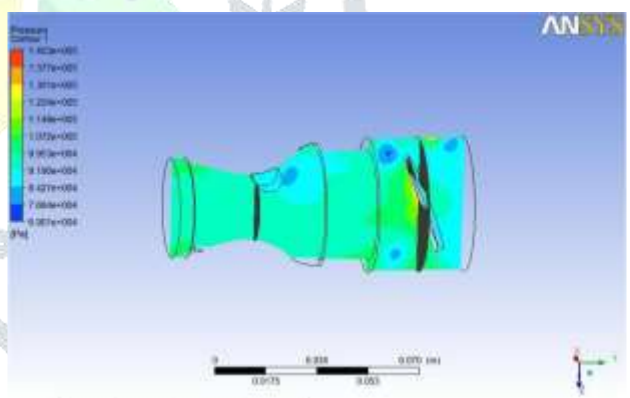
Same procedure we will follow for 20, 30 and 40 degree throttle position.

VII. RESULTS AND DISCUSSIONS

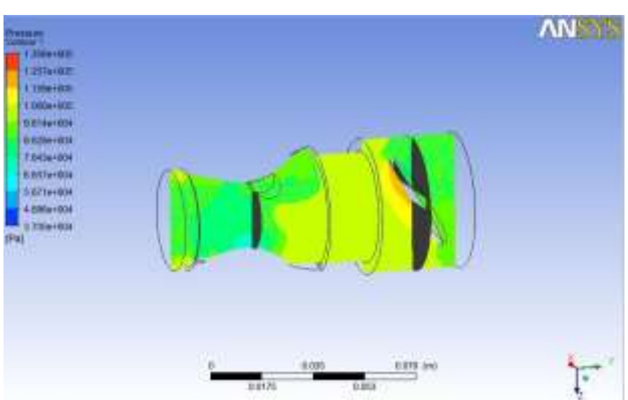
7.1 PRESSURE RESULTS



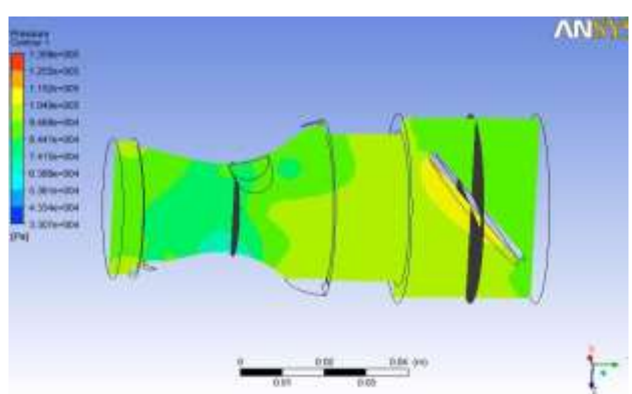
Pressure at 10-degree throttle



Pressure at 20-degree throttle

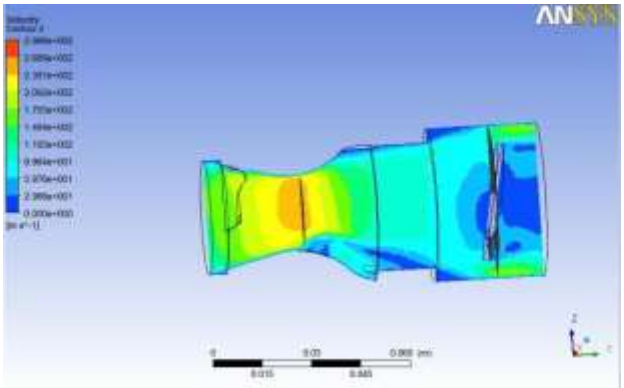


Pressure at 30-degree throttle

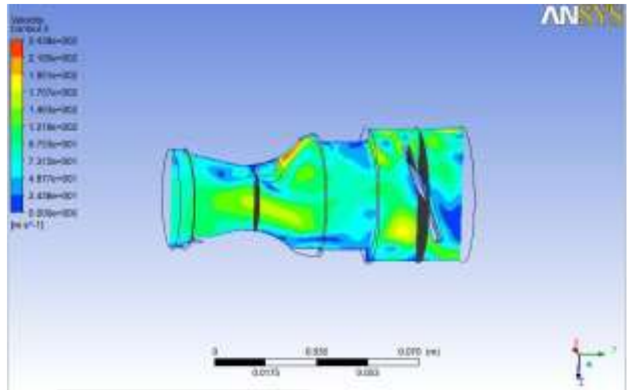


Pressure at 40-degree throttle

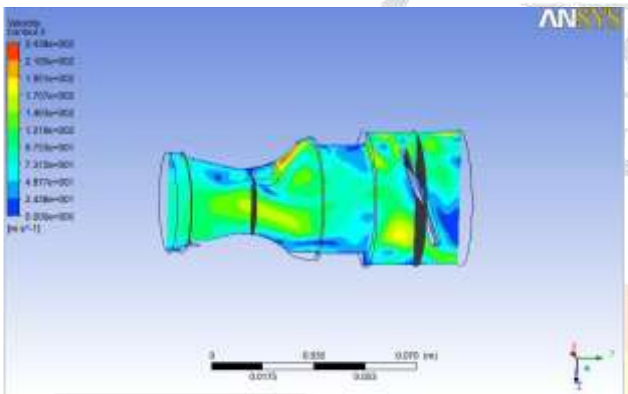
7.2 Velocity Contour



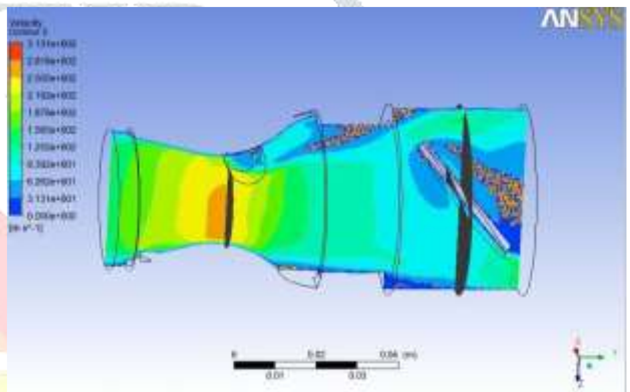
Velocity at 10 degree throttle



Velocity at 20 degree throttle

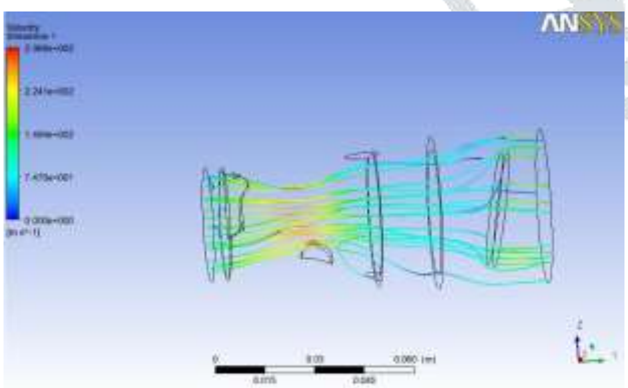


Velocity at 30 degree throttle

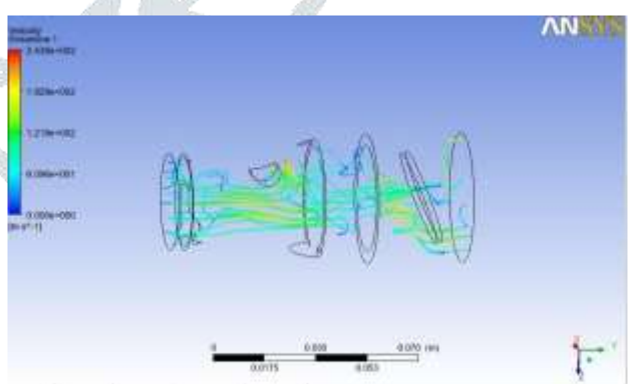


Velocity at 40 degree throttle

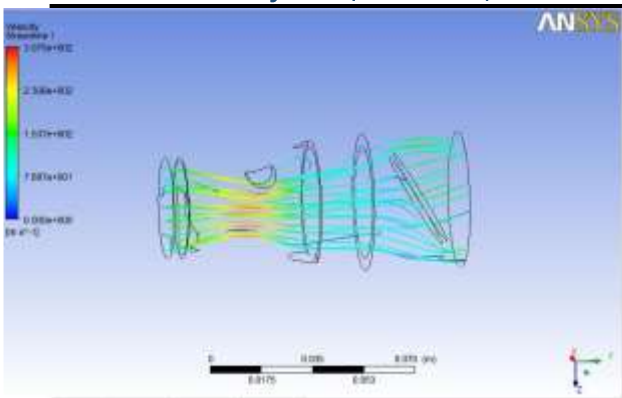
7.3 Streamline Flow



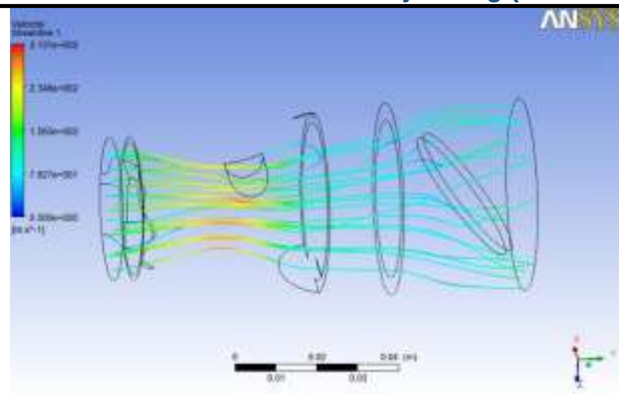
Streamline at 10-degree throttle



Streamline at 20-degree throttle



Streamline at 30-degree throttle



Streamline at 40-degree throttle

7.4 Result Table

Throttle angle	10^0	20^0	30^0	40^0
Inlet pressure (atmospheric) (P1)In Pa	101325	101325	101325	101325
Pressure at throttle valve(P2)in Pa	101402	96240.5	97943.2	95153.2
Velocity at throttle valve(v2)in m/s	97.16	97.2392	80.3882	77.3975
Pressure at throat (P3)in Pa	82199	95168.1	76912.6	73391.9
Velocity at throat(v3)in m/s	235.05	98.4075	239.539	242.629

Theorotical pressure at throat(P3')in Pa	65000	75000	85000	85000

VIII. CONCLUSION

From the above analysis, the conclusions obtained are

1. When the flow inside the carburetor was analyzed for different throttle opening angles, it was found that the pressure at the venturi neck decreased with increasing throttle opening. Because as the throttle opening increases, the air flow through the carburetor increases but the fuel flow remains constant. Thus, the mixture becomes leaner. But as obtained from the above throat pressure analysis, the throat also decreases with increasing throttle plate opening, so the flow of fuel from the float chamber in the throat increases and therefore the quality of the mixture tends to remain constant.

2. When analyzing the angle of the fuel discharge nozzle of 30 degrees, it was observed that the pressure distribution inside the carburetor body is quite even, which leads to better atomization and vaporization of the fuel inside the body of the carburetor. But in other cases, such as when the angle of the fuel discharge nozzle was 10, 20, 30 or 40 degrees, the pressure distribution is quite non-uniform inside the carburetor body. It is therefore concluded that for gasoline engines the optimum angle of the fuel discharge nozzle is 30 degree.

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