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CFD Analysis for Different Fuel Nozzle Diameter of Carburetor with different Throttle Positions

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Abstract: *Design of air intake system (i.e. carburetor) is very important in SI engine in order to improve fuel economy and engine efficiency. Primary function of carburetor is to evenly distribute combustion mixture. (i.e. air-fuel mixture) and supply it at the right time. Design of carburetor affects the distribution of air-fuel mixture. Proper design of carburetor elements alone ensures the supply of desired composition of the mixture under different operating conditions of the engine by CFD analysis.*
Key words—*Air-fuel ratio, Carburetor, CFD*

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I. INTRODUCTION

Engine transforms one form of energy into another form. Heat engine is a device that transforms the chemical energy contained in a fuel to another form of energy and utilizes that energy for some useful work. In Internal combustion engine combustion of the working fluid takes place inside the engine e.g. gasoline or diesel engine. SI engines generally use volatile liquids. The air fuel mixture preparation is done outside the engine cylinder. The process of forming a combustible fuel air mixture by mixing the right amount of fuel with air before admission to the cylinder of the engine is called carburetion and the device is known as a carburetor. The fuel droplets that remain in suspension also continue to evaporate and mix with air during suction and compression processes also. Carburetion provide required amount of Air-fuel mixture at required time. The flow through these internal passages may be quite complex and passages is short length.

Modern passenger vehicles with gasoline engines are provided with different carburetor for fuel air mixture supply. There is high fuel consumption because of many factors. One of the important factors that affect the fuel consumption is that design of carburetor. The venturi of the carburetor is important that provides a necessary pressure drop in the carburetor device. A wide range of air/fuel ratios can be obtained under different operating conditions by the vaporizing carburetor. For the same power output, an engine can operate with leaner mixtures by using the vaporizing carburetor as opposed to a conventional carburetor, so the fuel consumption is considerably reduced, and the amount of exhaust emissions are reduced.

The simple carburetor provides the required A/F ratio only at a certain opening of the throttle. As the throttle opening varies,

the air flow varies and a pressure differential is created between the float chamber and the venturi throat. Now as the pressure decreases the density of the air decreases but flow increases. So a rich mixture is produced because the density of the fuel remains unchanged.

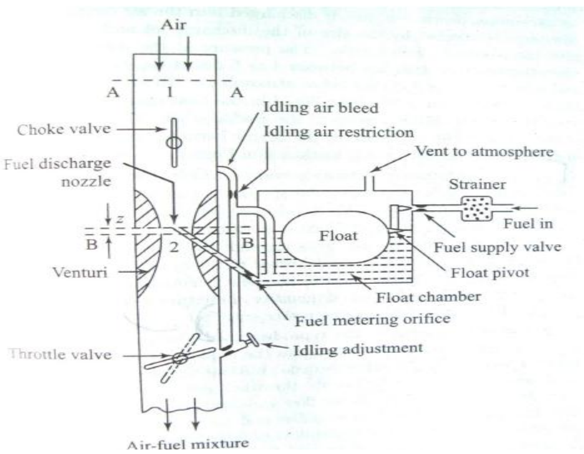


Fig 1 Simple Carburetor

II. Literature Review

Kirti Gupta analyzed the variation in pressure and velocity for diff cross section of throttle valve shaft in spark ignition engine. Models of different shape i.e circular, oval, square, hexagonal, rectangular, rhombus and triangular were been considered and designed for analysis. Study of flow pattern formed in CFD shows that hexagonal cross section is the most desirable for throttle shaft among all other analyzed shafts. Hexagonal section allows minimal velocity drop between inlet and outlet and enable most efficient flow. Due to less wake region air flow is also better. From the above study we can say that hexagonal section can be employed for use in throttle bodies in automobile engine.

Shashwat sharma carried out CFD analysis for pressure drop and fuel discharge nozzle angle of the carburetor. Analysis gives the result that they increase the opening of throttle plate pressure at the throat decreases so the fuel flow from the float chamber into the throat increases and hence the quality of mixture remains constant. When they analyzed flow for fuel discharge angles 30°, 35°, 40°. For 30°angle pressure distribution is quite uniform so that we can say that there is proper atomization and vaporization of fuel inside the body. But for 35°, 40° pressure distribution is not uniform. So we can conclude that for proper air fuel mixture 30° is optimum fuel discharge angle.

Chan chun Xu compared the angle of throttle opening positions when air flow through the throttle valve for pressure and velocity distribution of 0, 30, 45, 60 and 90 degrees. Better angle for throttle opening position is 60°. For 60° air fuel mixture is uniform and can reduce the air flow noise into engine cylinder. Velocity and pressure distribution for other angles are not quite uniform. So we can conclude that 60° is optimum throttle valve angle for uniform pressure and velocity distribution.

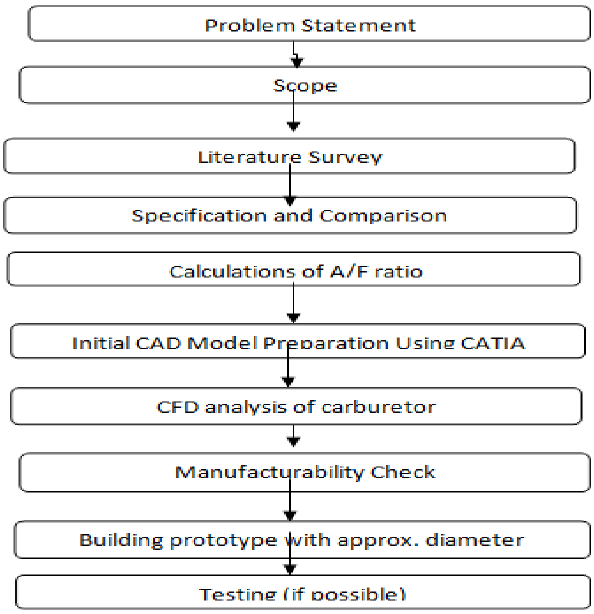
Nik Rosli Abdullah studied the effects of air intake pressure to fuel economy and exhaust emissions. The degree of opening of throttle plate influenced by the air intake pressure and venturi effects which draw fuel to the combustion chamber. This study encourages the vehicle users to ensure their vehicles air filter always in a clean and good condition. Clean and good condition of air filter will help to maintain higher intake pressure and it will help for complete combustion of fuel which eventually reduces hazardous exhaust emissions. From this we can conclude that as the air intake pressure increases the engine performance and fuel economy increases. Total combustion of fuel takes place and hazardous emissions are reduced because of the proper burning of fuel.

III. Problem Statement

As there are problem with engine efficiency and fuel economy of engines. Normal engine gives only 20-25% efficiency .So increase in efficiency and fuel economy there should be some modification in system.

1. To study the effects of varying diameter of carburetor nozzle jet of carburetor using CFD analysis.
2. Minimization of the cost by design modifications.

IV. Methodology



V. CARBURETOR MODEL

A. Specifications of Simple Carburetor

Sr No	Name of the part	Dimensions (mm)
1.	Inlet diameter	42
2.	Throat diameter	27
3.	Outlet diameter	37
4.	Length of the throat	5
5.	Length of the inlet section	51
6.	Length of the outlet section	51
7.	Total length of carburetor	122

Table 2 : Air Properties

Property	Value
Density	1.225 kg/m3
Specific Heat (Cp)	1006.43 J/kg-K
Viscosity	1.7894e-05 kg/m-s
Temperature	294 k
Pressure	1 atm
Density of Fuel	719.7 kg/m^3

VI. CALCULATIONS

The surrounding temperature was considered as 294 K i.e. 529.47 °R and pressure at inlet equal to the atmospheric pressure (101325 Pa i.e. 14.7psia).

A. Calculation of Inlet Velocity

Using the Continuity Equation, the inlet velocity has been calculated as shown,

$$Vt = \frac{Vdisp * 4 * N/2}{Cd * D * D * \Pi} \quad (1)$$

where,

Vt = Velocity at inlet (m/s)

V_{disp} = Displacement volume of engine (litre) = 0.6 litre

N = Maximum Engine Speed (rpm) = 5500 rpm

Cd = Coefficient of Discharge = 0.9

D = Diameter at inlet (m) = 0.038 m

Substituting these values in eq. (1), we obtain,

$$Vt = \frac{0.6/1000 * 4 * 9000/2 * 60}{C0.9 * 0.038 * 0.038 * \Pi}$$

= 40.32 m/s

B. Calculation of Outlet Pressure

The pressure drop between inlet and outlet is governed by the type of valve used and its valve flow coefficient. For butterfly valve, the value of Cv is specified using the standard tables. The calculation of pressure difference is as shown,

$$\Delta P = \frac{T1 * Gg}{P1} * \left(\frac{Q}{1260 * Cv * \Gamma}\right) * \left(\frac{Q}{1260 * Cv * \Gamma}\right) \quad (2) \qquad (29)$$

where,

ΔP = Pressure difference between inlet and outlet (psi)

T1 = Absolute upstream temperature (ºR) = 529.47 ºR

Gg = (Molecular weight of gas)/(Molecular weight of air) = 1

P1 = Upstream absolute static pressure (psia) = 14.7 psia

P2 = Downstream absolute static pressure (psia)

Q = Volumetric flow rate (standard cubic feet per hour)

Γ = Gas constant = 1.4

Cv = Valve flow coefficient (for 38mm diameter butterfly valve

For the calculation of volumetric flow rate, Q,

Q=Area of cross section*Velocity at inlet

=163.312 m^3/hr

=5767.308scfh (30)

Substituting the values in eq (2), we get

ΔP =0.09967 psi

Outlet pressure is calculated as follows

$$P_2 = P_1 - \Delta P \qquad (31)$$

Therefore,
P_2=14.7-0.09967=14.5903 psi =100596.57 Pa
Calculation of mass flow rate:

$$\dot{m}a = 0.1562Cda\frac{A2P1}{\sqrt{T1}}\emptyset$$

Where,

$$\emptyset = \sqrt{\left(\frac{P2}{P1}\right)^{1.43} - \left(\frac{P2}{P1}\right)^{1.71}}$$

=0.0446928

$$\dot{m}a = 0.95 * 0.1562\frac{\pi * (0.038)^2 * 101325}{4 * \sqrt{294}} * \emptyset$$

=0.0377028 kg/sec

$$\dot{m}f = Cdf * Af\sqrt{2\rho f(P1 - P2 - \rho fgz)}$$

=3.0570082*10^{-3}kg/sec
A/F ratio:
A/F=$\frac{\dot{m}a}{\dot{m}f}$

=12.32

Table 3: A/F ratio for various diameter

Sr No	Diameter (in mm)	A/F Ratio (Gasoline)
1.	1.80	15.216
2.	1.90	13.65
3.	2	12.32
4.	2.1	11.1817
	2.2	10.1883

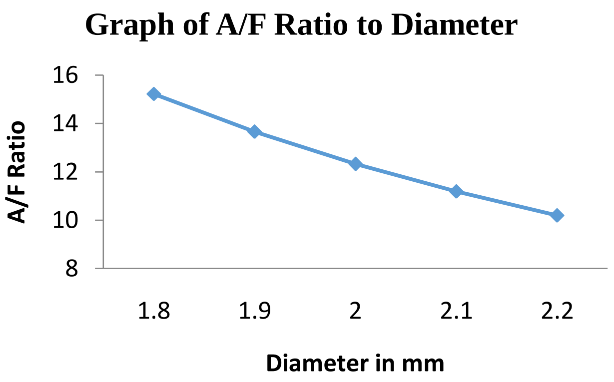
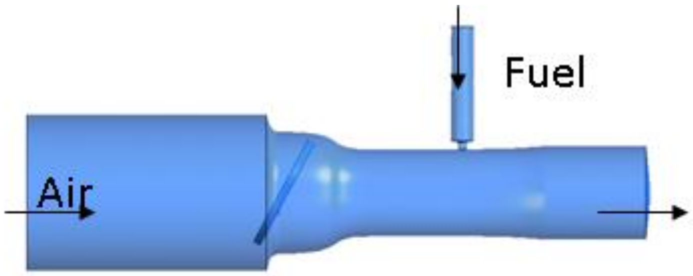


Fig 2 graph of air fuel ratio to diameter

Model Of Carburetor:



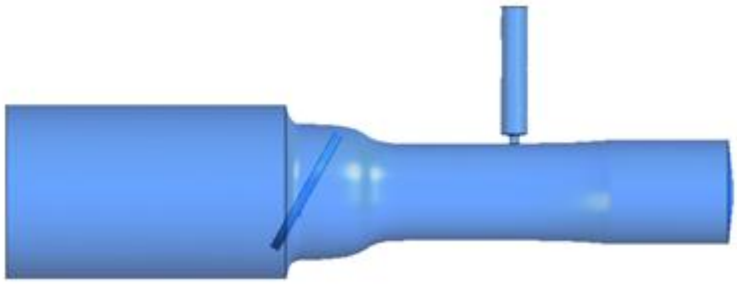


Fig 3 CAD model of carburetor

Meshed geometry

CFD stands for computational fluid dynamics. In this project a simple carburetor as shown in fig 3 was taken and its various dimensions were measured. Then according to the measured dimensions a CAD structure of the carburetor was drawn with the help of CATIA software. Then the structure was exported as the .stp file and was analyzed with proper boundary conditions using the software FLUENT and the results of this analysis were studied.

Boundary Conditions

Inlet Pressure: 14.7 psi

Outlet Pressure : 14.5903 psi

Number of Iterations : 1000

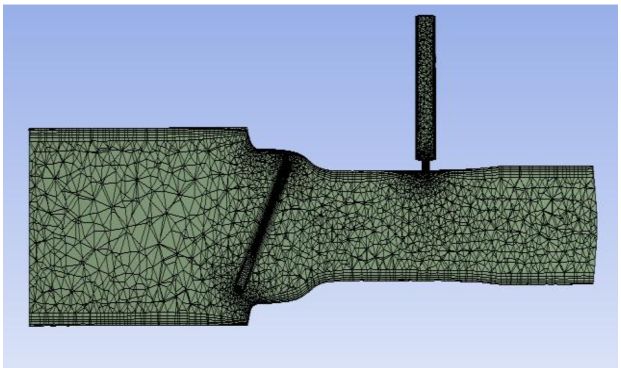


Fig 3 meshed model of carburetor

VII. RESULTS:

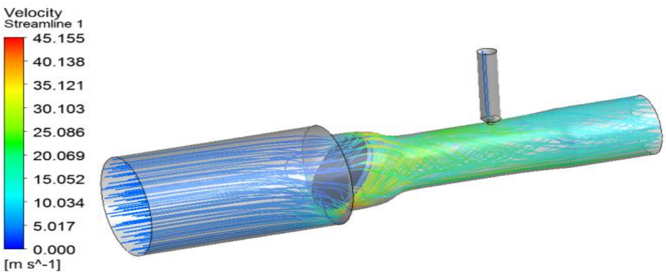


Fig 4 Velocity distribution on streamlines

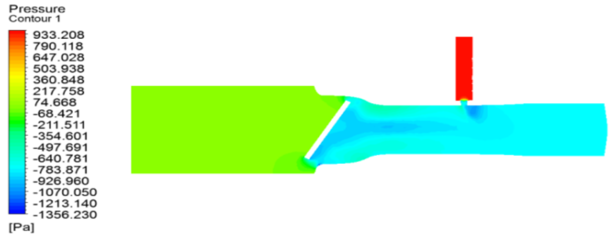


Fig 5 Pressure distribution

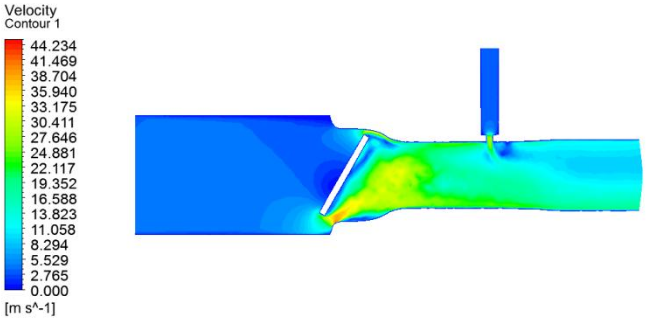


Fig 6 Velocity distribution

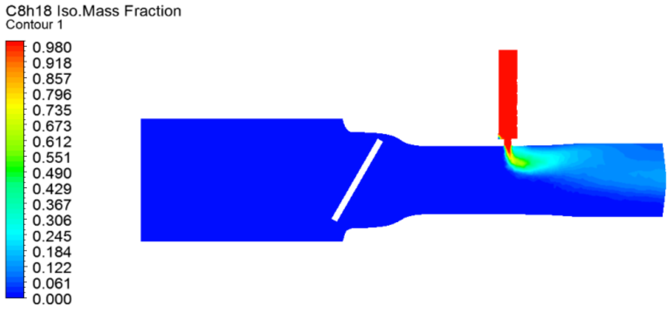


Fig 7 Contour of mass fraction for angle 30°

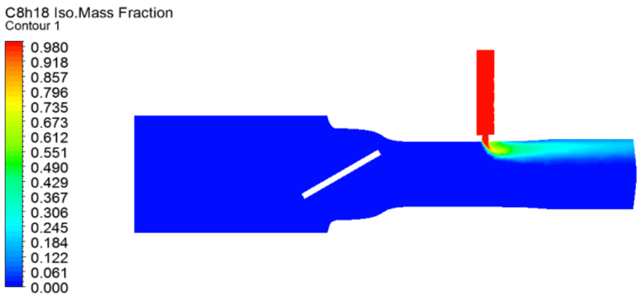


Fig 8 Mass fraction contour for angle 60°

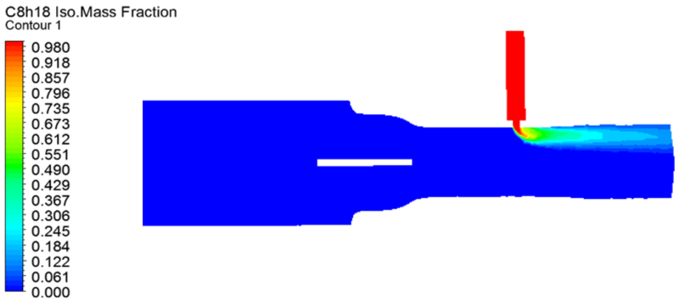
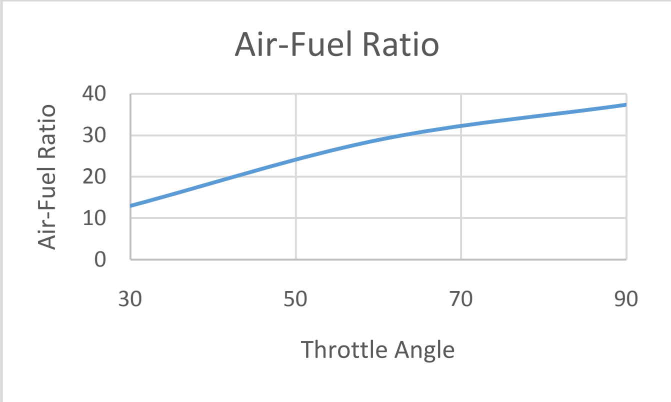


Fig 9 Mass fraction contour for angle 90°

Table 4

Throttle angle	Air-Fuel Ratio
30	13.016
60	28.915
90	37.384



VIII. CONCLUSION

In SI engine Carburetor plays an important role as it forms combustible air-fuel mixture by mixing the proper amount of fuel with air before admission to engine cylinder. Carburetor provides pressure drop with venturi shape of throttle valve.

When we calculate air fuel ratio as the diameter of fuel nozzle increase its air-fuel ratio decreases and when fuel nozzle angle decreases air-fuel ratio increases.

From the CFD analysis, as we increase the throttle angle from 30° to 90° Air-fuel ratio increases. It is minimum for angle 30°. For 30° Velocity and Pressure contours also plotted and uniform velocity and pressure distribution we get.

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