CFD Analysis Of Flow Through Venturi In A Carburetor

Ganesh.R, Durairaj.S
P.G (Student), (Assistant Professor)
Department Of Mechanical Engineering
A.K.T Memorial College Of Engineering And Technology
Kallakurichi

Abstract-Modern passenger vehicles with gasoline engines are provided with different compensating devices for fuel air mixture supply. Even then 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. Since different SI engine alternative fuels such as LPG, CNG are used in the present day vehicles to reduce the pollution and fuel consumption. Still for a better economy and uniform fuel air supply there is a need to design the carburetor with an effective analytical tool or software. In this work three parameters namely pressure drop and fuel discharge nozzle angle of the carburetor will be analyzed usingcomputational fluid dynamics. For this analysis CFD will be done using 2 softwares namely GAMBIT and FLUENT. The results obtained from the softwares will be analyzed for optimum design of a carburetor.

Keywords: Orifice, Venturi, Fluent analysis

1) INTRODUCTION

Engine is a device that transforms one form of energy into another form. Heat energy 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. 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.

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

Suction: Suction strokes starts when the piston is at the top dead centre. At this time the intake valve is open whereas the exhaust valve is closed. When the piston moves towards the bottom dead centre, suction is created and fuel-air mixture is drawn into the cylinder.

Compression: During the return of the piston from the bottom dead centre towards the top dead centre, the charge sucked during the intake stroke gets compressed. During this stroke both valves are in open condition. At the end the mixture is ignited with the help of a spark plug. Due to the ignition the chemical energy of the fuel is converted into heat energy and the temperature rises to about 2000^0C.

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

Exhaust: During this stroke the inlet valve remains in closed position whereas the exhaust valve remains open. The piston moves from bottom dead centre to the top dead centre and sweeps the burnt gases out of the cylinder

More than a century of carburetor development produced a device with a very complex set of internal passages designed to deliver the correct air-fuel mixture according to speed and load. This goal is achieved through several complex processes: flows through passages of short length and complex geometry; flows that transition from laminar to turbulent; high frequency pulsating flow; two-phase flow of various forms, i.e., bubbles, sprays and thin liquid films and flows with changing fuel and air properties due to rapid changes in temperature and pressure.

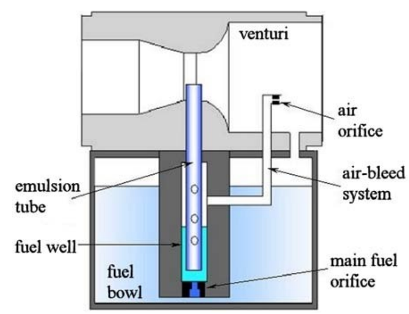


Fig.No:1Main parts of a typical carburetor used in small engines

Fig shows the main circuit found in a typical small engine carburetor. The acceleration of the air flow across the venturi creates a low pressure region at the venturi throat. This low pressure drives the fuel flow from a constant-level reservoir, known as a fuel bowl, to the venturi throat. On its path, fuel travels through a small orifice (main fuel orifice), whose function is to restrict its flow. Then, fuel goes into the emulsion tube, where it can mix with air coming from an airbleed system.

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

2) OBJECTIVE AND SCOPE OF PRESENT WORK

When the flow inside the carburetor was analyzed for different angles of throttle plate opening, 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 carburetor increases but the fuel flow remains constant. So the mixture becomes leaner. 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 fuel from the float chamber into the throat increases and hence the quality of the mixture tends to remain constant.

A) ACRONYMS

l	span
c	chord length (m)
α	angle of attack
D	Drag Force
L	Lift Force
M	Moment
$U\alpha$	Free Stream Velocity
ρ	Air density
μ	Dynamic viscosity (Ns/m^2)
$p\alpha$	Free stream pressure (Pa)
p	local pressure (Pa)
Re	Reynolds no ($\rho U\alpha c/\mu$)
C_p	Pressure coefficient ($(p-p\alpha)/(0.5\rho\mu U\alpha^2)$)
C_l	lift coefficient ($L/(0.5\rho U\alpha^2 C_l)$)
C_d	drag coefficient ($D/(0.5\rho U\alpha^2 C_d)$)

B) INTRODUCTION

SI engines generally use volatile liquids. The preparation of the fuel-air mixture is done outside the engine cylinder. The fuel droplets that remain in suspension also continue to evaporate and mix with air during suction and compression processes also. So carburetion is required to provide a combustible mixture of fuel and air in required quantity and quality

C) Definition of Carburetion

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 doing this job is called carburetor.

D) Factors Affecting Carburetion

The various factors affecting the process of carburetion are

1. Engine speed
2. Vaporization characteristics of the fuel
3. Temperature of incoming air
4. Design of the carburetor

3) LITERATURE REVIEW

Diego Alejandro Arias (1)studied and conducted an experiment to validate the steady statemodel of a carburetor by measuring the fuel and air flows in a commercial (Nikki) carburetor. He used a flow-amplifier to create a low pressure zone downstream the carburetor. He compared the results obtained from the experiment and prediction of the steady state model. The uncertainty in the measurement was found to be ±2 cm^3/min. These results indicated that the model was successful in showing the effects of the pressure drop and the metering elements in the emulsion tube.

Arias A Diego and Shedd A. Timothy (2)together worked to present a mathematical modelof network of complex flow which contained short metering orifices, compressible flow and two-phase flow in pipes of small diameter. They have done a detail review of pressure drop, effect of fuel well and dynamic flow in the previously developed models. The homogeneous two-phase flow model were found to be very poor in agreement with the empirical correlation derived from the experiments on small pipes.

Shashwat Sharma, Prateek Jain(3)Investigate that When analyzed for fuel discharge nozzle angle of 30,it was observed that the pressure distribution inside the body of the carburetor is quite uniform which leads to a better Atomization andvaporization of the fuel inside the carburetor body. But in other cases like where the fuel discharge nozzle angle was 35or 40 the pressure distribution is quite non-uniform inside the body of the carburetor. So it is concluded that for gasoline operated engine the optimum fuel discharge nozzle angle is 30

4) **PRINCIPLE OF CARBURETION**

Both air and gasoline are drawn into the cylinder due to suction pressure created by the downward movement of the piston. In the carburetor, the air passing into the combustion chamber picks up the fuel discharged by a fine orifice in a tube called the carburetor jet. The rate of discharge of the fuel depends on the pressure difference between the float chamber and the throat of the venturi of the carburetor and the area of the outlet of the tube.

In order that the fuel is strongly atomized the suction effect must be strong and the nozzle outlet must be comparatively small. To produce a strong suction, a restriction is generally provided in the pipe in the carburetor carrying air to the engine. This restriction is called throat. In this throat due to increase in the velocity of the air the pressure is decreased and suction is created.

A) THE SIMPLE CARBURETOR

It is the basic carburetor to describe the functions of other carburetors.The simple carburetor consists of the following basic parts.

- Float chamber
- Venturi
- Fuel discharge nozzle
- Metering orifice
- Choke
- Throttle valve

A constant level of fuel is maintained in the float chamber by means of a float and needle valve system. If the fuel level falls below required level then the float goes down and allows the fuel supply valve to open. Then the fuel flows into the float chamber. When the designed level is reached the float again closes the fuel supply valve and the supply of fuel is stopped

C) ALTERNATIVE FUELS

Now a days there is enormous increase in the number of vehicles and hence there is increase in demand of fuel. As after some days the quantity of petroleum and diesel will become almost scarce and most costly. So some countries are trying to develop new technologies to use the alternative fuels in the vehicles.

Another reason of using the alternative fuels in the IC engines is the raising issue of emission problems of gasoline and diesel operated vehicles.

One more reason is that a huge percentage of crude oil imported from other oil rich countries. So it affects the economy of a country. So a development in alternative fuel technology is much necessary.

The alternative fuel is divided into three major categories

- Solid fuels
- Liquid fuels
- Gaseous Fuels

Now a days solid fuels are almost obsolete for Internal Combustion engines.

Liquid fuels are best suited and they are preferred for IC engines because they are easy to store and they have a very good calorific value. The various liquid fuels are

1. Alcohol
2. Methanol
3. Ethanol
4. Reformulated gasoline

Water-gasoline mixture

D) ALCOHOL FOR SI ENGINES

Alcohols are most attractive and mostly used alternative fuels because they can be derived from both natural and manufactured sources. Methanol and ethanol are two widely used alcohols. There are certain advantages and disadvantages of alcohols and they are as follows

Advantages:

1. It is a high octane fuel having octane number of more than 100.
2. As compared to gasoline it produces less emission.
3. Burning of alcohols gives more amount of exhaust gases which leads to more power and high pressure in the expansion stroke.
4. Alcohols are having low sulphur content in the fuel.

Disadvantages:

1. Alcohols are having very less calorific value almost half of that of gasoline. So to produce same amount of power as that of gasoline, more than two times of the amount of gasoline is required.

E) ANASYS

You can use Workbench to perform coupled simulations using two or more systems (for example, ANSYS Mechanical (Transient or Static Structural) and ANSYS Fluent) using a System Coupling component system. As described in the separate System Coupling Guide, you can set up a one-way or two-way fluid-structure interaction (FSI) design analysis in Workbench by connecting a System Coupling component system to your Mechanical system and to your ANSYS Fluent fluid flow analysis system.The following is the list of supported coupling participants:

1. Fluent
2. Static Structural
3. Transient Structural
4. Steady-State Thermal
5. Transient Thermal
6. External Data

Connecting the Setup cell from an ANSYS Fluent analysis system to the Setup cell for the System Coupling component system signals the latter system that the Fluent solver will act asa co-simulation participant in a coupled analysis. Most of the coupling related settings for your analysis are made throughthe System**.** Coupling system's setup user interface. Once the coupling setup is complete, the coupled analysis is executed by updating the System coupling system's solution cell, rather than the same cell in the connected co-simulation participant systems.

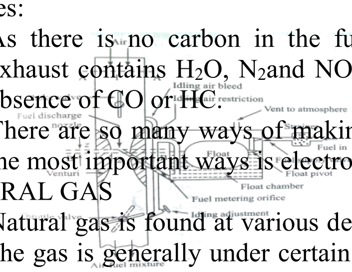
F)HYDROGEN

A number of automobile companies have built engines or prototypes which run with hydrogen.

There are certain advantages and disadvantages of using hydrogen in the engine.

Advantages:

1. As there is no carbon in the fuel so generally the exhaust contains H_2O, $N_2$and NO_2. There is complete absence of CO or HC.
2. There are so many ways of making hydrogen. One of the most important ways is electrolysis of water.



G) NATURAL GAS

Natural gas is found at various depths below the earth surface. The gas is generally under certain pressure and comes out naturally. If the gas has to be used in the vehicle then the entrained sand must be separated from the gas.

1. Its octane number is more than 100 and is around 110. This high value of octane number makes its flame speed higher and the engine can operate with a high compression ratio

H)**Liquefied Petroleum Gas (LPG)**

Propane and butane are the products of petroleum refinery process and are also obtained from oil and gas wells. Generally propane and butane are used separately for automobile use and sometimes a mixture of both of them is used.

Advantages:

1. The amount of carbon is less in LPG than that of petrol.

I) SPECIFICATION OF MODEL CARBURTOR

The model of the carburetor as drawn in the GAMBIT software is shown in the Fig.The various dimensions of the carburetor are mentioned below.

- Total length of carburetor = 122 mm
- Inlet diameter = 42 mm
- Throat diameter = 27 mm
- Outlet diameter = 37 mm
- Length of throat = 5 mm
- Length of the inlet part = 51mm
- Length of the outlet part = 51 mm
- Nozzle inlet diameter = 2 mm
- Angle of fuel discharge nozzle with the vertical axis of carburetor = ϴ

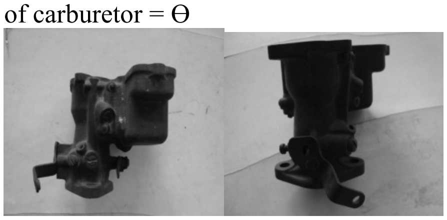


Fig.No:3 Model carburator

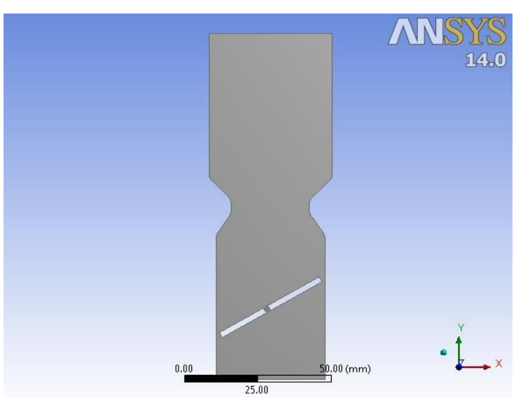


Fig.No:4 Simple Carburator(3d)

5) PROCEDURE

CFD stands for computational fluid dynamics. In this project a simple carburetor as shown in fig was taken and its various dimensions were measured. Then according to the measured dimensions a meshed structure of the carburetor 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.

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

The analysis was done for ϴ = 30^0, 35^0, 40^0, 45^0 where ϴ is the angle between the axis of the fuel discharge nozzle and the vertical axis of the body of the carburetor. Another analysis was done to calculate the throat pressure for different angles of the throttle plate.

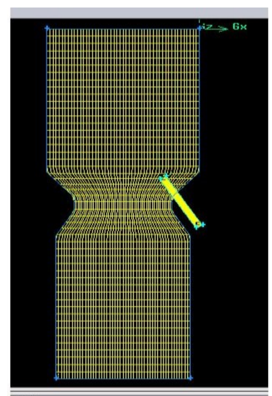


Fig.No:5 Meshed Carburator

B) RESULT AND DISCUSSION

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

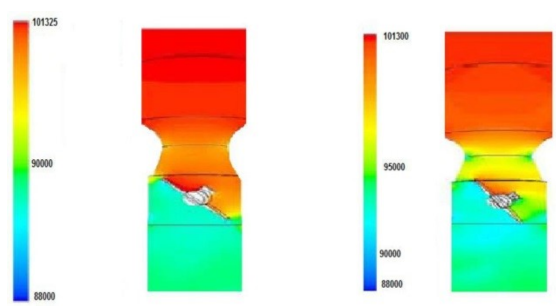


Fig.No:6 1) Static pressure at 45^0 throttle plate 2)Static pressure at 60^0 throttle plate

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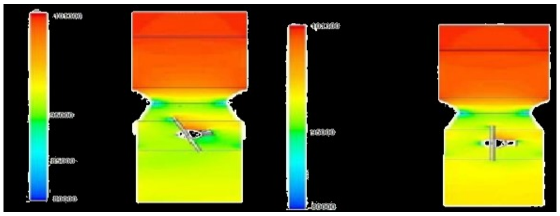


Fig.No:7 3)Static pressure at 75^0 throttle plate

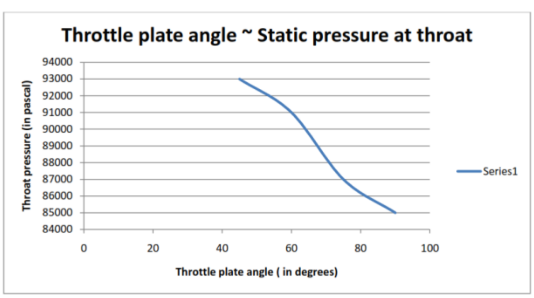
4) Static pressure at 90^0 throttle plateFig1shows the static pressure view for 45^0 throttle plate angle and fig shows the static pressure view for 60^0 throttle plate angle.
From fig it is clear that when the throttle plate is 45^0 open, there is less amount of air flow through the inlet valve and 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, when the throttle plate is 60^0 open, the mixture is slightly leaner than in case of 45^0 opened throttle plate condition. In this case the pressure at the throat of the venturi is found to be around 91000 Pascal.

Fig shows the static pressure view for 75^0 throttle plate angle and fig shows the static pressure view for 90^0 throttle plate condition.

From fig, when the throttle plate is 75^0 open, there is be more amount of air flow through the inlet of the carburetor. So the mixture will be leaner. In this case the pressure at the throat is found to be 87000 Pascal.

From fig, when the throttle plate is 90^0 open, there will be maximum amount of air flow through the inlet of the carburetor but the fuel flow remains same so the mixture will be leaned in this case. 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.



Graph.No:1 Graph showing variation of throat pressure with throttle plate opening

- Density of gasoline = ρ = 737 kg/m^3
- Acceleration due to gravity = g = 9.8 m/s^2
- Difference between the height of tip of fuel discharge nozzle and the
- float chamber = h= 8mm
- So the pressure at the inlet of fuel discharge nozzle =
- P = ρgh = 737 * 9.8*(.008) = 147780.8 Pascal

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

C) VELOCITY COUNTERS

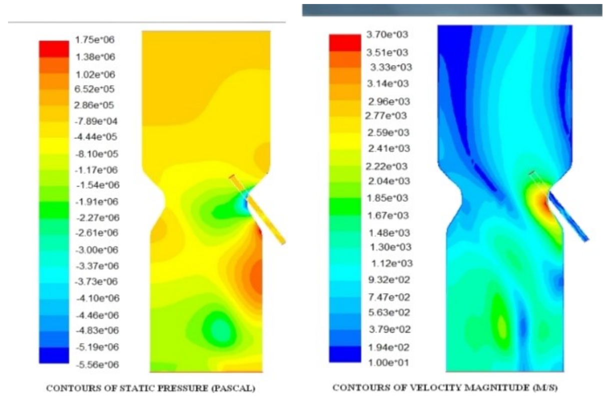


Fig.No:8 Static Pressure at 30^0

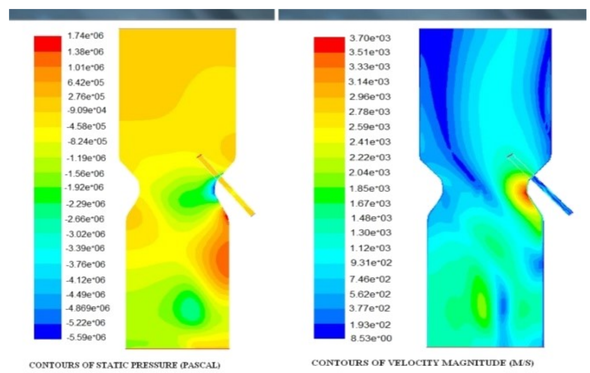


Fig.No:9Static Pressure 35^0

shows the static pressure contour for fuel discharge nozzle angle of 30^0 and Figshows 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 .whereas the pressure is the minimum at the venturi of the carburetor as shown in fig

shows a uniform distribution of pressure and fig shows that the velocity also uniformly increases from the inlet of the carburetor towards the throat. Since there is uniform distribution of pressure throughout the body of the carburetor, in this case the fuel will be easily atomized and will also be properly vaporized.

Fig shows the static pressure contour for fuel discharge nozzle angle of 35^0 and Fig shows the velocity contour for fuel discharge nozzle angle of 35^0. It is clear from both the figures that the velocity is maximum at the throat of the venturi as shown in fig 6.11 whereas the pressure is the minimum at the venturi of the carburetor as shown in fig 6.12.

Fig shows that the pressure is not distributed uniformly throughout the body of the carburetor and the distribution is also same in case of velocity as shown in fig 6.12. So, there will not be proper atomization and vaporization of fuel inside the body of the carburetor.

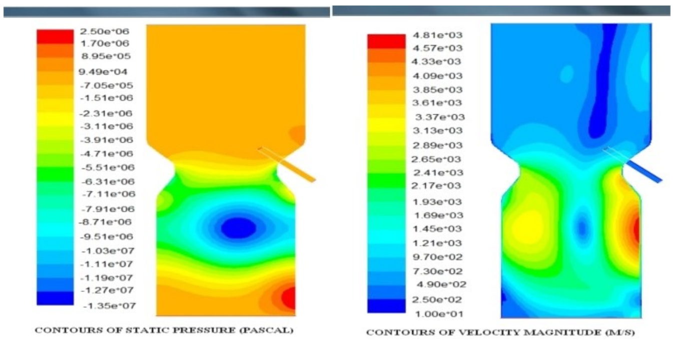


Fig.No:10 Static Pressure 40^0

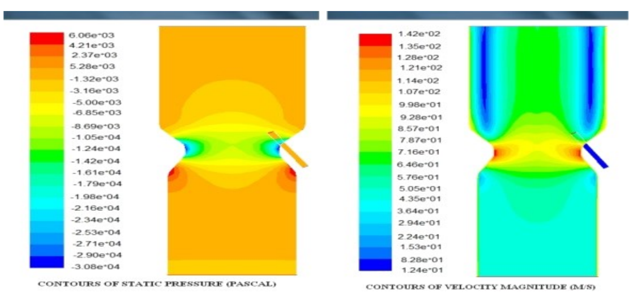


Fig.No:11 Static Pressure45^0

shows the static pressure contour for fuel discharge nozzle angle of 40^0 and Fig 6.14 shows the velocity contour for fuel discharge nozzle angle of 40^0. It is clear from both the figures that the velocity is maximum at the throat of the venturi as shown in fig whereas the pressure is the minimum at the venturi of the carburetor as shown in fig .

Fig shows that the pressure is not distributed uniformly throughout the body of the carburetor and the distribution is also same in case of velocity as shown in fig . So, there will not be proper atomization and vaporization of fuel inside the body of the carburetor.

Fig shows the static pressure contour for fuel discharge nozzle angle of 45^0 and Fig 6.16 shows the velocity contour for fuel discharge nozzle angle of 45^0. It is clear from both the figures that the velocity is maximum at the throat of the venturi as shown in fig whereas the pressure is the minimum at the venturi of the carburetor as shown in fig 6.16.

Fig shows that the pressure is not distributed uniformly throughout the body of the carburetor and the distribution is also same in case of velocity as shown in fig . So, there will not be proper atomization and vaporization of fuel inside the body of the carburetor.

6) CONCLUSIONS

From the above analysis the conclusions obtained are,

When the flow inside the carburetor was analyzed for different angles of throttle plate opening, 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 carburetor increases but the fuel flow remains constant. So the mixture becomes leaner. 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 fuel from the float chamber into the throat increases and hence the quality of the mixture tends to remain constant.

When analyzed for fuel discharge nozzle angle of 30^0, it was observed that the pressure distribution inside the body of the carburetor is quite uniform which leads to a better atomization and vaporization of the fuel inside the carburetor body. But in other cases like where the fuel discharge nozzle angle was 35^0, 40^0 or 45^0, the pressure distribution is quite non-uniform inside the body of the carburetor. So it is concluded that for gasoline operated engine the optimum fuel discharge nozzle angle is 30^0.

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