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INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

“CFD ANALYSIS AND PARAMETRIC OPTIMIZATION OF FLOW THROUGH A CARBURETOR VENTURI”

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ABSTRACT

A carburetor is an important component of a gasoline-operated internal combustion engine that prepares and supplies the required air–fuel mixture to the engine. The flow characteristics inside the carburetor strongly depend on its venturi geometry, throttle plate opening, and fuel discharge nozzle configuration. In the present study, Computational Fluid Dynamics (CFD) has been used to investigate and optimize the flow characteristics through a carburetor venturi. A three-dimensional model of the carburetor was developed according to the selected geometric dimensions, and numerical analysis was carried out to determine the pressure and velocity distributions inside the carburetor. The effect of different throttle plate opening angles was investigated at 45°, 60°, 75°, and 90°. The results showed that the static pressure at the venturi throat decreased with an increase in throttle opening. The throat pressure decreased from approximately 93000 Pa at 45° opening to approximately 85000 Pa at 90° opening. The reduction in throat pressure resulted in an increased pressure difference between the inlet and throat regions, which provides the driving force for fuel discharge from the float chamber through the fuel nozzle. The study also investigated the effect of fuel discharge nozzle orientation at angles of 30°, 35°, 40°, and 45° with respect to the vertical axis of the carburetor body. The CFD results indicated that the 30° nozzle configuration produced comparatively smooth and uniform pressure and velocity distributions inside the carburetor. Higher nozzle angles resulted in comparatively greater flow disturbance and non-uniformity in the flow field. In all investigated cases, the maximum airflow velocity was observed near the venturi throat, while the minimum static pressure occurred in the throat region. The comparatively uniform flow characteristics obtained with the 30° nozzle configuration provide favourable conditions for fuel–air interaction and mixture formation. Based on the investigated geometrical configurations and operating conditions, the 30° fuel discharge nozzle angle was considered the most suitable configuration among the selected cases. The overall study demonstrates that CFD can be effectively used to evaluate carburetor flow behavior and to investigate the influence of throttle opening and fuel discharge nozzle geometry on pressure, velocity, and air fuel mixture formation.

Key Words: Carburetor Venturi, Flow Behaviour, Parametric Optimization, CFD Analysis, Air-Fuel Mixture, Pressure Distribution, Velocity Distribution, Throttle Opening, Venturi Geometry, Fuel Mixing, Turbulence, Engine Performance.

I. INTRODUCTION

Carburetors are important devices used in conventional spark ignition engines for preparing and supplying the required air-fuel mixture to the engine cylinder. The quality of the air-fuel mixture has a direct effect on combustion, engine power, fuel consumption, and exhaust emissions. A carburetor operates by using the pressure difference created by the flow of air through a specially designed passage. The Venturi is the most important part of this passage because it

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increases the air velocity and produces a reduction in static pressure. This pressure difference helps to draw fuel from the fuel nozzle into the incoming air stream. A carburetor Venturi generally consists of a converging section, throat, and diverging section. When air enters the converging portion, its flow area decreases and its velocity increases. According to the basic principles of fluid flow, the increase in velocity is associated with a reduction in static pressure. The minimum pressure and maximum velocity generally occur near the throat region. This low-pressure region provides the necessary pressure difference for drawing fuel through the nozzle. After passing through the throat, the air enters the diverging section where the velocity decreases and pressure partially recovers. The flow behaviour inside a carburetor Venturi is affected by several geometric and operating parameters. Important geometric parameters include inlet diameter, throat diameter, throat length, outlet dimensions, fuel nozzle diameter, and nozzle angle. Operating parameters such as throttle opening, inlet pressure, air velocity, fuel velocity, and engine operating condition also influence the internal flow field. Changes in these parameters can produce significant variations in pressure distribution, velocity distribution, turbulence, and fuel-air mixing. Therefore, proper selection of Venturi parameters is necessary for obtaining desirable flow characteristics. The throttle position has a significant influence on the flow through a carburetor. At different throttle openings, the effective flow area changes, which modifies the airflow rate and pressure distribution inside the carburetor. A higher throttle opening generally allows greater airflow through the Venturi and changes the pressure difference available for fuel induction. However, excessive or unsuitable flow conditions may increase turbulence and pressure losses. Therefore, the effect of throttle opening must be considered while analyzing and optimizing the Venturi flow. The fuel nozzle is another important component that affects the formation of the air-fuel mixture. The position, diameter, and angular orientation of the nozzle influence fuel discharge and its interaction with the incoming air. An unsuitable nozzle angle may result in non-uniform fuel distribution and poor mixing, whereas an appropriate configuration can improve the uniformity of the mixture. Hence, the combined effect of Venturi geometry and nozzle configuration needs to be investigated for achieving improved carburetor performance. Computational Fluid Dynamics (CFD) is an effective numerical technique for analyzing complex fluid-flow problems inside a carburetor Venturi. CFD can provide detailed information about pressure, velocity, turbulence, and flow patterns at different locations within the flow passage. It also allows different geometric and operating conditions to be investigated without manufacturing a separate physical model for every case. Therefore, CFD reduces experimental effort and provides useful information for understanding the influence of individual design parameters. In the present study, CFD analysis is used to investigate the flow behaviour through a carburetor Venturi under different operating and geometric conditions. The study considers different throttle opening angles and fuel nozzle angles to determine their effects on pressure and velocity distribution. The carburetor geometry is modelled and meshed, and the flow field is analyzed using CFD techniques. The obtained results are used to identify the flow characteristics and important regions within the Venturi passage. Parametric optimization is carried out to determine suitable combinations of design parameters for improving the flow characteristics of the carburetor Venturi. The study mainly focuses on pressure reduction at the throat, velocity distribution, and the influence of nozzle angle and throttle opening on the internal flow. The optimized parameters can help in obtaining better fuel induction and more uniform air-fuel mixing. The results of the study may provide useful guidance for the design and improvement of carburetor Venturi systems used in spark ignition engines.

II. PROBLEM IDENTIFICATION

The flow through a carburetor Venturi is influenced by several geometric and operating parameters, making it difficult to obtain optimum flow conditions under different engine operating conditions. The pressure and velocity inside the Venturi change with variations in throttle opening, Venturi dimensions, air velocity, and fuel nozzle configuration. Improper selection of these parameters can lead to undesirable flow characteristics and affect the quality of the air-fuel mixture. One of the major problems in carburetor Venturi design is the non-uniform distribution of pressure and velocity inside the flow passage. The converging section, throat, and diverging section must be properly designed to obtain smooth flow development. Improper geometry can result in excessive pressure losses, turbulence, and flow separation, which may reduce the effective performance of the Venturi. The throat region is particularly important because the maximum air velocity and minimum static pressure generally occur in this region. The throat diameter and throat length directly influence the pressure drop and airflow through the carburetor. If the throat dimensions are not properly selected, the pressure difference may be insufficient for effective fuel induction or may produce excessive flow restriction. The throttle opening is another important parameter affecting the flow characteristics of the carburetor.

Different throttle angles change the effective flow area and consequently alter the airflow rate, pressure distribution, and velocity distribution. Therefore, it is necessary to investigate the flow behaviour at different throttle opening conditions to determine suitable operating conditions. The fuel nozzle angle also affects the fuel discharge and mixing process. An unsuitable nozzle angle may produce non-uniform fuel distribution and poor interaction between fuel and air. This can result in an improper air-fuel mixture and may reduce combustion efficiency. Therefore, the effect of different nozzle angles needs to be investigated along with the throttle opening. Experimental investigation of the internal flow field of a carburetor is difficult because of its complex geometry and continuously changing flow conditions. Measurement of pressure and velocity at different internal locations may require special instruments and considerable experimental effort. CFD analysis provides an alternative approach for obtaining detailed information about the flow field and evaluating different design conditions. Hence, there is a need to systematically analyze the flow through a carburetor Venturi and investigate the effect of important geometric and operating parameters. In the present study, CFD analysis is used to examine different throttle opening angles and fuel nozzle angles. The results are evaluated mainly in terms of pressure and velocity distribution to identify suitable parameters for improving Venturi flow behaviour and air-fuel mixing. Parametric optimization can therefore provide a systematic approach for selecting appropriate carburetor Venturi configurations.

III. RESEARCH OBJECTIVE

The main objective of the present research work is to analyse and optimize the flow characteristics through a carburetor Venturi by investigating the effect of important geometric and operating parameters using Computational Fluid Dynamics (CFD) analysis. The study focuses on understanding the relationship between throttle opening, fuel nozzle angle, pressure distribution, velocity distribution, and flow behaviour inside the carburetor Venturi.

The specific objectives of the present research work are as follows:

1. To develop the CAD model and computational mesh of the carburetor Venturi with appropriate inlet, throat, outlet, throttle, and fuel nozzle geometry.
2. To perform CFD analysis of airflow through the carburetor Venturi and determine the pressure and velocity distribution at different sections of the flow passage.
3. To investigate the effect of different throttle opening angles on pressure, velocity, and overall flow behaviour inside the carburetor Venturi.
4. To analyse the effect of different fuel nozzle angles on flow characteristics and identify a suitable nozzle configuration for improved air-fuel mixing.
5. To compare the CFD results for different parametric conditions and identify suitable throttle opening and nozzle angle combinations for improved flow characteristics and carburetor performance.

IV. METHODOLOGY

The methodology of the present research work includes CAD modelling, mesh generation, application of boundary conditions, CFD simulation, parametric analysis, and evaluation of flow characteristics. The study is carried out to investigate the effect of throttle opening and fuel nozzle angle on pressure and velocity distribution inside the carburetor Venturi. Initially, the dimensions of a simple carburetor are measured and the important Venturi parameters are identified. The selected geometry consists of an inlet, converging section, throat, diverging section, outlet, throttle plate, and fuel nozzle. The main dimensions considered include a total length of 122 mm, inlet length of 42 mm, throat diameter of 27 mm, outlet length of 37 mm, and throat length of 5 mm. The CAD model of the carburetor Venturi is developed according to the selected dimensions. The throttle and fuel nozzle are incorporated into the model, and different configurations are prepared by varying the throttle opening and nozzle angle. The developed geometry is then prepared for CFD analysis. A suitable computational mesh is generated over the flow domain. The mesh is refined near the throat, throttle, fuel nozzle, and converging and diverging sections because these regions have significant changes in flow characteristics. Proper mesh quality is maintained to obtain reliable CFD results. Air is considered as the main flowing fluid and gasoline is considered as the fuel. The gasoline density is taken as approximately 737 kg/m^3 . The inlet condition is specified at approximately 1 atm pressure and normal temperature. Appropriate boundary conditions are applied at the inlet, outlet, walls, throttle, and fuel nozzle. CFD simulations are performed for different throttle opening angles of 45° , 60° , 75° , and 90° . Fuel nozzle angles of 30° , 35° , 40° , and 45° are also investigated. The

simulations are carried out to determine the pressure and velocity distribution inside the Venturi and to identify the effect of the selected parameters on flow behaviour. The obtained CFD results are compared for different configurations using pressure and velocity contours and numerical values. Particular attention is given to the throat region, where high velocity and low pressure are important for fuel induction. Finally, suitable throttle opening and nozzle angle parameters are identified based on the pressure distribution, velocity characteristics, and overall flow behaviour of the carburetor Venturi.

The various dimensions of the carburetor are mentioned below.

- Total Length of Carburetor (L_{total}): 122 mm
- Inlet Diameter (D_1): 42 mm
- Throat Diameter (D_t): 27 mm
- Outlet Diameter (D_2): 37 mm
- Length of Throat (L_t): 5 mm
- Length of Convergence / Inlet Section (L_{in}): 51 mm
- Length of Divergence / Outlet Section (L_{out}): 51 mm
- Nozzle Inner Diameter (d_n): 2 mm
- Fuel Discharge Nozzle Angle (θ): Measured relative to the vertical central axis of the carburetor body ($\theta = 30^\circ, 35^\circ, 40^\circ, 45^\circ$).



Fig 4.1 The simple carburetor

V. RESULT AND DISCUSSION

The CFD analysis of the carburetor was carried out to investigate the effect of throttle plate opening and fuel discharge nozzle angle on the internal flow characteristics. The inlet air was assumed to enter the carburetor at normal atmospheric temperature, and the inlet pressure was considered to be 1 atm, approximately 101325 Pa. Initially, the analysis was performed for different throttle plate opening angles of $45^\circ, 60^\circ, 75^\circ$, and 90° to study the variation in static pressure at the venturi throat. The obtained pressure contours were used to understand the relationship between throttle opening, airflow, and throat pressure. Subsequently, the effect of fuel discharge nozzle angle was investigated for $30^\circ, 35^\circ, 40^\circ$, and 45° under the selected boundary conditions.

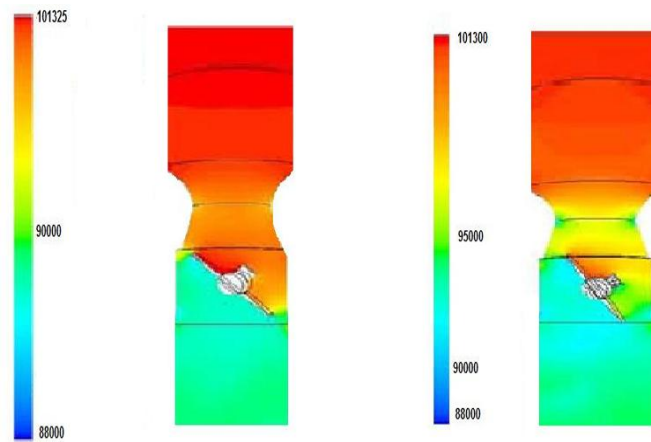


Figure 5.1 Static Pressure View for 45 °and 60 °Throttle Plate Angles

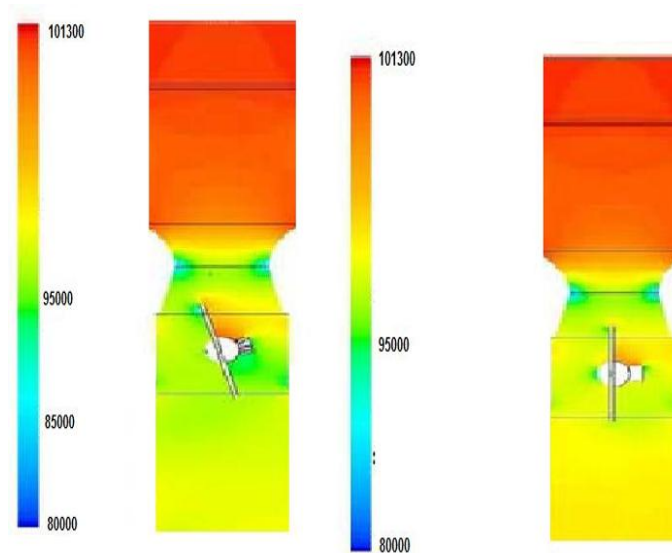


Figure 5.2 Static Pressure View for 75 °and 90 °Throttle Plate Angles

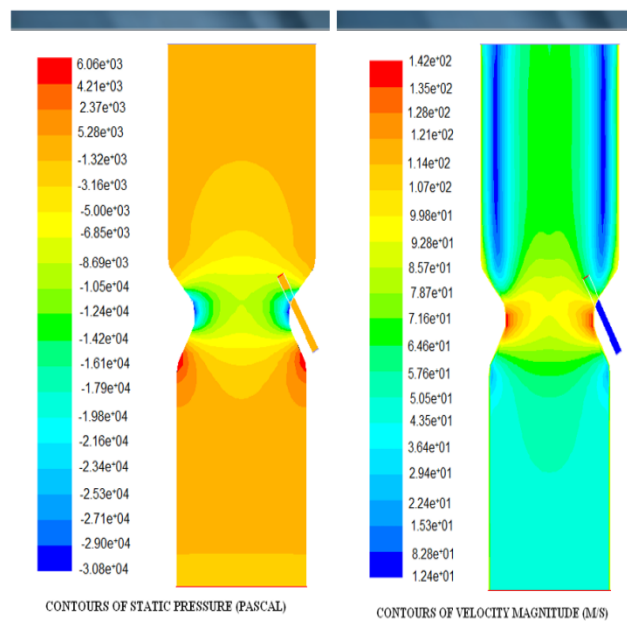


Figure 5.3 Static Pressure and Velocity Distribution for 30° Fuel Discharge

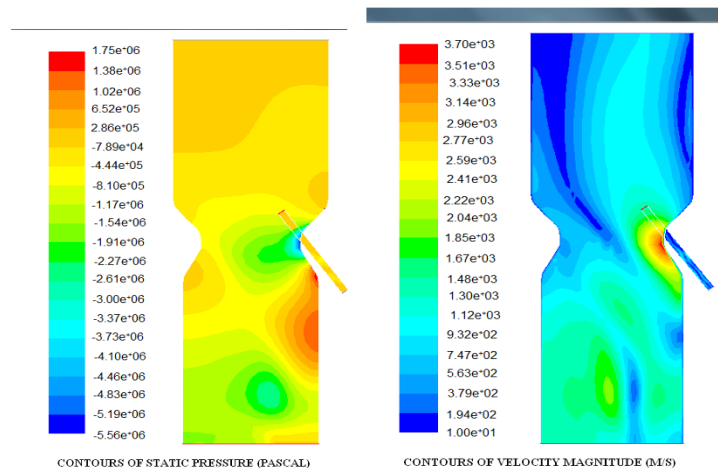


Figure 5.4 Static Pressure and Velocity Distribution for 35° Fuel Discharge

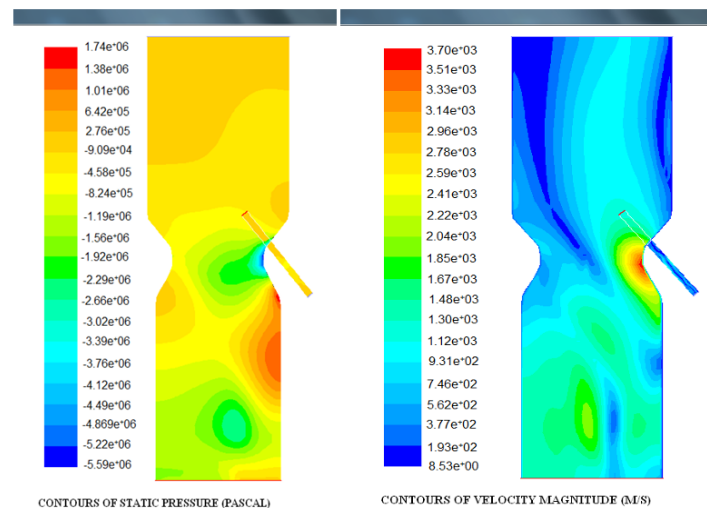


Figure 5.5 Static Pressure and Velocity Distribution for 40° Fuel Discharge

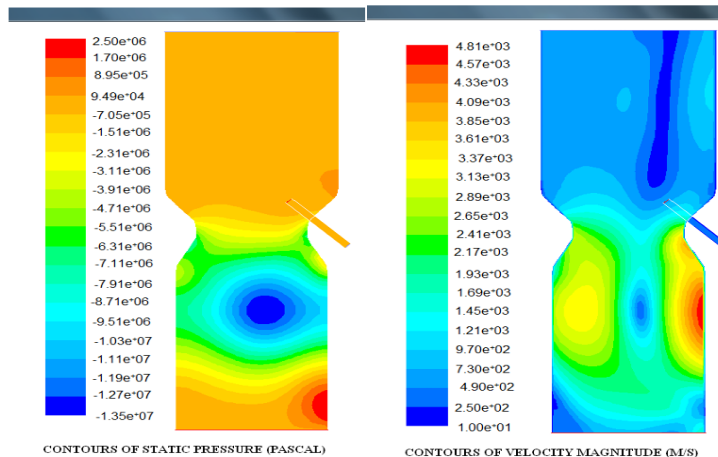


Figure 5.6 Static Pressure and Velocity Distribution for 40° Fuel Discharge

The CFD analysis shows that throttle plate opening significantly affects the flow characteristics of the carburetor. As the throttle opening increased from 45° to 90°, the Venturi throat pressure continuously decreased from approximately 93,000 Pa to 85,000 Pa. The throat pressure was approximately 91,000 Pa at 60° and 87,000 Pa at 75°. This pressure reduction was associated with an increase in airflow velocity through the Venturi. The pressure difference between the inlet and throat provides the driving force for fuel discharge through the nozzle. Thus, higher throttle opening results in increased airflow and lower throat pressure. The effect of fuel nozzle angle was also investigated for 30°, 35°, 40°, and

45°. Among the investigated configurations, the 30° nozzle produced comparatively smoother and more uniform pressure and velocity distributions. Higher nozzle angles resulted in greater flow disturbance and non-uniformity. In all cases, maximum velocity and minimum pressure occurred near the Venturi throat. Based on the investigated CFD conditions, the 30° nozzle angle was considered suitable for obtaining improved flow characteristics and air-fuel mixing.

VI. CONCLUSION

From the above CFD analysis, the following conclusions are obtained.

1. The flow characteristics of the carburetor were investigated for throttle opening angles of 45°, 60°, 75°, and 90°. The throat pressure decreased continuously with increasing throttle opening, from approximately 93,000 Pa at 45° to 85,000 Pa at 90°. This reduction in throat pressure increases the pressure difference between the carburetor inlet and Venturi throat, promoting greater fuel discharge through the nozzle. Thus, proper throttle opening is important for maintaining suitable airflow and air-fuel mixture formation.
2. The effect of fuel discharge nozzle angle was investigated for 30°, 35°, 40°, and 45°. The 30° nozzle produced comparatively smoother and more uniform pressure and velocity distributions. Higher nozzle angles resulted in greater flow disturbance and non-uniformity. Therefore, under the investigated conditions, the 30° nozzle angle was found to be the most suitable among the selected configurations for obtaining desirable flow characteristics and improved air-fuel mixing.

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