Optimization of Fuel Nozzle Diameter of Carburetor for Various Throttle Opening

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Abstract

This paper shows the effect of fuel nozzle diameter of carburetor at part medium and Wide Open Throttle condition of 100 cc single cylinder SI engine using CFD analysis. The nozzle diameter is varied from 1.6 to 2.2 mm in range of 1 mm. 3D-CFD model of carburetor throat is developed to analyze the pressure and velocity distribution of air fuel mixture for different nozzle diameters. Transport equations of mass, momentum, and energy are used to describe the fluid dynamics and behavior of air fuel mixture. Heat transfer is assumed to be unsteady state. In order to predict the effect of turbulence on the flow of flue gas the K-ε turbulence model is used. The results are compared theoretically, experimentally and analytically. Optimum diameter of 1.8 mm shows reduction in emission and improvement in fuel economy.

Keywords: Air-Fuel ratio, Carburetor, CFD, Fuel nozzle, Throttle valve, WTO

1. INTRODUCTION

Engine transforms heat energy into mechanical work. SI engine uses highly volatile fuel. Consumption of fuel is high due to many factors. Design of carburetor affects the fuel consumption in SI engine. A carburetor is most common device used to control fuel flow into intake manifold and distribute across the air stream. Air flows through converging-diverging nozzle which is known as venturi. Pressure difference is set between inlet and throat section for smooth fuel flows through nozzle. A simple carburetor provides the required air-fuel ratio for combustion. As the throttle positions varies air flow through the venturi vary and subsequently pressure drop at the throat increases. Due to decrease in pressure fuel flow increases through float chamber. Therotically corect air-fuel ratio is 15:1 . The uniform supply of correct mixture result into proper combustion without leaving excess air. But practically it is difficult to achive.Insufficient air results into rise in exhaust emissions. Excess air combustion reduces power output. Air-fuel ratio has lage influence on fuel economy and exhaust emissions. For reduction in emissions and improvement in fuel economy, carburetor must provide proper mixture of air and fuel at all required conditions.

2. Literature Review

Rangu P et. al. done CFD analysis to study the pressure drop and velocity profile for different throttle and fuel nozzle angle. From this study they concluded that with increase in throttle plate angle the pressure at the throat of the venturi decreases. It is due to the reason that as the angle increases velocity of air also increases and this will cause to reduce the throat pressure. With increase in nozzle angle from 33° to 39° velocity and pressure distribution becomes non-uniform. Uniform velocity and pressure distribution was observed for angle 33° which leads better atomization and vaporization of the fuel inside the body.

J Suresh Kumar et.al.studied throttle body assembly for a single cylinder SI engine for optimization. Two wheeler carburetor has been analyzed using CFD with investigation of critical flow. First throttle passage and by pass passage diameters were calculated from basic flow equation. With the help of CFD air flow rate for different throttle openings are predicted for main and bypass passage. For 12% opening it is observed that air flow through main and bypass passage are almost same. From this study they concluded that at idling two turns of by-pass screw opening is optimum.

G.sivarayuduet.al. developed complex geometry of three dimensional fully turbulent model of the venturi. CFD analysis was carried out of venturi with obstacles and fuel tube and various contours were plotted for velocity, pressure & turbulent kinetic energy. From this they concluded that in existing carburetor there is flow recirculation at downstream and causes pressure fluctuations which are undesirable. Velocity recirculation is reduced at downstream in modified model.

Shashwat Sharmaet. al. analyze carburetor by CFD analysis for different throttle valve angle and fuel discharge angle. From the study they concluded that the pressure at the throat section is decreased with the increase in throttle. As throttle valve angle increases velocity of air flow through the section increases. As the pressure drop increases at throat section, fuel discharge increases. This makes the mixture uniform for different conditions. With increase in nozzle angle from 30° to 40°, velocity and pressure distribution becomes non-uniform. Uniform velocity and pressure distribution is observed for angle 30° which leads better atomization and vaporization of the fuel inside the body.

Chang Chun Xuet.al. studied SI engine in order to improve intake power and intake fuel efficiency. Throttle body is important device to control air entering into the system. To find out best position of the throttle angle ANSYS FLUENT is used. For this they compare velocity and pressure distribution for various throttle opening conditions 0°, 30°, 45°, 60°, 90°. From the analysis they concluded that Throttle opening angle 60° is better for uniform air fuel mixture and noise reduction in the engine. It generates negative pressure regions which causes velocity reduction.

3 Experimental Analyses:

Experimentation was done on 97.2 cc single cylinder SI engine. Minimum load of 0.1 kg is used for performance and emission analysis. All the trials were performed at 3000,5000 and 8000 rpm at minimum load of 0.1 kg. The diameter of carburetor fuel nozzle varied by 0.2 mm from 1.6 mm to 2.2 mm. Air flow rate and Fuel flow rate is calculated at 30%, 60% and 90% throttle opening. With increase in nozzle diameter Air fuel ratio decreased with increase in HC, CO and NOx emissions. It is observed at 1.8 mm dia the emissions were reduced with increase in fuel economy. Maximum Air fuel ratio 16:1 is observed for nozzle dia of 1.8 mm.

Fig. a shows minimum emissions of 1.5 % by vol at 8000 rpm with increase in temperature. Fig b shows HC emissions increases with increase or decrease in diameter of carburetor nozzle. Minimum HC of 150 ppm is observed at 1.8 mm diameter of carburetor nozzle. Fig c shows oxides of nitrogen increases with increase in nozzle dia. It is due to increase in charge intake. Maximum NOx is observed for 8000 rpm due to increase in temperature. Fig. d, e & f shows variation of air fuel ratio w. r. t to nozzle diameter. Minimum A: F ratio of 15:1 is observed at 8000 rpm due rise in charge intake. Emission increased and fuel reduced due to higher speed and increase in dia of nozzle.

Hence CFD analysis is done at optimum diameter of 1.8 mm.

3.1 CAD Model of Carburetor

Using the same dimensions as that of actual dimensions of single cylinder engine carburetor mentioned earlier, modeling of Fluid domain was done in ANSYS design modeller. Fig. 1.1 shows the geometrical model developed.

3.2 Mesh model of carburetor

Fig 1 shows the meshed model developed using meshing tool of the ANSYS. After creating global mesh of the whole geometry, mesh quality check was done. Tetrahedral element was selected for meshing as geometry consists of various curved surfaces. Meshing resulted in 3, 71,487tetrahedralelements with 10, 9,468 nodes. Fig2 shows meshed portion of air inlet and air outlet.

3.3 Boundary Conditions

In the ANSYS workbench, ANSYS FLUENT was startedand FLUENT launcher was displayed to enable startup options. The generated meshed model was imported to ANSYS FLUENT solver. Pressure based, unsteady flow options were selected in numerical solver. The physical model used for mathematical formulation of the problem isselected to describe the fluid dynamics and thermal behavior of flue gases.

4. Results and Discussion

To obtain numerical results, SIMPLEC scheme in solution methods was used to solve the set of equations. Other parameters were kept with default settings for calculation and step size of 0.1 second with 600 steps was used to complete 1 minute cycle. Solution convergence for 1 minutes (60 seconds) required 53889 iterations to complete given end step with 14 cores on Xenon E5 series processor. It was assumed that the inlet air enter the carburetor at 394 K. The inlet pressure of the air is taken 1 atm. Results were obtained for pressure and velocity variation of the throttle opening of the carburetor. Various throttle positions i.e idling, part, medium and full throttle conditions are analyzed.

4.1 CFD Results for existing Carburetor

At idling conditions the non-uniform distribution of pressure and velocity of charge throughout the outlet throat of the existing carburetor lead to improper atomization and vaporization of the fuel. The same conditions are observed for part, medium throttle conditions.

At full throttle conditions the counters of velocity and pressure are uniform in existing carburetor. The uniform distribution of charge in venturi leads to proper vaporization and atomization of fuel. From Fig. 8 and Fig. 9 shows that velocity and pressure is distributed uniformly from the inlet of the carburetor towards the throat.

Graph shows the air fuel ratio for three different conditions 30°, 60°, 90° from graph it is clear that the air fuel ratio decreases with increase in throttle angle.

Graph shows the air fuel ratio for various throttle opening for the existing carburetor. From the graph it is clear that as we increase the throttle angle there will be decrease in air fuel ratio. As throttle angle is increased more air flows through the carburetor opening and this will affect the mixture strength. As angle increases air fuel mixture becomes rich.

4.2*CFD Results for Existing Carburetor with Modified Diameter*

Fig 11 to 16 shows the pressure and velocity distribution for 1.8 mm diameter of carburetor. As compare to existing diameter the results for changed diameter are quite uniform for idling conditions and medium throttle conditions. Due to uniform distribution of pressure and velocity through the venturi section fuel will be atomized and vaporized easily.

With the increase in the throttle valve opening from idling to wide open throttle the air velocity has increased, consequently the pressure at the throat section has decreased. This has a greater effect on the mixture strength with increase in pressure drop at the throat section.

Graph gives the air fuel ratio for three conditions 30°, 60°, 90°.From the graph it is clear that the air fuel ratio decreases with increase in throttle angle.

Graph shows the air fuel ratio for various throttle opening for the existing carburetor. From the graph it is clear that as we increase the throttle angle there will be decrease in air fuel ratio. As throttle angle is increased more air flows through the carburetor opening and this will affect the mixture strength. As angle increases air fuel mixture becomes rich.

4.3*Air Fuel ratio Analysis*

Air fuel ratio decreases with increase in throttle opening. Value of air fuel ratio should be increased with increase in throttle valve opening. Ideally the range of air fuel ratio should be 12-15. Following table gives value of air fuel ratio by numerical analysis.

Above graph shows the value of air fuel ratio calculated numerically and by CFD. Value for diameter 1.8 mm satisfies the condition for max power output and better fuel economy as compared to value we get for 2 mm diameter.

For existing carburetor air fuel mixture supplied by 2 mm diameter nozzle is rich and also there is non-uniform distribution of air fuel mixture. Modified carburetor fuel nozzle of 1.8 mm diameter shown uniform distribution and chemically correct mixture.

Following graph shows the modified diameter of carburetor gives the better results for all the analysis as compared to existing diameter. The air fuel ratio lies in between chemically correct ratio due to which fuel economy of the vehicle is increased.

Conclusion

Increase in fuel nozzle diameter shown decrease in air fuel ratio. Optimum nozzle diameter of 1.8 mm shows reduction in emission and increase in fuel economy. Chemically correct air fuel ratio of 15-18 is observed for 1.8 mm dia for part, medium and full throttle conditions. The results obtained experimentally, numerically and analytically shown close relation. Uniform velocity & pressure distribution is observed for 1.8 mm diameter at part, medium and full throttle conditions. Fuel economy increases by 13% with 1.8 mm dia fuel nozzle. As the diameter of fuel jet increases its air-fuel ratio decreases and when fuel jet diameter (i.e from 60 km/hr to 68 km/hr). With decrease in 0.2 mm diameter of fuel nozzle fuel economy increased by 13%.

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