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Research Article

EXPERIMENTAL INVESTIGATION OF IN-CYLINDER AIR FLOW TO OPTIMIZE NUMBER OF GUIDE VANES TO IMPROVE PERFORMANCE AND EMISSIONS OF DI DIESEL ENGINE

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ABSTRACT

This paper presents research that has sought to improve the in- cylinder air flow characteristics by using the guide vane swirl device (GVSD). Four guide vanes with various numbers of vanes were adopted to evaluate the performance and emission analysis before and after the installation to the normal engine. The investigation is performed by an experiment on a four-stroke single-cylinder D.I diesel engine test bed with four different types of guide vane swirl devices, were installed at the downstream of the air intake manifold. There by increasing the mixture quality of air & fuel in the combustion chamber before the initialization of ignition. The engine load tests were carried out at different loads with and without air swirl devices. This research found that five vanes was the optimized number of vanes since it decreased 21.2% of BSFC and 30.7% of NO_X respectively and Brake thermal efficiency was increased 23.04% as compared with normal engine at full load.

INTRODUCTION

Although there is large development in the CI engine in last few decades it is still lagging in the performance in the sense of fuel economy & exhaust emission. It is due to the ineffective use of air in the engine causes improper atomization of the air-fuel mixture results in the poor combustion, which affects the engine performance characteristics in terms of fuel economy and emissions at part load conditions. So to enhance the performance of engine better utilization of intake charge is necessary, different techniques are introduced in form of modification of intake manifold, development of swirl and tumble devices, modification of piston profile for efficient combustion of charge. In this paper different swirl generating devices are analyze and their result is compared with base model without swirl device. Resistance offered by device to flow is prime factor. Since volumetric efficiency of CI engine is always a critical parameter due to numerous component in intake system. Addition of swirl generating device should not develop more resistance to flow. Requirement of swirl is also varying in engine and is not constant at all loading conditions.

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At cold start conditions and part load conditions engine require slightly rich mixture. Modeling of device is done taken into consideration the fact that it should be able to develop variable swirl while its operation. In-cylinder flow field structure in an internal combustion engine has a major influence on the combustion, emission and performance characteristics. Fluid flows into the combustion chamber of an I.C engine through the intake manifold with high velocity. Then the kinetic energy of the fluid resulting in turbulence causes rapid mixing of fuel and air, if the fuel is injected directly into the cylinder. With optimal turbulence, better mixing of fuel and air is possible which leads to effective combustion. A good knowledge of the flow field inside the cylinder of an I.C engine is very much essential for optimization of the design of the combustion chamber for better performance. Swirl can be defined as rotational of intake charge about the cylinder axis. This can be done by carrying the intake charge flow with an initial angular momentum such that non uniform flow distribution will occur. At part load operating conditions it is advantageous to dilute air fuel mixture with introduction of swirl for these reasons. Geometry of device is maintained in such a way that it should allow max air to flow inside it will affect volumetric efficiency of engine as low as possible. In case of uniform flow device the volumetric efficiency is more because resistance in the flow way is less.

By considering this factor the geometry has created. The geometry has curvature like that flow gets deflected into angular momentum.

Literature Survey

Idris Saad & Saiful Bari has modeled the guide vane & tumble device for improving the air-fuel mixture for the highly viscous fuel in diesel engine. They have created a device with four & six number of vanes. Prime importance is given to improvement of the air flow & the effect of vane twist angle. number of vane device swirl generated is more than 4 vanes but the resistance in the flow way is increased on other hand. The vane angle is varied from 3^0 to 60^0 it is found that with 35^0 vane angle in-cylinder air pressure increases by 0.02%, total kinetic energy of air by 2.7% & velocity of air by 1.7% compared to the unmodified diesel engine (Idris Saad and Saiful Bari, 2013)

A.K. Mohiuddin investigates the swirl effect on the engine performance by using insert swirl adapter. The testing has carried out on the protons CAMPRO engine model of 1.6 liter. In swirl device adapter blade angle is maintained at 300 & is fitted in the intake port. Obtained results compared with the normal engine & it has found that at the full load condition the swirl generation is less but at the part load condition the swirl produce is effective. The BSFC reduces at part load condition but as the speed increases beyond 3500 rpm BSFC increases, as the speed increases beyond 3500 rpm BSFC increases (Mohiuddin, 2011).

Liu Shenghua investigates the effect of new swirl system & its effect on DI engine economy. In this ring type generator with four curvilinear blades used. The generator fitted in the intake air duct & the comparison is carried out, the result found out that with 1500 rpm effective swirl is generated and with reduced emissions (Liu Shenghua, 1999). Dr. Pankaj N.Shrirao, Dr. Rajeshkumar U. Sambhe (2014), have worked on the air swirl created by directing the air flow in intake manifold on single cylinder 4-stroke engine performance as well as its exhaust emissions. Experiments were done with different types of internal threads, viz. acme, buttress and knuckle of constant pitch and also take the exhaust emissions of different manifolds. Finally they have found experimentally that compare to other two conFigurations, the inlet manifold with buttress thread has better air-fuel mixing process and hence thermal efficiency is increases and BSFC and exhaust emissions are reduced.

Phaneendra *et al*.(2012) , have experimentally investigated that by designing and changing the orientation of the inlet manifold of a four stroke air cooled C.I engine at rated speed 1500 rpm the performance characteristics of an engine are increased and emissions levels are decreased. Experiments were done in various shaped threaded manifold of pitch 10mm, 15mm, 20mm, and 25mm, and they have proved that the performance characteristics with 10mm pitch showed better for performance as well as emission levels compared to normal manifold. The tests are carried with different conFigurations by varying the pitch of the helical groove from 2 mm to 10 mm in steps of 2 mm inside the intake manifold. The results indicate that conFiguration of 8 mm pitch groove has increases the turbulence and hence better mixing of air-fuel process takes place among all conFigurations and the soot emissions are reduced. They have also found that the laser carbon deposits in the combustion chamber, piston crown and exhaust system due to controlled combustion. Also, more power is derived from the same charge.

Ramakrishna Reddy *et al*. (2014), have performed various experiments to find the effect of swirl on the performance of the engine as well as on its emissions, by inducing swirl with different inlet manifolds having helical, spiral and helical-spiral shapes. The test were done on the 4-stroke, water cooled C.I engine. First they have made the 3D model of three manifolds and then take the observations. The analysis shows that all the three types of inlet manifolds yields much better performance and fewer amounts of emissions in comparison with normal manifold.

Objective of the study

The objective of this study is to investigate the ability of an air enhancement device in improving the performance of a DI Diesel engine and reduce emissions. This research intended to optimize the number of guide vanes to be used in DI Diesel engine.

Guide vane Swirl Device Model

The parametric optimization technique required the parameter (Number of guide vanes) to be varied and tested one by one on the base model. This research determined that the optimized number of guide vanes between 3 to 6 with equal spacing set between the vanes i.e the size of each space was equal to 360^0 divided by number of vanes. Hence, a total of four guide vane swirl devices were developed. While optimizing the number of vanes, the other parameters (Vane height, Vane angle and Vane length) were set as: R, 40^0 twist angle (TA) and 0.9 times R of vane length respectively. These values were selected by referring to various sources regarding the development of guide vanes to improve in cylinder air flow characteristics (Siber *et al*., 2012; Sun and Du, 2011 and Kim, 2006).Moreover this values set constantly for all four guide vane models in order to optimize the number of guide vanes. Table 2 summarizes the specifications of guide vane model. Fig 3.2 shows the guide vane assembly at the base model. Fig: 2 illustrate the Guide vane swirl devices.

Table 2. Specifications of Guide vane devices

Radius of intake manifold (R)	22 mm
Guide vane length (L)	0.9 R = 20 mm
Guide vane height(H)	R = 22 mm
Guide vane twist angle(θ)	40^0
Guide vane number	3 Vanes, 4 Vanes, 5 Vanes and 6 Vanes

Experimental Set Up

The investigation is performed by an experiment on a four-stroke single-cylinder diesel engine test bed with four different types of guide vane swirl devices, were installed at the downstream of the air intake manifold as shown in the Fig: 3.1. There by increasing the mixture quality of air & fuel in the combustion chamber before the initialization of ignition. The engine load tests were carried out at different loads with and without air swirl devices.

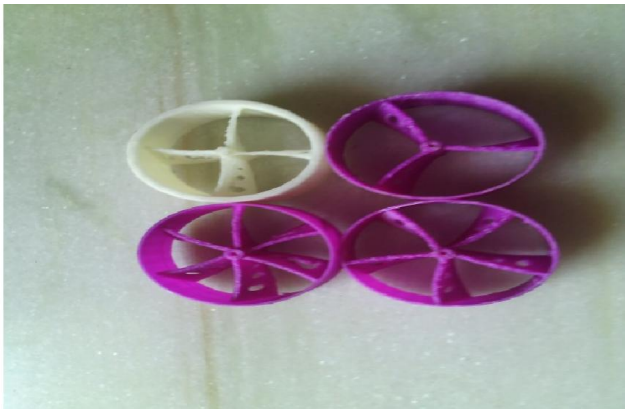

Fig. 2. Four different types of guide vane swirl devices

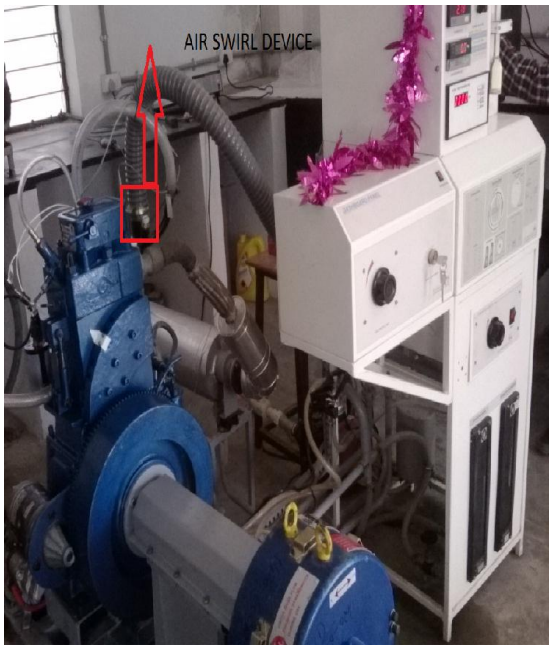

Fig. 3.1Engine Setup

The emissions from the engine were also tested before and after the setup installation to estimate the environmental effects. The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer as shown in Fig: 3.1 and the specifications of the test engine are shown in Table 3.1. It is provided with necessary instruments for combustion pressure, crank-angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data acquisition device. The set up has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of VCR engine performance for both Diesel and Petrol mode and study of ECU programming. Engine performance study includes brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis.

Table 3.1. Engine Specifications

Make and Model	Research Engine Test setup code 240 PE Apex innovations pvt.Ltd.
Type of Engine	Multi fuel
Number of Cylinders	Single cylinder, Four Stroke
Cooling Media	water cooled,
Rated Capacity	3.5 KW @ 1500 rpm,
Cylinder diameter	87.5 mm
Stroke length	110 mm,
Compression ratio range	12-18
Injection variation	0- 25 º BTDC
Dynamometer	Eddy current Dynamometer
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Fig 3.2 five gas analyzer

AVL Digas 444 five gas analyzer was used to measure the concentration of concentrations of gaseous emissions like oxides of nitrogen (NO_X), unburned hydrocarbons (UHC), carbon monoxide (CO) and carbon dioxide (CO_2) as shown in the Fig: 3.2.

RESULT AND DISCUSSION

Load Vs Brake Power

Brake power of the engine increases with the increase in load on the engine. It can also be seen that as we increase the load, torque increases and thus there is an increase in brake power with the load. Fig 4.1 illustrates that all most all guide vanes are showing slightly increase in brake power of normal engine. Four guide vane device shows slightly more at full load i.e 0.78% higher than base line engine.

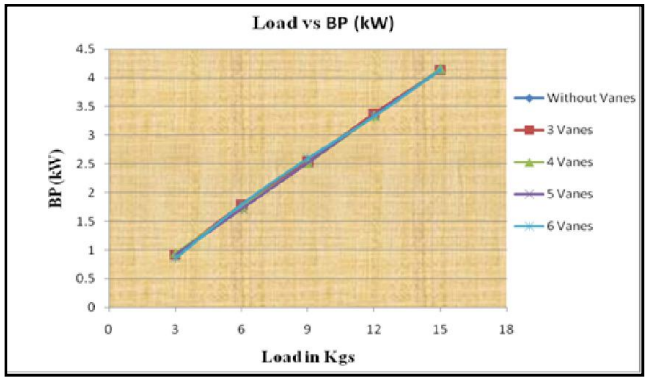

Fig: 4.1 Variation of brake Power with variation of load

Load Vs Brake thermal efficiency

Brake thermal efficiency of the engine increases with the increase in load on the engine. Fig: 4.2 illustrates that for 5 guide vanes is highest brake thermal efficiency at full load condition when compared with other devices as well as normal engine and observed that 23.04% of increase in brake thermal efficiency. The brake thermal efficiency for all types of guide vanes is more when compared to normal engine at all loads.

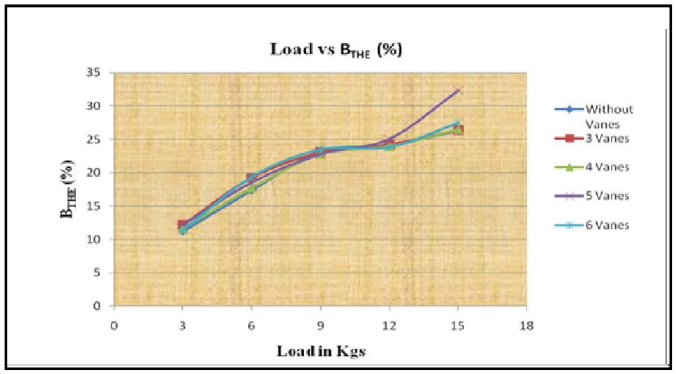

Fig: 4.2 Variation of brake thermal efficiency with variation of load

Load Vs Brake Specific fuel consumption

Brake specific fuel consumption of the engine decreases with the increase in load on the engine. Due to the air swirl generation there is an increase in the mixture quality of air & fuel in the combustion chamber before the initialization of ignition. Hence the amount of heat released is more so that the fuel consumption is less for the all vanes nozzle when compared to the normal engine. It is observed that in 5 guide vanes there is a decrease in 21.2 % of specific fuel consumption at full load.

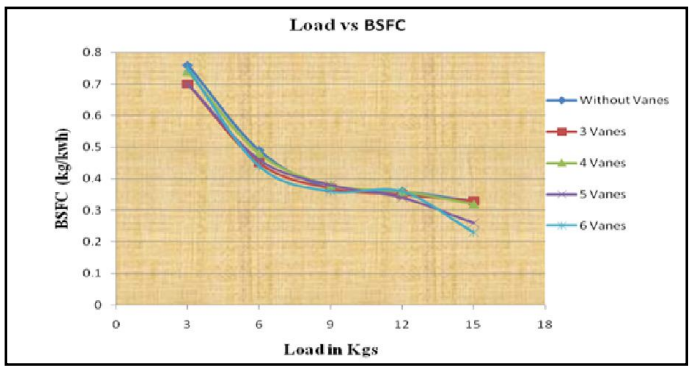

Fig: 4.2 Variation of brake specific fuel consumption with variation of load

Load vs Hydro Carbons

Unburned Hydrocarbons of the engine increases with the increase in load on the engine. From Fig: 3.4 it is observed that the hydrocarbon emissions decreases for all the types guide vane when compared to the normal engine. At 9 kgs load 5 guide vane emits low hydrocarbons and which is 47.6% lower when compared with normal engine.

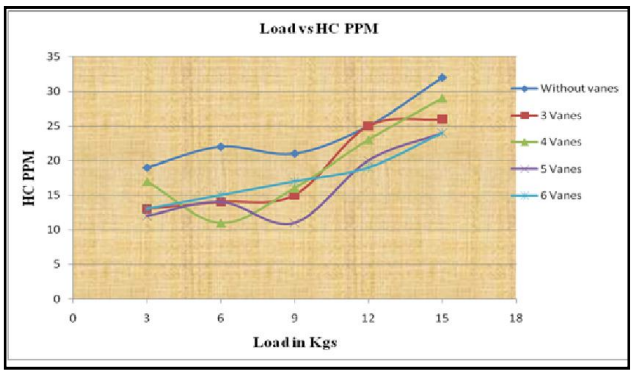

Fig: 4.3 Variation of Hydrocarbons with variation of load

Load Vs Carbon monoxide (CO)

The carbon monoxide emission depends upon the oxygen content and cetane number of the fuel. The maximum carbon monoxide emission was observed at full brake power of the engine. Fig. 3.5 illustrates carbon monoxide emissions decreases for all the guide vanes when compare to the normal engine. At full load 6 guide vane emits low carbon monoxide which is 36.36% lower than normal engine

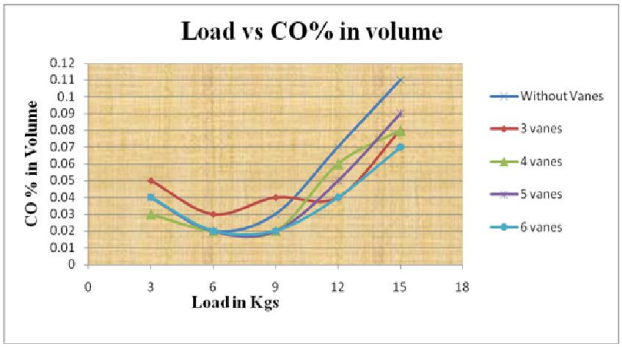

Fig: 4.5 Variation of Carbon monoxides with variation of load

Load Vs Carbon dioxide (CO_2)

The carbon dioxide emission depends upon the oxygen content and cetane number of the fuel. The maximum carbon dioxide emission was observed at full brake power of the engine. Fig. 3.5 illustrates the variation in Carbon dioxide with the change in load. The carbon dioxide emission depends upon the complete combustion of the fuel. At full load condition 4 guide vanes emits 23.3 % higher carbon dioxide when compared with normal engine.

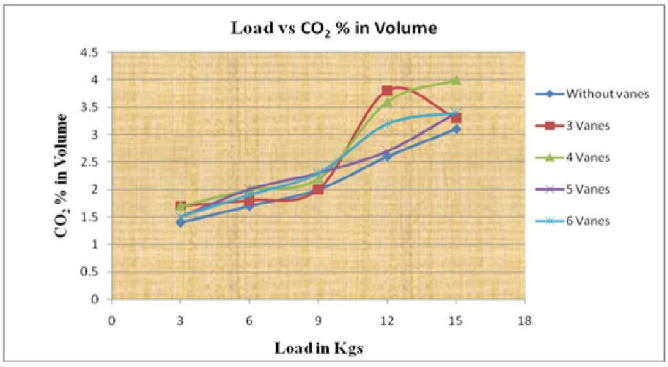

Fig: 4.6 Variation of Carbon dioxides with variation of load

Load Vs NOx

The variation in the NOx emissions at different engine load is shown in Fig. 3.6. Oxides in the engine exhaust are the combination of nitric oxide (NO) and nitrogen dioxide (NO_2). Nitrogen and oxygen react relatively at high temperature. Therefore high temperature and availability of oxygen are the two main reasons for formation of NOx. When the more amount of oxygen is available, the higher the peak combustion temperature the more is the NOx formed. . At lean and rich air-fuel mixture the NOx concentration is comparatively low. The NOx emissions are less in 5 guide vane emits less NOx and is 30.7% l decrease when compared with normal engine.

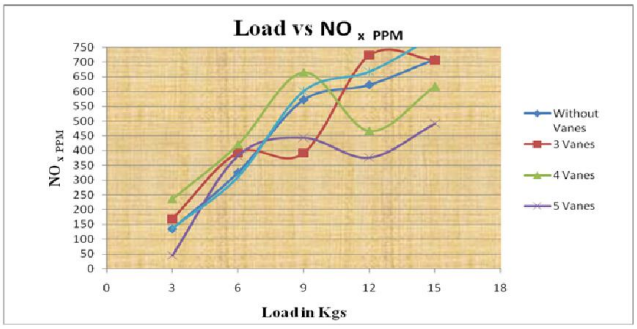

Fig: 4.7 Variation of NOx with variation of load

Load Vs Smoke Opacity

Fig 4.8 represents the smoke emission measured in the engine exhaust. Any volume in which fuel is burned at relative fuel-air ratio greater than 1.5 and at pressure developed in diesel engine produces soot. The amount of soot formed depends upon the fuel ratio and type of fuel. If this soot, once formed finds sufficient oxygen it will burn completely. If soot is not burned in combustion cycle, it will pass through the exhaust, and it will become visible. The size of the soot particles affects the appearance of smoke. Black smoke largely depends upon the air fuel ratio and increases rapidly as the load is increased and available air is depleted. At peak loads the smoke density is lower for 6 guide vane when compared with normal engine. The smoke density reduces to17.76% at peak loads when compared to normal depleted.

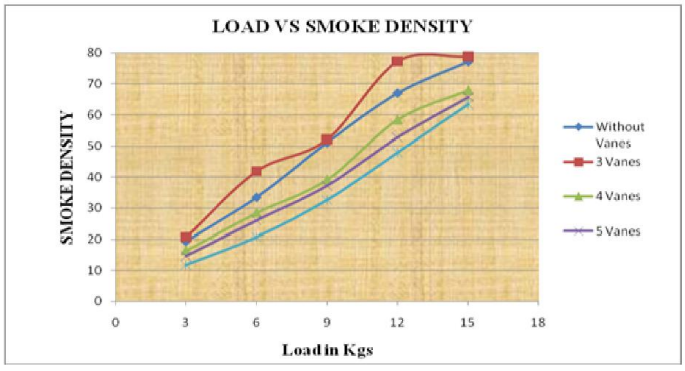

Fig: 4.8 Variation of Smoke densities with variation of load

Conclusion

Tests for emission and performance characteristics were conducted on a single cylinder, 4-stroke, constant speed diesel engine at a Compression ratio of 18. The combustion and emission characteristics of single cylinder compression ignition engine with vane nozzle have been analyzed and compared to the standard normal engine. Based on the experimental results, the following conclusions are obtained

- It was observed that at full load brake power is higher for 6 guide vane compared to normal engine which is 0.7% higher than the normal engine.
- Five guide vanes is highest brake thermal efficiency at full load condition when compared with other devices as well as normal engine and observed that 23.04% of increase in brake thermal efficiency when compared with normal engine.
- It is observed that in 5 guide vanes there is a decrease in 21.2 % of specific fuel consumption at full load.
- At 9 kgs load 5 guide vane emits low hydrocarbons and which is 47.6% lower when compared with normal engine.
- At full load 6 guide vane emits low carbon monoxide which is 36.36% lower than normal engine.
- At full load condition 4 guide vanes emits 23.3 % higher carbon dioxide when compared with normal engine.
- At peak loads the smoke density is lower for 6 guide vane when compared with normal engine. The smoke density reduces to17.76% at peak loads when compared to normal depleted.
- The NOx emissions are less in 5 guide vane emits less NOx and is 30.7% decrease when compared with normal engine.

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