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Experimental Investigation on Performance and Emission of IC-Engine by Modifying Inlet Manifold - A Review

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Abstract— *Better combustion in the engine occurs when it gets good breathing. Inlet manifold is the device attached to the engine which provides air/fuel charge for the combustion inside the cylinder. This combustion occurring in cylinder also depends on the type of flow entering through inlet manifold. Swirl and turbulence created in flow will distribute charge to each corner of cylinder uniformly. This leads to uniform complete combustion thereby improving performance and emission. Studies of various literatures indicate similar results. There are scopes to change the geometry of inlet manifold and improve the performance and emission of engine. This trend provided motivation to carry out a review on such research work. It will help in making the basis for an intended research work in similar direction.*

Keywords-*Inlet manifold, swirl, turbulence, IC-engine, volumetric efficiency, emission.*

I. INTRODUCTION

IC Engines are being developed to obtain higher performance and gain the potential to fulfill the need of next generation. Engine plays very crucial role in vehicle operation. It produces and supplies the energy needed by the other car component to function. Engine transfers chemical energy of fuel into thermal energy and utilize this form of energy to perform useful work. Hence thermal energy is converted into mechanical energy in engines. Engines are generally classified into two parts: 1) spark ignition engines and 2) compression ignition engines. One promising technology for improving IC engine efficiency is modification of intake system to create turbulence. Turbulence increases homogeneity of air-fuel mixture in all strata of combustion chamber.[1]

Flow of air through the manifold and mixing of the fuel with air inside the cylinder is more important in the case of diesel engine as all of these factors are directly affecting the volumetric combustion performance,efficiency, emission levels and output of the engine. Control of flow through the manifold is critical for meeting the emission regulations and fuel economy requirements. Parameters like engine speed, manifold and combustion chamber configuration directly influence the swirl in DI diesel engines and subsequently it plays a vital role in mixing air and fuel inside the cylinder. Optimization of swirl becomes an important aspect in the design of intake systems of diesel engines.[1]

Figure 1. Inlet Manifold[1]

An inlet manifold or intake manifold is the part of an engine that supplies the fuel/air mixture to the cylinder. The primary function of the intake manifold is to evenly distribute the combustion mixture (or just air in a direct injection engine) to each intake port in the cylinder head. Flow is distributed evenly to intake valve by ideal intake manifold. Even distribution is important to optimize the efficiency and performance of the engine. It may also serve as amount for throttle body,fuel injectors,carburetorand other components of the engine. The intake manifold has historically been manufactured from aluminum or cast iron but use of composite plastic materials is gaining popularity. The pulsating nature or intermittent of the airflow through the intake manifold into each cylinder may develop resonances in the airflow at certain speeds. Engine performance characteristics at certain engine speeds may increase by this, but it may even reduce at other speeds, depending on manifold dimension and shape[1].

In today's world, major objectives of engine designers are to achieve the twin goals of best performance and lowest possible emission levels. Excellent engine performance requires the simultaneous combination of good combustion and good engine breathing. Good combustion depends only in part on the characteristics of the flow within the cylinder. Good engine breathing is strongly affected by the unsteady flow in the intake manifold, and to a lesser extent, that in the exhaust manifold. History tells us that correctly harnessing the flow in the intake manifold of a naturally aspirated I.C. (Internal Combustion) engine can yield improvements in engine torque of 10% or more, whereas performing the equivalent in the exhaust manifold yields a more modest 4-6%. To maximize the mass of air inducted into the cylinder during the suction stroke, design of intake manifold, which plays an important role, needs to be optimized. Design becomes more complex in a multi-cylinder engine as air has to be distributed equally in all the cylinders. Thus, configuration of manifold geometry becomes an important criterion for the engine design[9].

II. LITERATURE REVIEW

Paul et al.[2] found the effect of helical configuration, spiral configuration, and helical-spiral configuration combination manifold configuration on air motion and turbulence inside the cylinder of a Direct Injection (DI) diesel engine motored at 3000 rpm. By using the CFD tool (FLUENT), they compared predicted CFD results of mean swirl velocity of the engine at different locations inside the combustion model stroke withεchamber at the end of compression and the turbulence modeled using RNG k- experimental results available in the literature. The volumetric efficiency of the modeled helical manifold was also compared.

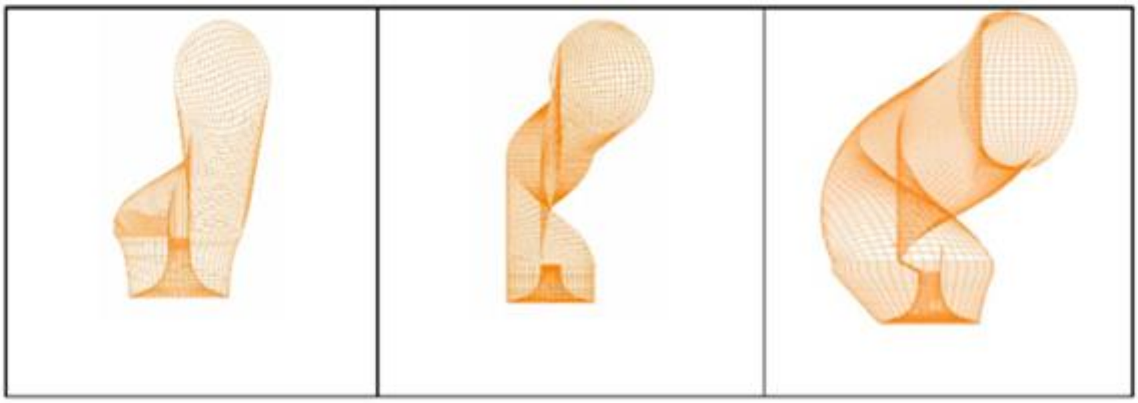


Figure 2. Modelled (i)Spiral, (ii)Helical, (iii)Helical spiral manifold configuration[2]

After the analysis many things were noticed such as higher velocity component inside the combustion chamber at the end of compression stroke was created by the helical-spiral manifold geometry. Turbulent kinetic energy and swirl ratio inside the cylinder are higher in spiral manifold. In spiral-helical combined manifold, volumetric efficiency is 10% higher than that of spiral manifold. Conclusion of result shows that Helical-spiral combined manifold creates higher swirl inside the cylinder than spiral manifold. Higher volumetric efficiency is obtained in helical manifold. Helical- spiral combined manifold provides higher mean swirl velocity at TDC of compression. Hence, for better performance a helical-spiral inlet manifold configuration is recommended by them.

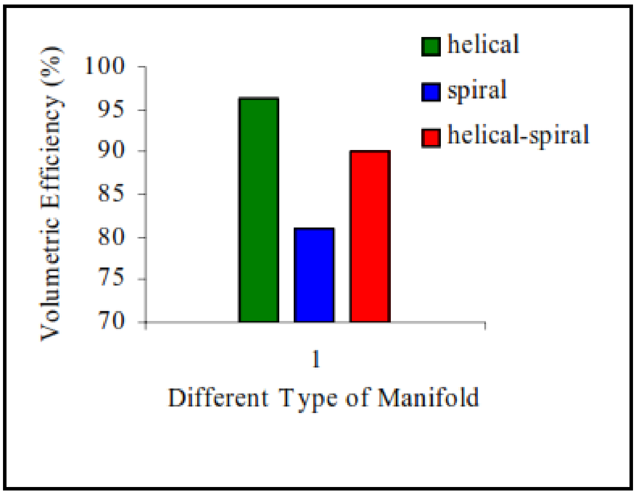
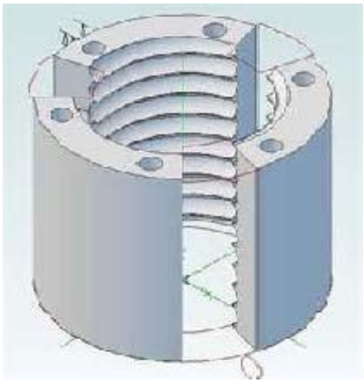


Figure 3.Volumetric efficiency of different manifold configurations at 3000 rpm.[2]

Dr. Pankaj et al. [3] worked upon the effects of swirl on the performance characteristics of the engine. It was done by inducing swirl in inlet manifolds. They did it with three different types of internal threads viz. acme, buttress and knuckle threads. They kept constant pitch of 2 mm in all three types of thread. They conducted experiments on a single cylinder Kirloskar make direct injection four stroke cycle diesel engine. It was concluded that the configuration inlet manifold with buttress internal threads enhances the turbulence and hence results in better air-fuel mixing process among all the configurations of inlet manifolds. As a result, the thermal efficiency w a s increased and BSFC and exhaust emissions were reduced. Inlet manifold with buttress internal threads was the best trade-off between performance and emissions..



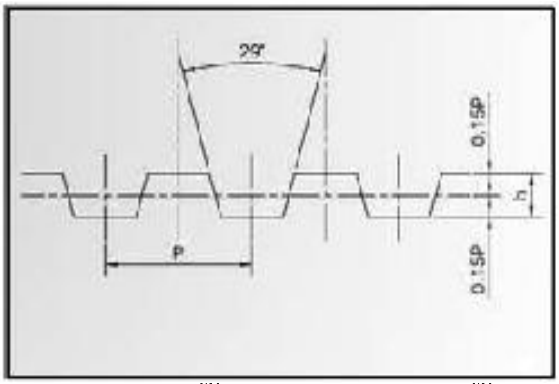
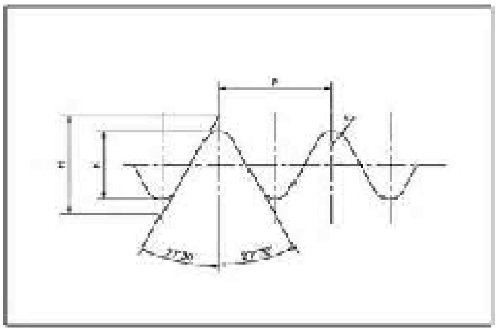


Figure 4.Internally ThreadedInlet Manifold[3]Figure 5. Acmethreads[3]



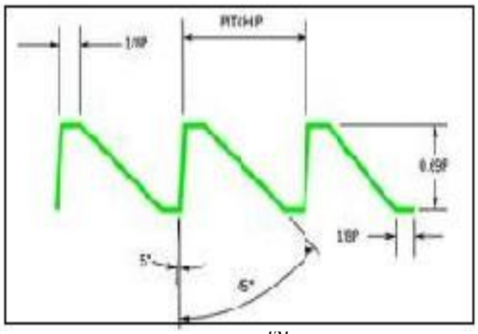


Figure 6.Knucklethreads[3]Figure 7. Buttressthreads[3]

1. It was observed that 11.62% of reduction in BSFC at 2.5kW load for engine with inlet manifold having buttress internal threads compared to engine with normal inlet manifold.
2. The exhaust gas temperature was higher for diesel engine with inlet manifolds having all these three different types of internal threads than engine with normal inlet manifold.
3. It was observed that 12.32%, 26.66% and 3.6% of reduction in HC, CO and NOx emissions respectively at 2.5kW load for engine with inlet manifold having buttress internal threads compared to engine with normal inlet manifold.
4. The results indicated that inlet manifold with buttress threads were identified as optimum configuration based on performance as well as exhaust emissions of diesel engine.

A.K.M. Mohiuddin [4] studied swirl is the rotational flow of charge within the cylinder about its axis. Engine used in this investigation is a basic Double Overhead Camshaft (DOHC) which has a capacity of 1597 cc and it was installed with a total of 16 valves developed by Malaysian car manufacturer PROTON. The intake port of the Engine consisted of the swirl adaptor. The Adapter angle was set to 300 to force the charge to bounce off the wall of the port to create swirl. Paper Objective was to find the effect of swirl on the engine and to compare it with the mixing process by normal turbulence. Analysis of swirl effect was done by using the GT-SUITE which has a standard swirl flow embedded within it. Effect was simulated on the GT-SUITE and it was found that the swirl affects the engine in reducing the fuel consumption and the volumetric efficiency also increases. Experimental result showed that the effect of swirl increased the power as well as torque in the idle and cruising speed conditions when normal turbulence was compared with it. It also decreased rapidly in the acceleration speed. /it happened because of the inability of the swirl adapter to generate swirl at higher wind flow velocity during the condition of higher throttle opening. Brake Specific Fuel Consumption was considerably lower at the lower speed but increased above the normal aspirated graph when the speed went above 3500 rpm

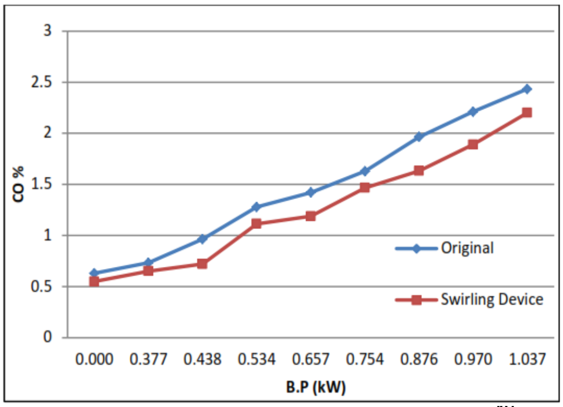
Kim J.S.[5] patented "Fluid Swirling Device" includes a pair of flat planar vanes securely mounted within a cylindrical housing. The vanes have a medial slit extending from the center to a longitudinal end of the vane. The vanes are interconnected at the slits so that they are in crisscross positioning. The vanes are axially angled so that when positioned in an intake air duct the vanes impart a swirling motion to the air entering the engine providing more complete mixing of the air and fuel. These devices utilize vanes which are radially curved to attach both ends of the vanes to the same side of the cylindrical housing. However, the vane portions which are at the central area produce higher stresses at the attachment points due to the effects of leverage. In addition, the absence of a secure central connection and thereby lack of rigidity of the vanes at the central area results in deflection movement in response to the forces of the fluid flow. The movement of the vanes may adversely affect the fluid flow movement by setting up harmonics in the fluid.

Norbert G. Lyssy [6] patented "Fixed Blade Turbulence Generator" is device and method for installing a device for improving the fuel/air mixture in internal combustion engines with or without a fuel injection system. An intermediate member operatively dispositional between the engine intake manifold and the intake port comprises at least two helically twisted blades attached to the inner bore of an intake port opening in the intermediate member; these blades are angled in relation to the fuel/air flow path and twisted so as to impart a swirling to the fuel/air mixture. The swirl is imparted to the air flow just prior to encountering the umbrella mist injected to the intake port by the fuel injector in fuel injected systems. The swirl mixing of the fuel/air improves engine performance, reduces pollutants, and increases gas mileage. Also, the device in the fuel injection system reduces or eliminates the common occurrence of a burned intake valve caused by a clogged injector

Kuang-Hsiung et al. [7] patented "Air Swirling Device" comprising of a pipe member connected in between an internal combustion engine and an air cleaner. A plurality of swirl flow ducts spirally formed in the pipe member about an axis defined at a longitudinal center of the pipe member. A central flow duct axially formed in the pipe member and surrounded by the plurality of swirl flow ducts. Upon suction by the engine, the inlet air flow will be swirled as guided by the plurality of swirl flow ducts to form a plurality of streams of swirling air flow to be combined with a central air flow through the central flow duct to form a forced-draft air how to enter the engine. This swirling flow motion gives better mixing of air and fuel in combustion chamber.

Wijaya [8] patented "The air-stirring blade" is provided that comprises a cylindrical body whose mid portion is provided with blade of such a construction that the inner side of the blade takes the form of stirred grooves with dip angle of about 10° to 80° or typically 30° with respect to vertical axis of the body. The outer side of the blade is of the same shape with the inner side thereof and there are four tangent lines between the blade and body forming a channel of cap-shaped cross section which is twisted along the body.

Smit et al. [9] performed an experimental study which was conducted to evaluate various performance and emissions parameters of original configuration intake manifold and swirling device attached to intake manifold of engine According to the results of experiments, Swirling device in intake manifold of engine has overall positive impact on performance and emission parameters. Maximum percentage decrease in Specific Fuel Consumption was 12.72 % at rated power with swirling device attached to intake manifold. Maximum percentage increase in Brake Thermal Efficiency was 14.52 % at rated power with swirling device attached to intake manifold. Maximum percentage increase in Indicated Thermal Efficiency obtained is 8.12 % at rated brake power with swirling device attached to intake manifold..



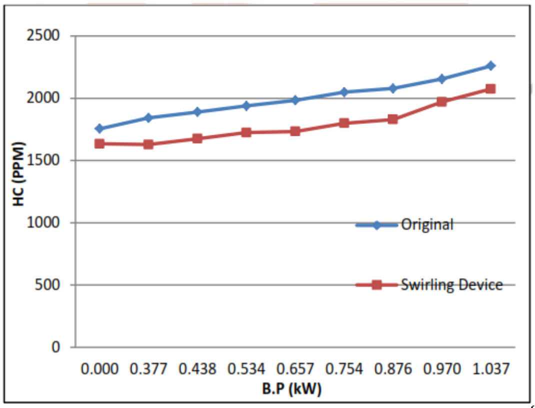


Figure 8. CarbonMonoxideversusBrakePower[9] Figure 9.UnburnedHydrocarbonsversusBrakePower[9]

Volumetric efficiency decrease, as there is obstruction to flow due to swirling device attached to intake manifold. But maximum percentage decrease in Volumetric Efficiency obtained is 4.00 % at full brake power. Carbon monoxide and unburned hydrocarbon emissions are reduced in large amount. Maximum decrease in percentage is 16.90 % and 12.01 % respectively. So, from above findings, it is concluded this Swirling Device improves performance and emission of SI engine.

Sarang et al. [10] worked upon comparison of various swirl generating devices in single cylinder SI engine. Engine referred for this study was Kirloskar TAF-1 which had a capacity of 662cc. Total three swirl generating devices were modeled and analyzed in ANSYS–Fluent. The swirl generating devices were inserted inside the intake port of the Engine. The objective of paper was to find the effect of swirl on the engine and to compare it with the existing base model. It was found that the swirl helped in providing initial Location of device angular momentum to charge before entering cylinder and thus providing improved combustion phenomenon. With analysis, it was found that blade type device added advantage of comparatively increased velocity and swirl motion at outlet, however actual strength of swirl generated would be precisely calculated only after actual installation of device.

Table 1. Specification of device[10]

OverallLength	80mm
InnerDiameter	40mm

Figure 10.Markedlocationofdeviceonengine.[10]

Total 3 such devices were modeled and their flow performance was compared with base system (without any swirl device). All comparisons were done in ANSYS–Fluent and compared on basis of outlet velocity, pressure drop across device and turbulence kinetic energy of device.

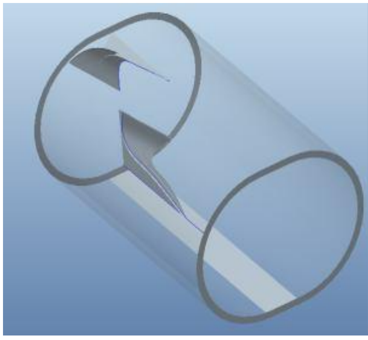
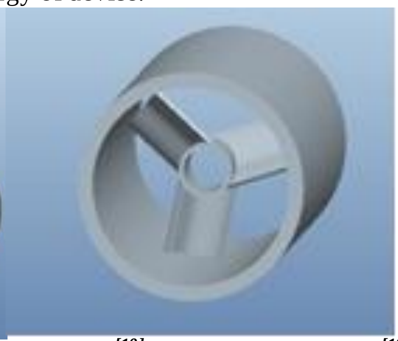
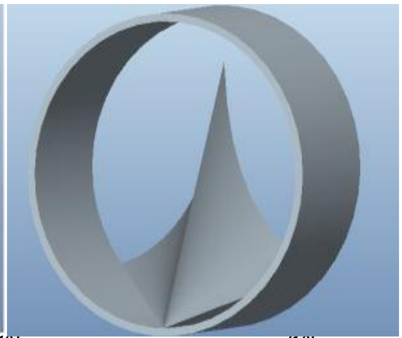




Figure 11.VaneType.[10]Figure 12.BladeType.[10]Figure 13.DeflectorType[10]

Table 2.Evaluatedvaluesforalldevices[10]

Model	**Pressure drop(pa)**	**Outlet velocity(m/s)**	**Strengthof swirlgenerated**
Base Model	3249	78.36	Very Less
Vane Type	6000	92	Medium
Blade Type	4078	69	High
Deflector Type	2254	67	Less

From above evaluated values for all devices, it was concluded that blade type geometry generated high swirl as compared to others, also one can explore the possibility of variable swirl in this device. Pressure drop across this device was less as compared to other and thus its implementation in intake duct of engine was justified. This study gave information about which device is more effective in swirl generation, however actual strength of swirl generated would be validated precisely only after the implementation of device in intake manifold.

Idris et al. [11] 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 on the air flow characteristic. Finally it is found that with six 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 o to 60o it was found that with 35o vane angle in-cylinder air pressure increased by 0.02%, total kinetic energy of air by 2.7% & velocity of air by 1.7% compared to the unmodified diesel engine.

Mohiuddin et al. [12] investigated the swirl effect on the engine performance by using insert swirl adapter. The testing was carried out on the protons campro engine model of 1.6 liter. In swirl device adapter blade angle is maintained at 30 o & is fitted in the intake port. Obtained results were compared with the normal engine & it was 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.

Shenghua[13] investigated the effect of new swirl system & its effect on DI engine economy. In this, ring type generator with four curvilinear blades used. The generator was fitted in the intake air duct & the comparison was carried out, the result found out that with 1500 rpm effective swirl was generated and with reduced emissions.

Karthikeyan et al. [14] investigated that from the AVL BOOST software, sudden increase in pressure waves are observed with previous manifold design. The previous intake manifold was unable to provide uniformly distributed air to all cylinders. Due to that reason, performance of the engine was not good. Increasing smoke level indicated this thing. Hence, the initial inlet manifold was optimized for uniform flow, with the help of CFD software. By CFD results, mass fraction of air observed for all the 3 runners at 1800 rpm was 76%. Next, experimentally air pressure inside the runners were investigated and increased air pressure of 13% showed increasing air flow inside the runner for the optimized inlet manifold design. The reduced smoke level indicated better air and EGR mixing inside the engine using optimized manifold.

III. CONCLUSION

From this review, it can be concluded that, design of inlet manifold configuration has very much importance in IC-engine. Uniform combustion air distribution to each inlet port of cylinder head is the main function of inlet manifold. Flow is evenly distributed to the piston inlet valves by an ideal inlet manifold. Optimum efficiency and performance of the engine is obtained when this even distribution occurs. Volumetric efficiency is also influenced strongly by inlet manifold. If the distribution of air is uneven, then it leads to reduction in volumetric efficiency, power loss and fuel consumption also increases. Hence, there is a scope for research in variation of the geometry of inlet manifold to check effect in increasing the velocity and volumetric efficiency and even distribution of air/fuel mixture to the cylinders.

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