

A Review Paper on Effect of Intake Manifold Design on C.I Engine Performance and Soot Formation

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ABSTRACT: Fluid motion in Compression Ignition engine is induced during the induction process and later modified during the compression process. The problem in compression ignition engine is soot formation which is formed due to improper mixing of air and fuel. In order to reduce the soot formation proper mixing of air and fuel particles should take place which improves the engine performance. With the change of intake manifold design the final velocity of the air entering the engine cylinder gets altered leading to the variation of many engine parameters which includes fuel consumption, swirl, power output, etc. In this paper I have studied some papers and also gone through basics of my topic from various books to understand the phenomena.

KEYWORDS: Soot, Compression Ignition, Inlet Manifold, Swirl

I. INTRODUCTION

Thermal energy (heat) is one of the oldest forms of energy known to mankind. Thermal energy is usually evolved from energies such as chemical energy and electrical energy. The device for converting one form of energy to another is termed as engine.

In an energy conversion process the conversion efficiency plays a vital role and it determines the efficient use of the supplied energy. Heat engine is the device that can transform chemical energy of a fuel into thermal energy and utilizes this thermal energy to perform useful work in other words the engine that can convert the basic thermal energy into the useful mechanical work is the heat engine.

A diesel engine (also known as a compression-ignition engine) is one type of heat engine which comes under the category of internal combustion engines uses the heat of compression to initiate ignition for burning the fuel injected into the combustion chamber during the final stage of compression. The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio.

In Direct injection diesel engines fuel is injected directly onto the compressed air and gets mixed depending upon the motion of the air in the chamber. The in-cylinder fluid motion in internal combustion engines is one of the most important factors controlling the combustion process. It governs the fuel-air mixing and burning rates in diesel engines. In-cylinder flow field structure in an internal combustion (I.C) engine has a major influence on the combustion, emission and performance Characteristics. Fluid enters the combustion chamber of an I.C engine through the intake manifold with high velocity. Then the kinetic energy of the fluid results in turbulence and 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.

The increased turbulence causes better cooling of the cylinder surfaces thereby reducing the heat loss to the surroundings. The heat from the cylinder walls gets absorbed by the air supplied during suction and used for reducing the delay period thereby increasing the thermal efficiency of the engine. Air is directed into the cylinder through the

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inlet manifold and this air flow is one of the important factors, which governs the engine performance and emissions. It is quite familiar that a designed intake manifold is essential for the optimal performance of an internal combustion engine. Hence the flow phenomenon inside the intake manifold should be fully optimized to produce more engine power with better combustion and further reduces the emission. In general the position of the intake valve is designed in such a way to generate better swirl when the air is induced into the cylinder.

II.LITERATURE SURVEY

IdrisSaad et al.[1] 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 4vanes but the resistance in the flow way is increased on other hand. The vane angle is varied from 30 to 600 it is found that with 350 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.

Mohiuddin[2] investigated 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 3500rpm BSFC increases.

LiuShenghua[3] 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 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.

PankajN.Shrirao et al.[4] 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.[5] 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 insteps 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. [6], 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.

S.L.V. Prasad, V. Pandurangadu [7], have experimentally investigated the effect of air swirl generated by directing the air flow in intake manifold on engine performance. They have performed experiments on single cylinder 4-stroke water cooled engine at constant speed of 1500rpm. The turbulence is achieved in the inlet manifold by grooving the inlet

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manifold with a helical groove of size of 1 mm width and 2 mm depth of different pitches to direct the air flow. 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.

Jorge Martins, Senhorinha Teixeira & Stijn Coene [8] , have re-design the inlet port of a small I.C engine in order to have better turbulence by swirl. For this work they have used three software programs viz. Solid Works, Gambit and Fluent. With optimal Geometry design of the inlet manifold assembly, which was consist of cylinder, valve seat, valve and valve guide. They have done the meshing of the assembly with the three different valve lifts: 1.5mm, 2.0mm and 2.5mm. Finally they have used this model in FLUENT for simulations. The simulations were made to measure the swirl on a spark ignition combustion engine. For different valve lift they have analyzed that the required amount of swirl is created between 1.5 to 2.0 mm valve lift.

Benny Paul, V. Ganesan [9] , worked on the comparisons of volumetric efficiency with three different configurations viz. helical, spiral an helical-spiral combination at 3000rpm speed on single cylinder 4-stroke engine. Three-dimensional model of the manifolds and the cylinder is created and meshed using the pre-processor GAMBIT. The flow characteristics of these engine manifolds are examined under transient conditions using Computational Fluid Dynamics (CFD) code STAR-CD. The turbulence is modeled using k- ϵ model. The solid model was consisting of intake manifold and cylinder geometry with valves. At the end of analysis they found that the swirl inside the cylinder is more in case of Helical- Spiral combined manifold then spiral manifold, which is recommended for better engine performance and less emission.

Suresh .Aadepu, I.S.N.V.R. Prasanth, Jarapala.Murali Naik, [10] , have design the intake manifold of an 870cc naturally aspirated ,twin cylinder diesel engine to achieve the higher volumetric efficiency with taking care of space considerations in to account. For the above purpose they have made two models in Pro-e and then did the CFD analysis. They have also used the Boundary conditions and K- ϵ , turbulence model for the steady state conditions. Using this method , a better design of manifold giving 7% increase in volumetric efficiency could be achieved.

S. A. Sulaiman, S. H. M. Murad, I. Ibrahim and Z. A. Abdul Karim [11] studied the flow characteristics of air flowing in various designs of air-intake manifold of a 200-cc four stroke Go-Kart engine. The study is done by three dimensional simulations of the flow of air within six designs of air-intake manifold into the combustion chamber by using commercial CFD software, Fluent version 6.2. The simulation results are validated by an experimental study performed using a flow bench. The study reveals that the variations in the geometry of the air-intake system can result in a difference of up to 20% in the mass flow rate of air entering the combustion chamber. Comparisons between the experimental and simulation results with two intake manifold configurations show reasonably good agreement, thus suggesting the reliability of the simulation in demonstrating the effects of valve lifts and intake manifold configurations. From the simulation work it is seen that the flow in the intake manifold can never become fully developed due to the short pipe length, and this may probably affect the flow coefficient. In the simulation using a new design of intake manifold, which had a surge tank with tapered edges and bell mouth inlet, the flow coefficient is shown to be improved by up to 6% and is found to be better than the existing carbureted system.

B. Murali Krishna and J.M. Mallikarjuna [12] , worked with the experimental investigations of the in-cylinder fluid tumble flows in a motored internal combustion engine with a flat piston at different engine speeds during intake and compression strokes using particle image velocimetry (PIV). The two-dimensional in-cylinder flow measurements and analysis of tumble flows have been carried out in the combustion space on a vertical plane at the cylinder axis. To analyze the fluid flows, ensemble average velocity vectors have been used. To characterize the tumble flow, tumble ratio has been estimated. From the results, it is found that the tumble ratio mainly varies with crank angle positions At the end of compression stroke, maximum turbulent kinetic energy is more at higher engine speeds. Present study will be very useful in understanding the effect of engine speeds on the in-cylinder fluid tumble flows under real engine conditions. On the whole, it is found that for an engine equipped with flat piston, TKEs are higher at higher engine speeds among the low speed.

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D.Ramasamy, Zamri.M, S. Mahendran, S.Vijayan [13], have worked on the optimizing the geometry of an intake system in automobile industry to reduce the pressure drop and enhance the filter utilization area by adding guide vane. 3D viscous Computational Fluid Dynamics (CFD) analysis was carried out for an existing model to understand the flow behavior through the intake system, air filter geometry and ducting. Results obtained from CFD analysis of the existing model showed good improvement. They have also performed another work on existing model CFD results, geometrical changes like guide vane placement in inlet plenum of the filter, optimization of mesh size, removal of contraction in clean pipe of intake system etc are carried out, to improve the flow characteristics. The CFD analysis of the optimized model was again carried out and the results showed good improvement in flow behavior. By using 3D CFD analysis, optimal design of the intake system for an automobile engine is achieved with considerable reduction in development time and cost. As the result of the above CFD they found that all the above changes incorporated in the design of the guide vane improved overall pressure drop by 12.01% for the rpm speed of 1000 to 7000.

Martínez-Sanz, S. Sánchez-Caballero, A. Viu, R. Pla-Ferrando [14], have designed a high performance intake manifold through a combination of CAD and FEM. First a FEA model was done, which included a complete thermal and structural analysis of the new intake manifold and the contact area between the aluminum coupling, using the combined tools of CATIA, ANSYS WORKBENCH, MATHCAD. Then several composite prototypes were made where analyzed. As a result they found that the compact design of the manifold increases the performance of the engine and the space requirements are also reduced.

F. Payri, J. Benajes, X. Margot and A. Gil [15], have studied the flow characteristics inside the engine cylinder equipped with different piston configurations were compared. For this, complete calculations of the intake and compression strokes were performed under realistic operating conditions and the ensemble-averaged velocity and turbulence flow fields obtained in each combustion chamber analyzed in detail. The results confirmed that the piston geometry had little influence on the in-cylinder flow during the intake stroke and the first part of the compression stroke. However, the bowl shape plays a significant role near TDC and in the early stage of the expansion stroke by controlling both the ensemble-averaged mean and the turbulence velocity fields.

S. Siva, Dr.M.Subramanian And K.Sivanesan [16], have studied on validating the fundamental numerical and computational fluid dynamic aspects which can lead to the definition of following models. The models used for analysis of Standard k- ϵ model, Realizable k- ϵ model, V2F k- ϵ model, AKN k- ϵ model, and Standard k- ω (Wilcox) model. Modeling of the KIRLOSKER OIL ENGINE TV1 was done using GAMBIT. Flow inside the engine is analyzed and validated by various turbulence models using STARCD. The cold flow simulation is carried out with various turbulence models under adiabatic wall boundary condition. The pressure distribution and temperature distribution and contours of the cold flow simulations for Standard k- ω (Wilcox) model was nicely match with the experimental results.

Jay V. Shah and Prof. P.D.Patel [17], have worked on the orientation of the Intake Manifold was changed by inclining it at several different angles viz. Normal Intake Manifold, Intake Manifold at 25° inclination, 50° inclination and 75° inclination w.r.t. Normal Intake Manifold Position and then the effects of these different orientations of the Intake Manifold on the Performance and Emission parameters of the Single Cylinder 4-Stroke naturally aspirated Diesel Engine were analyzed and then comparisons of the computed results were made with those of the Normal Intake Manifold. From the experimental research work, they found that the BSFC reduces, brake thermal efficiency increases and there is an improvement in the exhaust gas emissions as orientation of the Intake Manifold is changed from Normal Manifold Position to 50° inclination w.r.t. Normal Manifold Position.

Y.K. Loong and Salim M. Salim [18], have studied the Computational Fluid Dynamics (CFD) using k-epsilon model with standard wall function was applied to simulate and quantify the improvements of the new design by benchmarking against the original intake. It was found that the original intake manifold from the manufacturer could be improved by more than 79% by changing the geometry, shape and surface finish. Based on the results, they found that the new and improved intake manifold port has a much higher mass flow rate capacity based on CFD simulations. The main reasons for the improvement are due to the surface finish and geometry of the intake manifold. The distribution balances between all 4 cylinders are also almost equal which helps in providing a proper air fuel mixture which in turn will increase the performance and efficiency of the engine.

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III. CONCLUSIONS

From the review of literature, it can be analyzed the design of inlet manifold configuration is very important in a CI engine. In general, the presence of a swirl in the cylinder of an internal combustion engine improves proper mixing of air and fuel which enhances combustion rate and reduces formation of soot

The design of the Intake Manifold has a major influence on the C.I Engine which in turn creates swirling motion of the air due to which thermal Efficiency increases by reducing the formation of soot in turn reduces emissions.

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