# A Review Paper on Effects of Intake Manifold Design on Diesel Engine Performance and Emissions

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*Abstract*— One of the objectives of car manufacturers is to improve engine performance, reduce consumption and reduce emissions. To achieve this objective, it is important to understand the phenomena involved in the combustion chambers of engines. There are various factors that influence the engine performance such as compression ratio, atomization of fuel, fuel injection pressure, and quality of fuel, combustion rate, air fuel ratio, intake temperature and pressure and also based on piston design, inlet manifold, and combustion chamber designs etc. Geometrical design of intake manifold is one such method for the better performance of an I.C. Engine. Air swirl motion in CI engine influences the atomization and distribution of fuel injected in the combustion chamber. Intake manifolds provides Air motion to the chamber. So, to get the maximum output with the least input on Diesel engine researchers are experimentally and computationally working on construction of the intake manifold configurations for increase in engine performance and reduction of Exhaust Emissions. In this paper i have studied few papers and also gone through basics of my topic from various books to understand the phenomena.

***Key words:*** Combustion, compression Ratio, Inlet Manifold, Swirl

## I. INTRODUCTION

Internal combustion engines are the engines which burn the fuel inside it and produce the energy. Of all the engines the direct injection diesel engines have their own importance because of their higher thermal efficiencies than all the others. They can be used for both light-duty and heavy duty vehicles.

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. Air is directed into the cylinder through the inlet manifold and this air flow is one of the important factors controlling the combustion process. It governs the fuel-air mixing and burning rates in diesel engines. Air 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. The increased turbulence causes better cooling of the cylinder surfaces thereby reducing the heat loss to the surroundings. The heat from the cylinder walls get absorbed by the air supplied during suction and used for reducing the delay period thereby increasing the thermal efficiency of the engine. [19],[20].

Two general approaches are used to create swirl during the induction process. In first approach, swirl is created by discharging the flow into the cylinder tangentially towards the cylinder wall (helical port) and in the second approach, the swirl is generated in the manifold runner so that the flow rotates about the valve axis before it enters the cylinder. In general, the presence of a swirl in the cylinder of an internal combustion engine improves the homogenization of the air-fuel mixture, and consequently, enhances fuel combustion. [22],[23].

## II. LITERATURE SURVEY

**Dr. Pankaj N.Shrirao, Dr. Rajeshkumar U. Sambhe** [1] , 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.

**V.CVS Phaneendra,V.Pandurangadu & M. Chandramouli** [2] , 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.

**S. L. V. Prasad, V. Pandurangadu** [3],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 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.

**P. Ramakrishna Reddy ,K. Govinda Rajulu, T. Venkata Sheshaiah Naidu** [4] , 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 less amount of emissions in comparison with normal manifold.

**Jorge Martins, Senhorinha Teixeira & Stijn Coene** [5] , 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** [6], worked on the comparisons of volumetric efficiency with three different configurations viz. helical, spiral a 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,** [7] , 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** [8] 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** [9] , 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.

**D.Ramasamy, Zamri.M, S. Mahendran, S.Vijayan** [10] , 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.

**Idris Saad and S. Bari** [11] ,have investigates the in-cylinder air flow of a compression ignition (CI) engine modified by a guide vane swirl and tumble device (GVSTD) where the number of GVSTD vanes was varied to optimize its dimension to improve the CI engine performance using higher viscous fuel (HVF). Hence, eleven 3D CI engine models were developed; a base model and 10 GVSTD models, via Solid Works. Computational fluid dynamics (CFD) were performed by utilizing ANSYS-CFX and simulated under motored conditions for two continuous complete cycles. The results are presented of the simulation of in-cylinder pressure, turbulence kinetic energy (TKE) and velocity during the fuel injection period until expansion. It was found that six vanes improved about 1.3% of in-cylinder air pressure, 2% to 8.3% of TKE and a maximum of about 22% of velocity. Six vanes were chosen as the best number of vanes to be coupled with 0.2 times radius of the vane height, 35° twist angle of the vane and an intake runner three times the radius of the vane length.

**A. Martínez-Sanz, S. Sánchez-Caballero, A. Viu, R. Pla-Ferrando** [12], 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** [13] , 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** [14], 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 were nicely match with the experimental results.

**Jay V. Shah and Prof. P. D. Patel** [15] , 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** [16], 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 is almost equal which helps in providing a proper air fuel mixture which in turn will increase the performance and efficiency of the engine.

**Laxmikant P. Narkhede & Atul Patil** [17] , have studied work the flow within the intake port in both steady and unsteady states and analyze the results to evaluate and improve the ability of the intake port to convey air identically to all cylinders with the least possible pressure losses. Also the effect of engine speed on the volumetric efficiency has been analyzed by 2D CFD model at different engine speeds. Steady state air flow calculations are performed for three different intake valve lifts viz. low lift, medium lift and high lift to investigate the flow features. Sufficient mesh refinement has been provided near the throat area because the flow velocity changes rapidly in this region and capturing the gradients is key for an accurate simulation. The calculations are performed by solving compressible Navier-Stokes equation for mass, momentum and energy. Also two equation turbulence model, Realizable κ −ε is used to capture the flows involving rotation, boundary layer under strong adverse pressure gradients, separation and recirculation. The CFD code of STAR-CD for finite volume method has been utilized to solve the discredited continuity and Navier- Stokes equations. then they have did the meshing of in the CFD and at the end as a result they found that the better performance and improvement in the exhaust emissions.

**Amit Kumar Gupta and Abhishek Mishra** [18] have studied the current design of the intake manifold of truck engine and found that truck engine is having less plenum volume which is not suitable for air requirement of engine and hence result in reduced volumetric efficiency. To simplify the design & make the component in pressure die casting & to increase the yield also to qualify the engine noise, performance and durability requirement and to reduce the part cost new inlet manifold is designed and developed. for this they have carried out various design concepts will be evaluated like equal runner length Design, Centre Feed Design, Dual Plenum design will be evaluated and also design requirement at air intake system level. Initially they concept is made and then with the help of CFD they have try to optimize the shape and size and then through prototyping and bench test confirmation of performance they performed test.

## III. CONCLUSION

From the review of literature, it can be analyzed the design of inlet manifold configuration is very important in an CI engine. In general, the presence of a swirl in the cylinder of an internal combustion engine improves the homogenization of the air - fuel mixture, and consequently, enhances fuel combustion. From literature survey, different findings are concluded.

– Combustion efficiency of Diesel Engine can be increased, by creating swirl of air by proper designing of intake system.
– Swirling motion of an air is a strong function of engine speed. As speed is increased, swirl increases and this increases the rate of evaporation, mixing of air-fuel and leads to complete combustion.
– The CFD analysis of the intake manifold for optimum air swirl in the cylinder is useful to save the time and cost in the experimental test.
– The design of the Intake Manifold has a major influence on the air flow- field generated within the Diesel Engine Cylinder which in turn helpful to get maximum engine output, minimum fuel consumption, highest thermal efficiency and least exhausts emission.

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