Special Issue on Proceedings of International Conference on Newer Trends and Innovation in Nanotechnology, Materials Science, Science and Technology March 2021. International Journal of Aquatic Science, Vol 12, Issue

Review on Design and CFD Analysis Of Intake Manifold Port For Increasing Engine Performance

Madana Gopal, R[1] and Arun Kumar, N. K.[2], V.Rajasubramanian[3]

[1,2]Assistant Professor, Department of Automobile Engineering, Nehru Institute of Technology, Coimbatore
Correspondent e-mail:rishirajaraja@gmail.com

Abstract- The aim of this project is to increase the efficiency and performance of the engine by improving the design of the intake manifold port. Air or Air fuel mixture inside the intake manifold is one of the important factors, which governs the engine performance. 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.

Various journals were reviewed in this paper, and in new engine development the pressure waves for the intake manifold is designed using Unigraphics NX-8.0 software and simulated using Ansys workbench 14.5 Fluent software, to study the internal air flow characteristic for the multi cylinder diesel engine. The simulations are carried out by using different steady state conditions Reynolds Averaged Navier Stoke (RANS) turbulence models such as Standard k-epsilon (k-ε) Re- Normalization Group k-ε (RNG), Realizable k-ε, k-omega (k-ω) and Reynolds Stress Model (RSM). Modeling and analysis carried out for conventional existing manifold and results were determined. Also new models created for future simulation work to study, compare and to provide better performing Intake manifold port.

Keywords:- Realizable,k-omega, Navier Stoke Reynolds Stress Model

1. Introduction

Engines are being developed to achieve high performance and gaining the potential to fulfill the need of next generation. The main objective of this introductory chapter is to sketch out a brief review of Automobile Sector such as concept of Intake Manifold port, for better performance in developing engines and there benefits to the Automobile world. In automotive engineering, an Inlet manifold or Intake manifold is the part of an engine that supplies the fuel/air mixture to the cylinders. 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 heads. Even distribution is important to optimize the efficiency and performance of the engine. It may also serve as a mount for the carburetor, throttle body, fuel injectors and other components of the engine.

Air flows through the air filter which provides 'clean' air to the engine, the sole task of the air filter is to remove any particulate matter from the air to reduce the potential for wear and or damage to engine components. The air the passes through a section of piping, the length of this section of pipe is almost entirely dictated by geometric constraints around the engine. From here the air passes through the throttle body, the role of a throttle body is to control the amount of air which is allowed to pass into the engine.

Fig 1.1: Conventional Intake Manifold

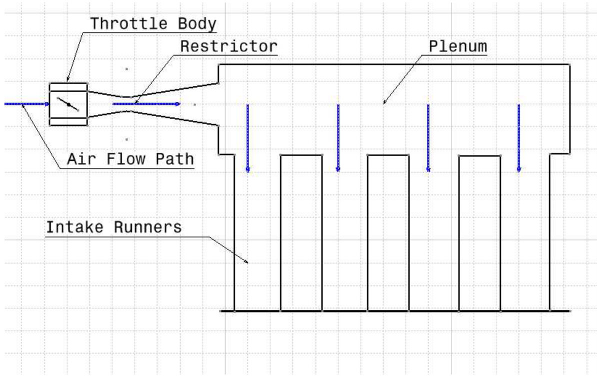

Fig 1.2: Cross section of a basic intake manifold

The objectives of the research project are as follow:

• To obtain valid intake gas condition such as gas temperature and pressure from a running internal combustion engine.

• To validate CFD simulation against experimental setup on engine.

Two sensors were connected to the engine control unit using a wiring harness. The two sensors are Air Temp Sensor and Manifold Air Pressure Sensor from Haltech. (Y.K. Loong1, Salim.M et.al 2013) Based on the results, it can be seen that the new and improved intake manifold port has a much higher mass flow rate capacity based on CFD simulations.

1.2 Optimizing Methodolgy

Based on the 1D simulation results (stage-I), the intake manifold design is optimized using 3D CFD software under steady state condition. The flow phenomenon and to study the internal air flow characteristic for the 3-cylinder diesel engine during transient conditions. As a result of this 3D CFD (stage-I) analysis, the disproportionate flow of air inside the runners is identified and pressure inside the runner is also experimentally investigated on the engine test bench. From the investigation, (Karthikeyan. S, Hariganesh. R et.al 2011) identified that the pressure inside the runners are uniform and smoke level is also reduced for optimized inlet manifold design. Results suggested that the sudden increase in pressure waves are observed with initial manifold design. The initial intake manifold is not able to provide uniform distribution of air to all the cylinders. Due to this performance of the engine is poor. This is observed by an increase in the smoke level.

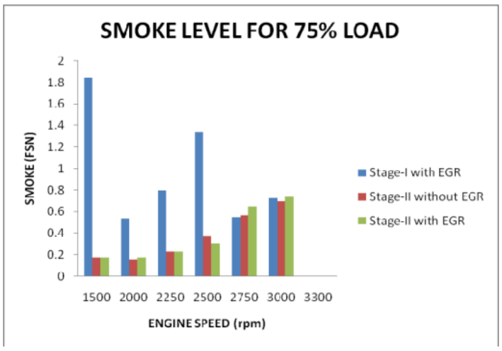

Fig 1.3: Smoke level for initial and optimized manifold for 75% load

The pressure drop for individual runners observed that the pressure drop across runners was non-uniform and higher-pressure drop was observed in runner 1 which is due to the large flow separation region near runner 1.The flow is highly three-dimensional. It is strongly dependent on the valve lift except upstream of the port bend. At higher valve lift flow separation is critical. From the steady state analysis the pressure drop for individual runners were determined. (B.M.Angadi, Anandkumar S Malipatil 2010) observed that the pressure drop across runners was non-uniform and higher-pressure drop was observed in runner 1 which is due the large flow separation region near runner 1. Both steady and unsteady state simulations have been accomplished for this case. Steady state simulation results are compared with flow bench rig data for validation. Boundary condition for unsteady state simulation was obtained from 1-D WAVE code. The 3-D Simulation of a XU7 Engine Intake Manifold and the results will be discussed. Three hypothetical models have been made that all of their runners' length is increased to 110,120 and 130% of initial value. Negin Maftouni , Reza Ebrahimi (2006) concluded this model, with 20% extended runners, the volumetric efficiency increases at 3500 and 4500 rpm.

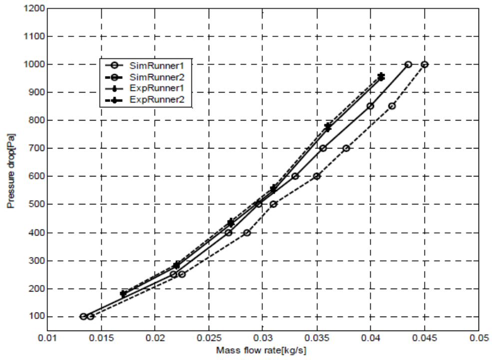

Fig 1.4: Comparison of Experimental and simulation results

According to these results some suggestion has been recommended to improve the performance of this intake manifold. To achieve a favorable volumetric efficiency in a wide range of engine speed, it is suggested to increase the length of IM runners to 120% of initial value.

1.3 Evaluation:

Each model produces almost similar results when it comes to pressure drop inside plenum and inlet velocity. However, RNG k- ε accounts for swirl dominated flow, predicting better flow conditions inside the manifold. Therefore, RNG k- ε is best to capture intake manifold flow turbulent conditions.

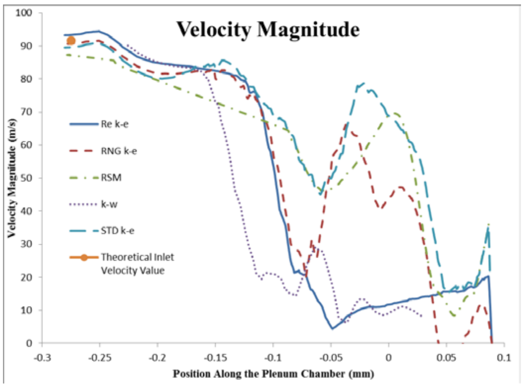

Fig 1.5: Velocity Magnitude

(M. M. Khan, S. M. Salim 2013) observed that velocity magnitude discretization of each model differs greatly while static pressure drop has almost the same results with minor fluctuations. The theoretically calculated inlet velocity (using the piston swept volume of 1.6L) is well predicted by RNG k- ε and Standard k- ε with up to 5 percent error while Realizable, k- ω and RSM shows discrepancies giving up to 10 percent error. For static pressure all model shows larger deviation in the pressure drop compared to experimentally calculated values.

To maximize the mass of air inducted into the cylinder during the suction stroke, the intake manifold design, which plays an important role, has to be optimized. The current manifold delivers a maximum volumetric efficiency of 84% at rated torque, i.e. 2400 RPM. The objective of the project is to achieve higher volumetric efficiency taking the space considerations into account. (Suresh.Aadepu, I.S.N.V.R.Prasanth 2014) used this method, a better design of manifold given 7% increase in volumetric efficiency was achieved.

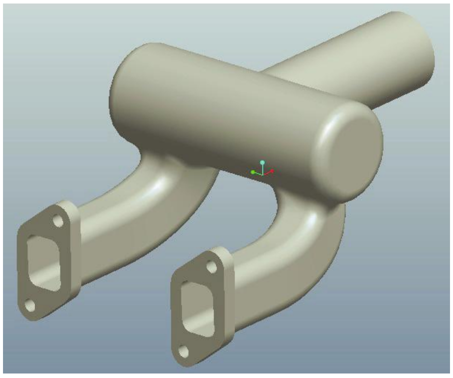

Fig 1.6: Pro-E model of manifold model

The project is to analyze the characteristics of the air-fuel mixture taking into account the inlet velocity of the mixture, other parameters and most importantly the size/dimensions of the plenum and runners or collectively the Intake manifold. Simulation of Flow dynamics inside an Intake manifold of a multi-cylinder SI engine. It has been done with the objective to find out the mixing model of the air-fuel mixture going through the turbulence phase in the plenum and runners of the manifold.

1.4 Experimental Test:

The internal flow characteristics in the intake manifold of a sixcylinder diesel engine are investigated computationally for the variation of spacer and chamber width under steady state. Model with spacer is more efficient than the other model without spacer. In the case of the engine performance test, with regards to the fuel consumption rate and smoke at low speed, the case of the model without the spacer decreased more than the model with the spacer. But at high speed, it shows a tendency to increase, contrary to the finding at low speed. In case of the model with the spacer, as the chamber width increased at low speed, the fuel consumption and the smoke level decreased, but increased at high speed.

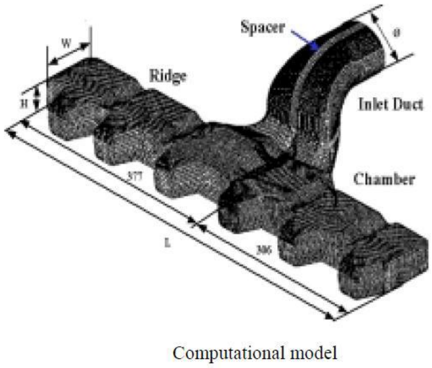

Fig 1.7: Computational model of six cylinder engine manifold

Therefore, in order to develop a high efficiency, low emission engine at high speed, the attachment of a spacer inside the intake manifold and the reduction of the chamber width are required for optimum results.

3. OBJECTIVE

For better performance of intake manifold, pressure inside the manifold should be higher and necessary changes should be made in geometry to achieve a peak pressure at outlet of manifold.

So the objectives of this research are:

- To reduce the pressure losses in intake manifold,
- To achieve equal velocity of air flow in all runners of intake manifold, and To propose new geometry model for IM to improve the performance of engine

4. Experimental work:

In this project I have modeled 3-D geometry of an intake manifold with one plenum and four runners in Unigraphics and then analyzed in fluent software. Numerous past models on intake manifold have been studied and observed with those experimental results and as well as theoretical results. The conventional model is first designed, simulated and results are obtained. After obtaining the results complete evaluation is done and sort out the issues like Losses, improvement in geometry etc.

Different intake manifold configurations were studied. By saying different configurations, it means that we can change the five variables, i.e. primary pipe runner and diameter, plenum volume, and secondary pipe length and plenum volume. But the primary pipe diameter cannot be changed as it is same as port outlet and the secondary pipe too cannot be modified as it connects air cleaner. Hence, the primary pipe length, plenum volume and secondary pipe length as used as variables.

4.1 Dimensioning of manifold:

The dimensions of a simple intake manifold are taken. The manifold has been tested at different velocities through it and when we have the results from its physical testing we can compare these results by using these basic dimensions.

Table 4.1: Dimension Of Intake Manifold

Inlet duct diameter mm	60
Length of plenum chamber mm	270
Diameter of runner outlets mm	40
Length of inner runners mm	80
Length of outer runners mm	300

After determining the shape and configuration of the Intake Manifold, another key feature to decide upon is its size. This size refers to the internal volume of the intake manifold. The size of the intake manifold directly affects the performance of the engine, but is a component that is difficult to determine the suitable size for. On the one hand, the intake manifold volume must not be too small. It is required that the intake manifold be at least the size of the engine capacity, such that it holds enough air to provide for the cylinders during each cycle. It is also recommended that the size be at least two times to allow the engine to be able to draw air while maintaining a stable pressure in the manifold. Tests have, however, determined that for a steady state analysis, the larger the intake manifold, the better, as it increasingly approximates to an open atmospheric environment from which the engine can draw air from.

However, while the static analysis of the airflow suggests that the manifold be as large as possible, an increasing large manifold has a detrimental effect on the throttle response of the race car, considering that the throttle body has to be located prior to the intake manifold. An example of this effect is that the pressure in a manifold that is very large will change very slowly, with respect to the

Special Issue on Proceedings of International Conference on Newer Trends and Innovation in Nanotechnology, Materials Science, Science and Technology March 2021. International Journal of Aquatic Science, Vol 12, Issue

change in the throttle position. On a race car, where the driver changes his throttle inputs at very quick rates, it would not be acceptable. The size of the intake manifold, must therefore, be a compromise between a size large enough to provide the individual cylinders with sufficient air, but yet not too large that throttle response is compromised.

5. Modelling of Intake Manifold:

Based on limitations of the other components in the air intake system determining the entry and exit points of the manifold, adjustments to the shape can be made through iterative flow simulations and analysis, targeting for a manifold that can allow the air to settle before entering the runners, as well as to ensure that the cylinders are evenly-fed air.
During the 3D model development for intake manifold, plenum and runner length and mixing area volume should be taken into account based on diesel engine requirement. Optimum engine cylinder charging is achieved by proper breathing of an engine and this depends on IM design.

Initially model designed for conventional employed diesel engine intake manifold with basic size and design considerations. Model created using two different types of modeling software namely CatiaV5 and Unigraphics NX.

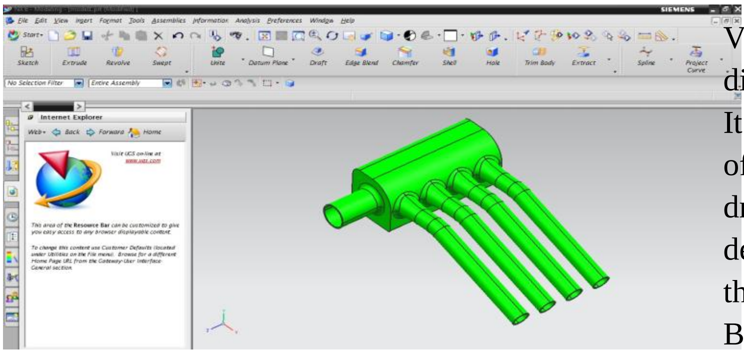

Figure 1.8: Model creation of conventional Intake manifold

6. CFD analysis of Intake manifold:

CFD simulation following steps:
1. Simplifying the geometry.
2. Setting up the model.
3. Meshing of the model which includes decomposition of complex geometry.
4. Post processing (analyzing meshing quality).
5. Defining boundary conditions (for CFD solver).

With using this method we can predict, observe and analyze the flow within an intake manifold and evaluate how the IM works under steady and unsteady situations. In this work the flow had been simulated in both steady and unsteady states and the results were analyzed to improve the intake manifold performance.

7. RESULTS AND DISCUSSION:

The steady state analysis has been carried out for Intake manifold plenum area. By this a volume inside the plenum area can be visualized and understanding better about the flow turbulence.

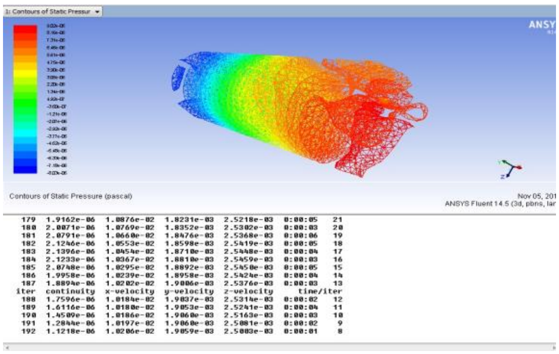

Fig 1.9: Pressure contour if IM air plenum area

Velocity vector give the good idea of velocity distribution inside the intake manifold plenum.
It is observed that velocity magnitude discretization of increases at the inlet area while static pressure drop occurs almost all over the plenum area due to design considerations and lack of air sucking inside that.
By simulating the various design parameters, a significantly improved design is needed to improve the flow turbulence which in turn helps increase the performance of the engine.

8. Conclusion:

Some reverse flow occurs inside the plenum area and travelling velocity from inlet to outlet decreases rapidly. This is because improper geometry of IM. In order to overcome these problems new model is created and analyzed with same boundary conditions and specs.

For future studies, it is important to model and analyze each new model using transient flow conditions for better accuracy and predictability of the flow inside IM.

Finally it should be noted that according to the experience of this work, 3-D simulation can be used as a strong and useful tool for design or optimization of intake manifolds.

9. Reference:

1. Y.K. Loong, Salim M. Salim (2013) Experimentation and Simulation on the Design of Intake Manifold Port on Engine Performance EURECA – Experimentation and Simulation on the Design of Intake Manifold Port on Engine Performance.
2. Karthikeyan S, Hariganesh R, Sathyanadan M, Krishnan S,(2011).“ Computational Analysis Of Intake Manifold Design And Experimental Investigation On Diesel Engine For LCV”, ISSN: 0975-5462, vol. 3 no. 4, International Journal of Engineering Science and Technology (IJEST).
3. B.M.Angadi, Anandkumar S Malipatil, V.V.Nagathan, R.S.Kattimani (2010) Modelling and Analysis of Intake manifold of a Multi-cylinder SI engine. Proceedings of the 37th National & 4th International Conference on Fluid Mechanics and Fluid Power, IIT Madras, Chennai, India
4. Negin Maftouni , Reza Ebrahimi (2006) Intake Manifold Optimization By Using 3-D Cfd Analysis With Observing The Effect Of Length Of Runners On Volumetric Efficiency. Proceedings of the 3rd BSME-ASME International Conference on Thermal Engineering, Dhaka, Bangladesh.
5. Suresh.Aadepu, I.S.N.V.R.Prasanth, Jarapala.Murali Naik,(2014) Design Of Intake Manifold Of IC Engines With Improved Volumetric Efficiency
6. M.A. Ceviz (2006) Intake plenum volume and its influence on the engine performance, cyclic variability and emissions Energy Conversion and Management 48 (2007) Elsevier Journal
7. M. M. Khan, S. M. Salim (2013) Evaluation of CFD Sub-Models for the Intake Manifold Port Flow Analysis. EURECA – Evaluation of CFD Sub-Models for the Intake manifold port flow analysis
8. Benny Paul, Ganesan V, (2010). “Flow Field Development In a Direct Injection Diesel Engine With Different Manifolds”
9. Jemni M .A, Kantchev G, Abid M. S, (2011). “Intake Manifold Design Effect On Air Fuel Mixing And Flow For An LPG Heavy Duty Engine”
10. Ceviz M.A and Akın M., (2009). “Design of a new SI engine intake manifold with variable length plenum” Elsevier Journal