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DESIGN AND OPTIMIZATION OF INTAKE MANIFOLD IN LIGHT DUTY VEHICLE

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ABSTRACT - *Intake manifold is a crucial part in an engine that acts as a medium for airflow to mix with the fuel before entering the combustion chamber. The primary function of the intake manifold was to deliver the air/air-fuel mixture to the engine cylinder through the intake port with least losses. In addition, based on the engine cylinder firing order, the flow must be evenly split among the cylinder. Intake manifolds affect the volumetric efficiency which ultimately makes impact up on the engine power and torque. Conventional intake manifolds have fixed geometry and thus does not cater for the demand of wide range of engine speed. Gas dynamics of intake system plays a key role deciding the performance of an engine. This dynamics are different for fuel injected and carbureted engine and vary according to type of engine, number of cylinders, temperature of inlet, valve timing, valve angle and other factors. This paper investigates the effect of intake runner length on the performance characteristics of a four cylinder compression ignition engine with electronically controlled fuel injector.*

Key Words*: Intake Manifold, fuel injector, *four cylinder compression ignition, short runner, plenum, runner.

1. INTRODUCTION

The word_manifold_comes from the Old English word 'manigfeald'. The word manigfeald which means 'manig' as many and 'feald' as repeatedly. Intake manifold refers to the multiplying of one (pipe) into many. 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.

The more air and fuel you feed your engine, the more power the engine is going to produce. This reduces weight significantly and production costs generally are reduced. Performance improves with the precise control of the interior surface finish and reduces air induction temperature.

There are three types of fuel injection system in the intake manifold:

1. Single Point
2. Multi Point
3. Direct Point

The proper entry of air to fuel mixture provides the greater swirl and increases in the efficiency of the engine.

1. Single Point Injection
2. Multi Point Injection
3. Direct Injection

Parts of fuel Injection Process:

1. Fuel supply
2. Air intake
3. Throttle
4. Intake manifold
5. Fuel Injector (or Injector)

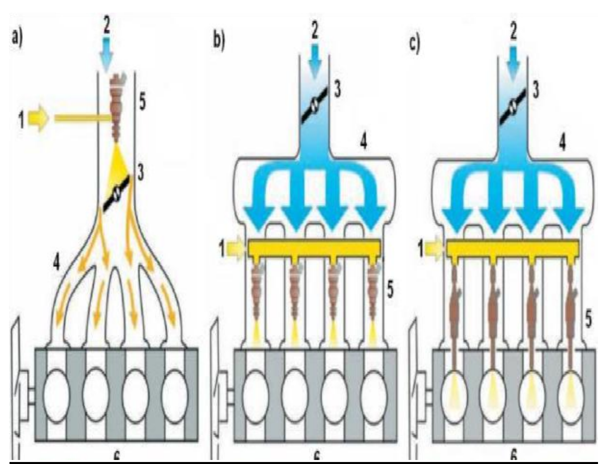

Fig 1: Systems of fuel injection

1.1 Scope:

The breathing capacity of the intake manifold should maximum for higher volumetric efficiency. The main aim or objective of any manufacturer is to create an efficient model by varying the dimensions of plenum or runner.

Intake manifold is the breathing system of any engine. Design of intake manifold for light duty locomotive engine by adopting different approaches and various analytical calculations also analyze fluid flow characteristics of intake manifold by using CAE and CFD.

Recent development in the computer simulation-based methods for designing automotive components had been gaining popularity even though the results obtained from numerical simulation (CFD) were comparable with the experimental studies; there's been continuous research to improve the simulation accuracy.

1.2 OBJECTIVES

1. Generate the mathematical model by referring analytical calculations.
2. Perform vibrational analysis to minimize the vibrations in manifold.
3. Find out localization of thermal Stresses and minimize their effects.
4. Determine the flow of air and fuel mixture and their effect in intake manifold by CFD analysis.

2. METHODOLOGY

Steps in Methodology

1. Analytical calculations for Runner diameter and plenum length
2. Generating the model using CAD software
3. CAE Analysis for determination of vibrations and localization of thermal stresses
4. Perform CFD analysis to study the flow of mixture and its through intake manifold
5. Verification and comparison of results
6. Optimization and reconstructing the model

3. LITERATURE REVIEW

Shrinath Potul, Rohan Nachnolkar, Sagar Bhave [1] described in Analysis of Change In Intake Manifold Length And Development Of Variable Intake System that Gas dynamics of intake system plays a key role in deciding the performance of an engine. This dynamic is different for fuel injected and carbureted engine and vary according to type of engine, number of cylinders, temperature at inlet, valve timing, valve angle and other factors. Careful design of the manifolds enables the engineer (designer) to manipulate the characteristics to the desired level. This paper investigates the effects of intake runner length on the performance characteristics of a four-stroke, single cylinder spark-ignited engine with electronically controlled fuel injector. In this paper basic intake tuning mechanisms were described. Engine performance characteristics such as brake torque, brake power, brake mean effective pressure and specific fuel consumption were taken into consideration and virtual simulation software LOTUS ENGINE SIMULATION was used to evaluate the effects of the variation in the length of intake plenum on these parameters. It was found that change in runner length had a considerable effect on the rpm at which peak value of torque was obtained (occurred). Accordingly, a system to adjust the manifold length (tuned adjustable intake pipe) was designed and developed. According to the simulation graphs, in order to increase the torque performance, plenum length must be extended for low engine speeds and shortened as the engine speed increases.

Arvindkumar K, Adhithiyan N Darsak & V S Dinesh c [4] described in Optimization of Intake Manifold Design Using Fiber Reinforced Plastic that In this paper we discuss the design and manufacture of an intake system for a 600cc YAMAHA ZF engine.

Intake system have a major effect on a vehicle's engine performance, noise and pollutants. Differences in engine outputs and applications require different designs of intake-air manifolds in order to achieve the best volumetric efficiency and thus the best engine performance. As a result, the geometry of the intake system has been redesigned to result in reduced weight by using FIBER REINFORCED POLYMERS (due to lower material density and lack of welds, thermal, heat aging, fatigue, impact, creep, stress and chemical resistance), improved charge distribution, and increased torque through a wide RPM range when compared to its traditionally-manufactured aluminum counterpart.

This lead to incorrect air/fuel ratios were some cylinders ran too lean at times, while others were running too rich. Incorrect air fuel ratios can lead to excessive exhaust gas temperatures, pre-ignition detonation, causing components such as head gaskets and pistons to fail. The new manifold is aimed at tackling these issues by supplying uniform amount of air to all four cylinders. 3D modeling is done using Solid-Works and the internal flow distribution will be calculated.

A Jason D'Mello, B Omkar S. Siras [3] described in Performance Analysis for 4-Cylinder Intake Manifold: An Experimental and Numerical Approach that the primary function of the intake manifold was to deliver the air / air-fuel mixture to the engine cylinder through the intake port with least flow losses. Also, based on the engine cylinder firing order, the flow must be evenly split among the cylinders. This had been investigated in this work for a 4-Cylinder IC engine intake manifold for five flow rates – 4 kg/min, 4.5 kg/min, 5.0 kg/min, 5.5 kg/min and 6.0 kg/min. CFD simulations, using STAR CCM+, were carried out for estimating the flow losses, mass flow distribution between the engine cylinders, swirls inside the intake manifold. The Realizable k-epsilon turbulence model with All Y+ Two Layer Model was applied for these simulations. An experimental validation was also carried out. An innovative boundary condition method for the CFD simulations was suggested for improving the CFD simulation accuracy. The flow path for the cylinders 2 and 4 provide high flow losses. Also, un-even distribution of the mass flow between the ports had been observed.

4. INTAKE MANIFOLD

The intake manifold connects the throttle body to the intake ports on the cylinder head. A manifold has a plenum or an air chamber where air is stored and a set of runners connected to the intake ports of the engine on the engine head. With port fuel injection, only air flows through the manifold and the top half of the runner. Fuel is injected into the air as it flows through the intake ports. When the throttle valve opens, air flows into the plenum. During the intake stroke, the intake valve opens and air-fuel mixture flows through the runners into the cylinder where combustion takes place. This auto part is not just a passageway for the mixture to flow into but it also contributes to a better distribution of the fuel and air.

4.1 Design Theory

Various design theories have been suggested throughout the history of intake, manifold development. The basic layout of the fuel injection manifold will be determined by its application. A racing application will generally, tend toward a design with one throttle plate per cylinder. Typically, a street manifold will employ just one throttle plate or one multi-plate progressive throttle body attached to a plenum that that will feed all cylinders. Because we are dealing with everyday user motorcycle engine, we opt for the single throttle body design because it generates a considerably crisper intake manifold vacuum signal. This greatly increases the accuracy with which low speed fuel and ignition can be calibrated and is this thus better suited to a street driven engine. Of the single plate throttle two plenum design theories have been prominent in the Racing team. The dual plenum and single plenum design. Though both design theories have their own benefits and disadvantages, the main deciding factor to select one of these plenums is based on a concept called resonance charging.

This pressure wave bounces back and forth in the runner and if it arrives back at the intake valve when the valve opens, it is drawn into the engine. This combination of synchronized events is known as 'resonant conditions'.

The following parameters affect resonance charging: -

1. Engine speed
2. The number of crank rotation degrees the intake valve is closed
3. Length of the intake runner tube
4. Volume of the plenum
5. Diameter of the intake runner

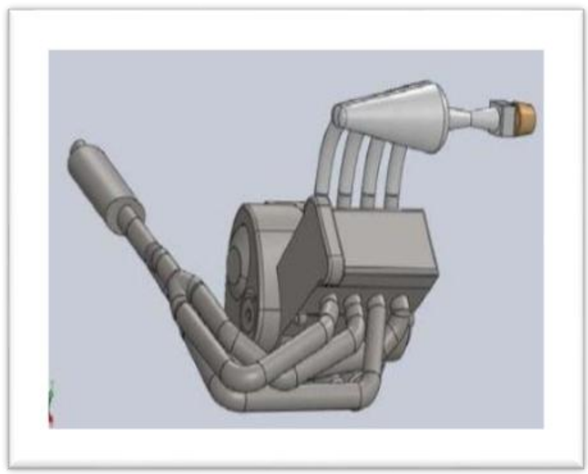

Fig 2: Assembled View of Manifold

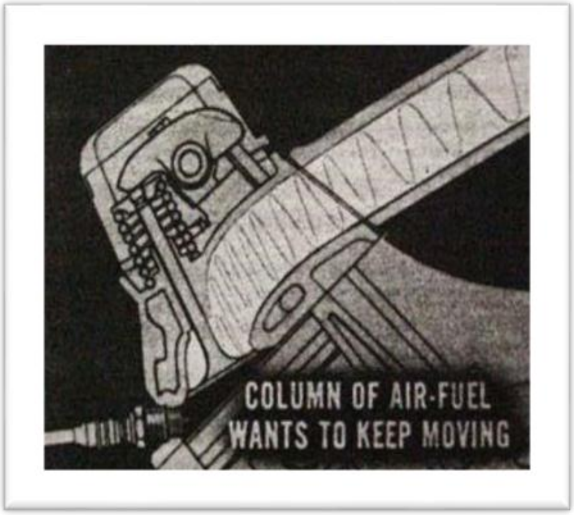

Fig 3: Column of Air-Fuel Wants To Keep Moving

4.2 ANALYSIS OF INTAKE MANIFOLD

CAE Analysis

Static Structural

The Pressure Loss Coefficients for individual runners can be determined.

3D CFD allows the designer to see what the flow structure is like inside the manifold

The Boundary Conditions in Steady State simulation can be Mass Flow

Rate, Constant Static or Total Pressure Can be used to make the design ready for unsteady state simulation

Transient State Analysis

1. Steady State study can be fast and can provide the loss coefficients but this cannot provide any information about an Intake Manifold performance in the operating
2. Conditions.
3. Transient simulation can predict how an Intake Manifold works under real world conditions.
4. The Boundary Conditions are no longer constant but time variant
5. These Boundary Conditions are obtained from the 1-D gas dynamics analysis by using the Wave Code.

CFD Analysis

Steps in CFD analysis

1. Simplifying the geometry
2. Setting up the model
3. Meshing of the model which includes reduction in geometry complexity
4. Defining boundary conditions
5. CFD-Post for results

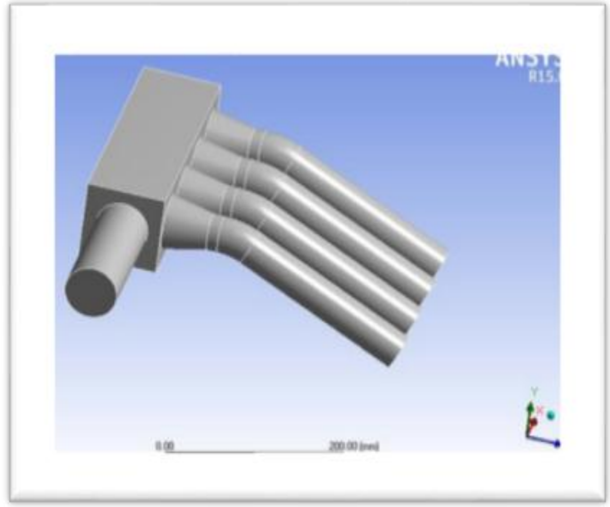

Fig 5: Manifold Geometry side view

5. Standard & optimized parameters

Sr. no.	Parameters	standard value	optimized value
1	Total pressure	5.31 Pascal	5.78 Pascal
2	Overall velocity	0.130 m/s	0.193 m/s to 0.214 m/s
3	velocity in runner	0.269 m/s to 0.401 m/s	0.326 m/s to 0.6 m/s
4	velocity at outlet of runner	0.906m/s to 0.969 m/s	1.28 m/s to 1.30 m/s
5	velocity at outlet	2.69 m/s	3.261 m/s
6	pressure at outlet	-	1.178 Pascal

Table 1: Comparison between standard and optimized parameter

6. CONCLUSIONS

Based on this extensive research work, the following were the conclusion.

A new CFD simulation methodology in terms of boundary conditions – For the intake manifold was proposed. The result from this approach was in close agreement with experimental data.

High flow swirl had been noted for all the operating conditions which could enhance the engine combustion characteristics.

It can be easily concluded that intake geometry made a conside5rable impact of outlet velocity. The main impact is on the volumetric efficiency of the engine which ultimately affects the torque and power produced a different engine speed.

The intake manifold design with less curvature at the runner. This is shown in results there is a percentage increase in outlet velocity as compared to conventional manifold model of INDICA VISTA.

Based on the computational fluid dynamics theory, three dimensional numerical simulation of the engine's intake manifold system is carried out, which is an effective and feasible method of analysis.

The results shows that the pressure loss and flow uniformity of intake manifold are two major evolution indicators.

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