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Intake Manifold Flow Study using Numerical Method with all Runners Opened

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ABSTRACT

Intake manifolds have to be designed to improve engine performance by avoiding the phenomena like inter-cylinder robbery of charge, inertia of the flow in the individual branch pipes, resonance of the air masses in the pipes and the Helmholtz effect. The objective of work is to predict and analyze the flow through intake manifold of four cylinder spark ignition engine. One of the important factors is air flow inside the intake manifold; the ideal intake manifold distributes flow evenly to the piston valves. The structural analysis has been conducted to decide the thickness and material that is suitable for intake manifold to withstand bursting pressure. Three-dimensional inlet manifold was modeled in ANSYS workbench and numerically analyzed by using the commercially available FLUENT software to study the pressure, velocity and flow characteristics inside the runner. The steady state analysis has been carried out for three for All runners open, The predicted results of total pressure loss and total outlet mass flow were discussed. Inlet pipe and plenum connection creates a back step geometry which causes more total pressure loss due to flow recirculation in conventional model. Tapering the geometry is causing more inlet mass flow due to reduction in total pressure loss in the plenum chamber.

Keywords: Fluent, Intake, Manifold, Runners

I. INTRODUCTION

An intake manifold is one of the primary components regarding the performance of an internal combustion engine. An intake manifold is usually made up of a plenum inlet duct, connected to the plenum are runners depending on the number of cylinders which leads to the engine cylinder. Intake manifolds have to be designed to improve engine performance by avoiding the phenomena like inter-cylinder robbery of charge, inertia of the flow in the individual branch pipes, resonance of the air masses in the pipes and the Helmholtz effect. Tuning the intake manifold means the intake runners are of proper size and length to produce the highest possible pressure in the cylinder when the intake valve closes. A tuned intake manifold takes advantage of the opening and closing of intake valves to produce slight “ram” effect, when the intake valve opens and air or air / fuel mixture flows into the cylinder. Theflow stops when the valve closes. However, due to the inertia of the air, a ram is created against the closed valve. If the intake valve opens while this is taking place, additional mixture is forced into the cylinder resulting in greater engine power. The ideal intake manifold distributes flow evenly to the piston valves. 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. The intake manifold has historically been manufactured from aluminum or cast iron but use of composite plastic materials is gaining popularity. The intermittent or pulsating nature of the airflow through the intake manifold into each cylinder may develop resonances in the airflow at certain speeds. These may increase the engine performance characteristics at certain engine speeds, but may reduce at other speeds, depending on manifold dimension and shape.

A. **Static Length Intake Manifold**

Static intake manifolds for vehicles have fixed air flow geometry and static intake manifold. With a static intake manifold, the speed at which intake tuning occurs is fixed. A static intake manifold can only be optimized for one specific rpm.

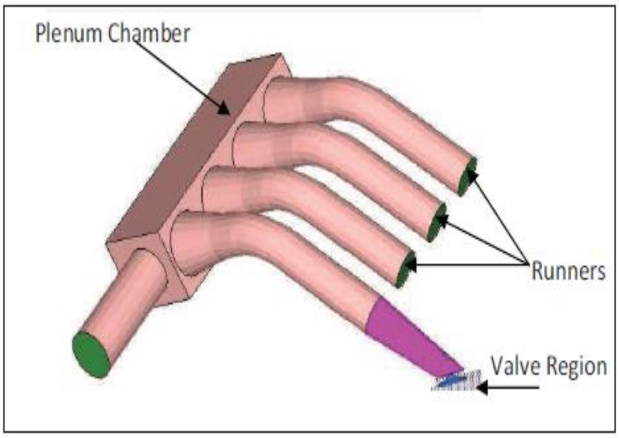

Figure 1. Intake manifold with plenum chamber

B. **Variable Length Intake Manifold**

Variable length intake manifold technology uses the pressure variations generated by the pulsating flow due to the periodic piston and valve motion to produce a charging effect. By varying the intake length/volume, we can operate engine over a broad speed range. Various designs for variable intake geometry have met with varying degrees of success. The designs of the variable intake manifolds may be rather complex and expensive, to produce. Difficulty in servicing and a limited range of variable tuning may also be disadvantageous design results of variable intake manifolds.

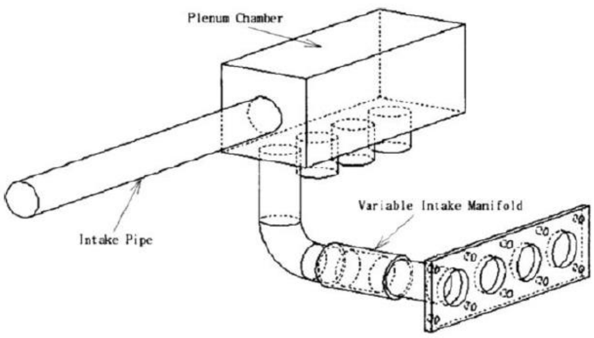

Figure 2. Variable length intake manifold

C. **Modification Scope of Intake Manifold**

The main task of an Inlet Manifold is to distribute air inside the manifold runner uniformly, which is essential for an optimized inlet manifold design. The inlet manifold design has strong influence on the volumetric efficiency of the engine. An uneven air distribution leads to less volumetric efficiency, power loss and increased fuel consumption .Depending on the amplitude and phase of pressure waves inside the inlet manifold, filling of cylinders by air can be affected positively or negatively. The amplitude and phase of these pressure waves depend on inlet manifold design, engine speed and valve timing. The unsteady nature of the induction means and the effect of the manifold on charging is extremely dependent upon the engine speed. This is because the entry of air inside the inlet manifold is a function of varying pulses. Therefore these pulses should be fine-tuned in engine manifolds to give required power.

II. LITERATURE

Abu Bakar[1] developed an advanced intake system for CNG fuelled engine. This study comes up with a design of mixer and a swirl-device that produced the combination of pressurized and turbulent flow in the intake process. A research mixer that combined a venturi-burner principles with three variables; 2,4,8 and 16 number of hole surrounding the mixing arena, input angles (300, 400,500 and 600) and output angles (200, 300, 400 and 500). A swirl-device has two variable; numbers of revolution (1, 1.5, and 2) and angle of plane (150, 300, 450 and 600). All models then fabricated and tested in a CNG engine performance test rig. Mardani Ali Sera[2] experimented to investigate the effect of air/fuel mixer on the engine performance and exhaust emission of a CNG fuelled engine. Three types of mixers were fabricated to create the turbulent effect of an air-fuel mixture. The modification is based on the mixing characteristics and turbulent coefficient. In this investigation, the CNG fuelled engine is not optimized. In order to get the optimum results, the CNG operation required some specific condition such as: high compression ratio, advance ignition timing, supercharge or turbocharge condition, intake valve close timing and a suitable air fuel ratio.

M.A. Ceviz[3] showsthe effects of intake plenum length/volume on the performance characteristics of a spark-ignited engine with electronically controlled fuel injectors. The results showed that the variation in the plenum length causes an improvement on the engine performance characteristics especially on the fuel consumption at high load and low engine speeds According to the test results, plenum length must be extended for low engine speeds and shortened as the engine speed increases. ZuoyuSun[4] proves swirling is very important phenomena used for efficient burning of fuel. Generally swirling is needed at the end of intake manifold.so introducing good swirler at the end of intake manifold increases the performance of the engine. In this paper, the authors design four types of swirler including one straight-shaped swirler and three arc-shaped swirlers. In order to research the fundamental characteristics of swirler, the authors make series of experiments researches. The results show that this new device can induces intake swirl efficiently and can improve fuel economy at on an optimized swirl ratio.David Chalet[5] shows simulation of pressure waves in inlet and exhaust manifolds of internal combustion engines remains challenging. A new model is presented in order to analyze these pressures waves without the use of a one-dimensional description of the system. It consists on studying the system using a frequency approach. The principle of the dynamic flow bench used here is to create an initial steady flow rate through the tested part and then to interrupt the flow very quickly in approximately 0.5 m/s. Inlet and exhaust manifolds can be studied by a one-dimension approach by solving the Euler equations. A new model equation is given,Han Wenyan[6] showsthe effects of both intake manifold length and valve timing on the torque, volumetric efficiency and fuel consumption are investigated To overcome the conflicts between low speed and high speed engine performance, variable valve timing(VVT) strategy is also investigated.. In modeling process, Wiebe's law for heat release behavior in the cylinder and Woschni's correlation for heat transfer to cylinder wall are modeled separately in simulation. Designing the intake system by taking into account the gas dynamic effect can result in the considerable torque improvement and it's called tuned induction. With the increase of intake manifold length, the maximum volumetric efficiency tends to lower speed and decreases earlier at high speed .So it conclude that Intake manifold length has a significant effect on volumetric efficiency and torque, long manifold increases them at middle speed but decreases at high speed. Backflow during valve overlap period occurs at high Speed problem overcomes variable valve timing (VVT).Matching valve timing with intake manifold length using gas dynamic effect can obviously improve engine torque and BSFC at low and middle speed.

Hyoun-Jin[7] Proposes an optimal design scheme to reduce the noise of the intake system by using support vector regression (SVR) techniques. In general, the intake noise is low frequency noise below 500Hz. The booming noise generated by the intake noise transferred to the interior of the vehicle has an uncomfortable impact on riding quality. Support vector regression (SVR) as an alternative technique for approximating complex engineering analyses. Therefore, we consider support vector regression, which is suitable for computer experiments, to improve the performance of the system with a low cost and time savings. V. V. NAGA DEEPTHI[8] studied the effect of air swirl generated by directing the air flow in intake manifold on diesel engine performance. The turbulence was achieved in the inlet manifold by grooving with a helical groove of size of 1mm width and 2mm depth of different pitches to direct the air flow in inlet manifold. 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.

III. METHODOLOGY

A. **CFD analysis of intake manifold**:

In CFD simulation following steps is follow:

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).

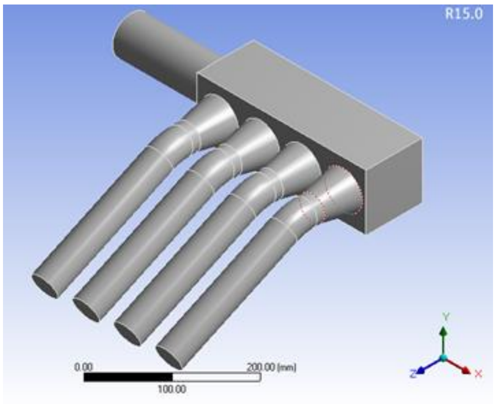

Figure 3. Geometry of intake manifold

B. **Meshing of model:**

Meshing: The accuracy of the results depends highly upon the meshing quality. Thus the choice of meshing scheme (grid pattern) is very important for fluent to provide accurate results. For doing simulation of the intake manifold model we have to do first meshing ,in this technique the flow domain is converted or split into various subdomain primitives like hexahedral and tetrahedral. Care must be taken to ensure proper continuity of solution across the common interfaces between two subdomains, so that the approximate solutions inside various portions can be put together to give a complete picture of fluid flow in the entire domain. We use the tetrahedral mesh for this purpose which imposed on model.

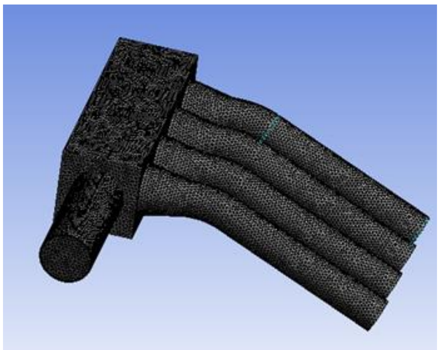

Figure 4. Meshing of intake manifold

C. **Boundary conditions:**

In this problem inlet is open to atmosphere and at outlet suction pressure will act due to pistons down motion. So inlet is chosen as pressure inlet and outlet is chosen as pressure outlet. Pressure inlet boundary condition needs total pressure at the inlet. The default value of reference pressure in the operation condition is given as 101325. So Gauge pressure (0) = Absolute pressure (101325) – reference pressure (101325). In the Turbulent – specification method needs to choose Intensity and length scale. Turbulent intensity value is assumed as per standard cfd assumption.

IV. RESULTS AND DISCUSSION

A. **Velocity:**

All runners open:

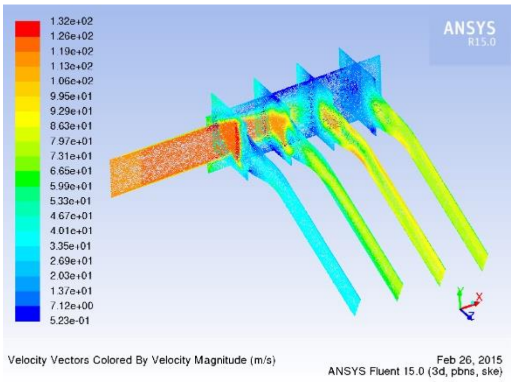

Figure 5 Velocity vector of intake manifold(all runners open)

From Fig it is observed that velocity drops as the flow proceeds through the plenum chamber. This is due to sudden increase of the area within the plenum. There is a drop in velocity at the inlet of the runner 1 compared to other runners when all runners are in open condition. This is due to a sharp bend at the region of runner 1 inlet and the plenum wherein the flow does not smoothly enter runner 1. At runner 2 and 4 local regions an increased in the velocity is observed.

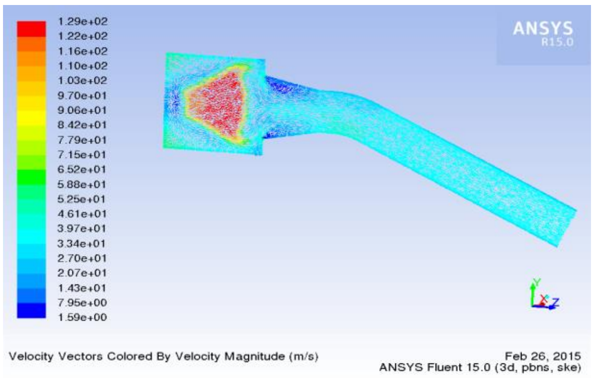

Figure 6 Velocity vector at runner 1(all runners open)

From Fig., it is observed that there is a drop in velocity at the inlet of the runner 1. This is due to a sharp bend at the region of runner 1 inlet and the plenum wherein the flow does not smoothly enter runner 1.

Fig ., shows the velocity vector at runner 2 when all runners are open.

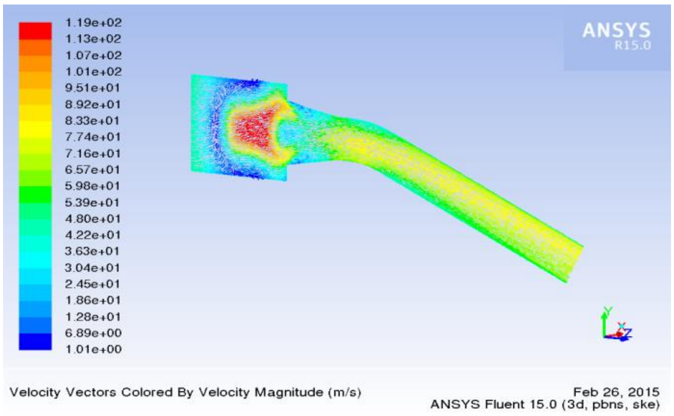

Figure 7 Velocity vector at runner 2(all runners open)

It is observed an increased in the velocity at runner 2.

Fig . shows the velocity vector at runner 3 when all runners are open.

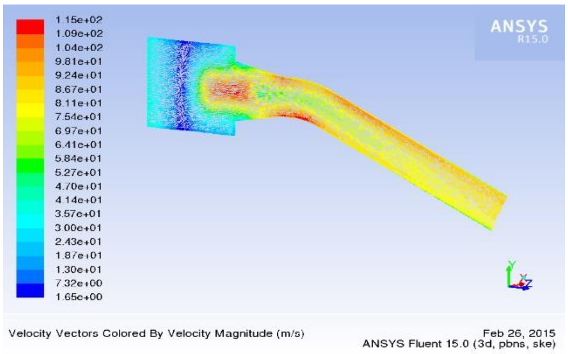

Figure 8 Velocity vector at runner 3(all runners open)

It is observed an increased in the velocity in runner 3.

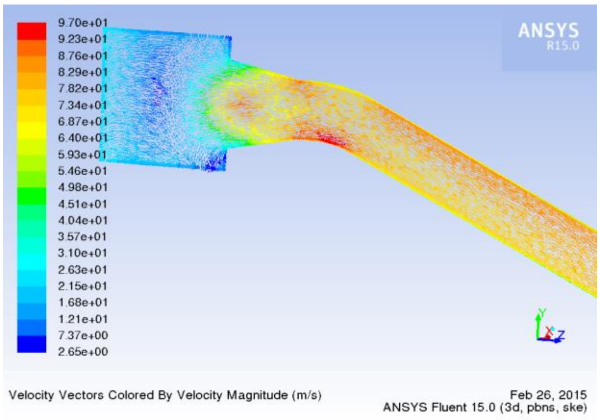

Figure 9 Velocity vector at runner 4 (all runners open)

It is observed an increased in the velocity at runner 4.

B. **Contours of Static Pressure:**

Following figures shows the pressure contours of intake manifold when all runners are open.

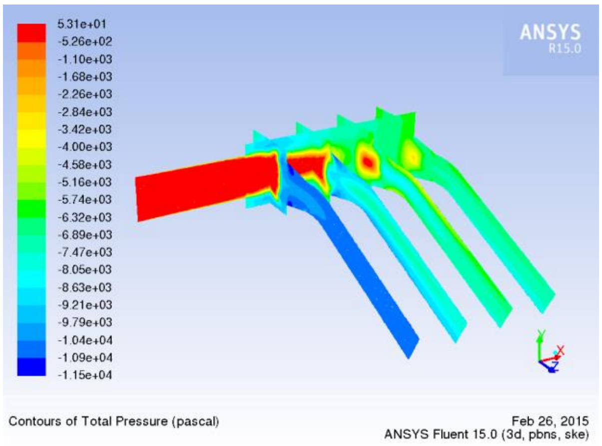

Figure 10 Pressure contour of intake manifold(all runners open)

Due to the stagnation of fluid occurring at the end corners of the plenum high pressure regions are created. It show the static pressure variation along the plenum chamber. The pressure within is lower comparatively for the condition when all runners are open

V. CONCLUSIONS

The purpose of this reported work is to numerically analysis the base and modified models of an Intake manifold of a Multi-cylinder SI engine. After analysis, the concluded points are as follows:

1) Total pressure loss for all runners open) is 8338 pa.
2) Outlet total pressure for all runners open is runner 1 is -10543 pa, runner 2 is -8415 pa, runner 3 is -6896 pa, runner 4 is -7499 pa.
3) Total outlet mass flow for all runners open is runner 1 is 0.0542 kg/sec, runner 2 is 0.1043 kg/sec, runner 3 is 0.1288kg/sec, runner 4 is 0.1201 kg/sec.
4) Inlet pipe and plenum connection creates a back step geometry which causes more total pressure loss due to flow recirculation.

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