Optimization of Intake Manifold for Two Wheeler Application- A Review

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Abstract— It is quite well known that a properly designed Intake Manifold is vital for the optimal performance of an IC engine. The power and torque output of an engine can be dramatically improved through good intake design. For example, performance can be improved by reducing pressure losses in the intake system. Simulation is a very powerful tool for cutting product development cycle. It significantly reduces time required for optimization and also gives the designer flexibility of going for wide variety of design options, which is not feasible otherwise through experimentation. Simulation also helps in detailed understanding of the physical phenomenon of the respective system.

Key words: Two Wheeler, Intake Manifold

I. Introduction

An intake manifold is one of the primary components from the performance point of view of an gasoline engine. The intake system provides the internal combustion engine with fresh air and it has a major effect on engine performance and emissions. An uneven air distribution leads to non-uniform power production resulting in increased engine vibrations. Therefore great attention has to be focused on the design of the intake system. Many investigations are related to the improvement of the breathing capacity of the engine, to the minimization of pressure losses along the pipes and to the distribution uniformity of air among the cylinders of the engine.

In SI engine, the intake system typically consists of an air filter, a carburetor or fuel injector and throttle or throttle with individual fuel injectors in each intake port and intake manifold. During the induction process, pressure losses occur as the mixture passes through or by each of these components. The pressure drop depends on engine speed, the flow resistance of the elements in the system and cross-sectional area through which the fresh charge moves. In a CI engine intake system, the carburetor or EFI system and the throttle plate are absent. Intake manifold of throttle-body injection/carburetion engines are designed to provide optimum flow of air-fuel mixture and to reduce the chances of the vaporized fuel re-condensation. Intake manifold runners on these engines have a few bends as possible. In port/direct injection SI engines (also CI engines), the manifold is designed for air flow only, so, these can have larger runners and sharp bends as these do not have to keep fuel suspended in air. The design of an intake manifold can be accomplished in different ways. 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. The flow 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.

Due to inertia effect and time required in attaining full opening, the inlet valve is made to open earlier so that by the time the piston reaches TDC, the valve is fully open. During the operation of an IC engine, pressure waves occur because of pressure drop in cylinders in intake strokes.

Depending on amplitude and phase of these pressure waves at the time of closing of intake port, filling of cylinders can be effected positively or negatively. The amplitude and phase of these pressure waves depend on IM geometry, engine speed and valve timing.

II. Literature Review

The basic concept of intake manifold design is matching the intake manifold to engine demands. An intake manifold is usually made up of a plenum, a throttle body, and runners which connect to the engine cylinders. The classical method of increasing power was to increase the manifold throat size of the carburetor to increase the air flow and thereby increase the available power. It was thought that an increase in throat and carburetor/throttle valve sizes would produce a comparable increase in power at the engine output. One of the approaches to increase power without increasing displacement was to obtain a higher charge / air-fuel mix in the engine chamber. Merely increasing the throat size resulted in a corresponding drop in air flow speed which produced incomplete fuel atomization because the air flow through the carburetor/throttle was too slow. One of the methods of moving the desired volume of air-fuel mix into the chamber of the engine is to adapt the throat diameter and shape of the air intake velocity stack (bell mouth) to provide for proper air flow into the carburetor. [1]

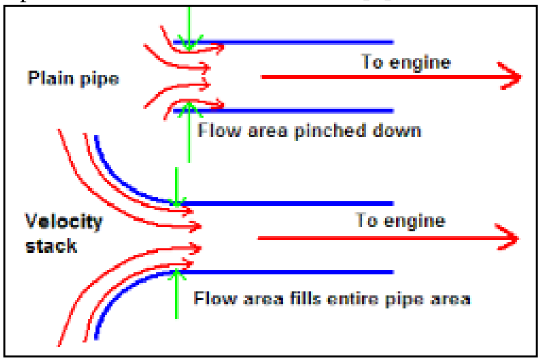

Fig. 1: Flow through pipe

Fig. 1. shows how the charge flows through the inlet of the manifold. Due to the plain pipe at the inlet, the flow area gets squeezed due to the turbulent flow results in the formation of eddies. The restriction formed due to this results in increase in pressure drop hence the performance of engine reduces. The bell mouth (velocity stack) present at the start of the intake produces smooth flow even at higher

velocities with the flow stream parallel to the intake wall known as laminar flow resulting in ramming effect.

Gordon P. Blair et. al. [1] compares different types of bell mouth and found that the elliptical shape bell mouth gives the highest coefficient of discharge. Further explains that within different elliptical bell mouths, short and fat elliptical bell mouth are the best with an optimum length criterion L of one diameter De, and an optimum entry diameter Di of 2.13 times the exit diameter (De) and the corner radius Rc can be usefully designed as 0.08 times the entry diameter Di.

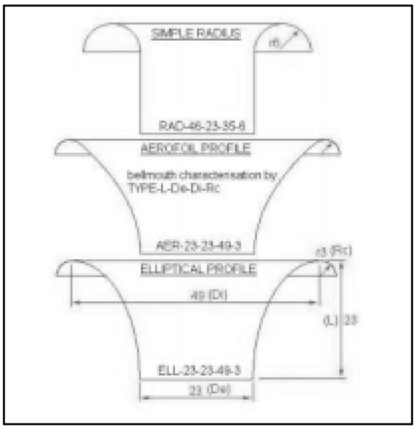

Fig. 2: Different bell mouth shapes [1]

Plenum Volume acts like a reservoir which is placed just before the throttle body and provides more amount of air when required to overcome the throttle restriction and wall friction. In some case where manual restrictions are provided at the start of intake manifold, the plenum volume is placed after the throttle body known as Helmholtz resonator which provides ramming effect to overcome the restriction at the start. The plenum volume generally assumed to be 2 to 3 times the swept volume of engine. Depending upon this assumption the dimension of plenum is calculated.

Plenum volume can take any geometrical shape such as cone, cylindrical, trapezoidal. Cone and trapezoidal are best suitable for multi-cylinder engines for which plenum has single inlet and multiple outlet, for single cylinder engine cylindrical shape plenum volume is best suitable candidate.

M.A. Ceviz [2] investigated the effects of intake plenum volume variation on engine performance and emissions to constitute a base study for variable intake plenum. The results of this study showed that the variation in the plenum volume causes an improvement on the engine performance and the pollutant emissions. The brake torque and related performance characteristics improved pronouncedly about between 1700 and 2600 rpm by increasing plenum volume. M.A. Ceviz and M. Akin [3] investigated the 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. According to the test results, plenum length must be extended for low engine speeds and shortened as the engine speed increases.

Intake runner acts as the connection between the intake port and plenum/throttle body. The length of the runner plays vital role in order to increase the performance of the engine. The length of the runner should be designed such that the intake charge should reach just before the port at the time of intake valve opening. If the runner is too long then the intake valve will open during suction stroke but charge will not present to enter into cylinder also, if the runner length is too short then before the opening of the valve, the charge will reach the intake port and will be deflected back. Both this cases drastically reduces the performance of engine. In their paper D. Saravanan et. al. [4] deals with the design and development of Dual Intake Manifold system which improves the torque at Partially Open Throttle (POT) condition by making the charge to flow through the longer path and at Wide Open Throttle (WOT) condition the charge flows through the shorter path. The flow of charge between the two paths is controlled based on the flow characteristics of charge at different operation conditions namely POT and WOT conditions. Dual Intake manifold with longer and shorter manifold merged at the entry and exit such that at POT the charge is directed into the longer manifold and at WOT the charge directly flows through the shorter manifold, the flow diversion is achieved by the relative position of carburetor throttle and a flow splitter (The merging point of long and short manifold). With the flow based Dual Intake Manifold system more than 47% improvement in Torque and Power is observed at 25% throttle position and upto 11% improvement in torque and power is observed at 50% throttle position, this significantly improves the drivability at POT conditions. At 75% and 100% throttle position the DI Manifold is able to produce the torque characteristics similar to that of SI manifold system, thus DI manifold system is able to improve the torque at POT condition without any compromise of performance at WOT condition. This dynamics are 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. [5] Shrinath Potul, Rohan Nachnolkar, Sagar Bhave 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. Suresh .Aadepu [6] A methodology for design of intake manifold of IC engines with improved volumetric effi ciency has been presented. This methodology combines optimization using 1-D engine simulation software and threedimensional, steady state CFD technique, rather than experimental comparison. The 1-D software served as a platform to obtain the confi guration of the manifold which gives better volumetric effi ciency, while the CFD simulations enabled to visualize the fl ow within the manifold. Such simulations give better insight of fl ow within the manifolds. Design modifi cations could be done using CFD simulations to enhance the overall performance of the system. Using this method, a better design of manifold giving 7% increase in volumetric effi ciency could be achieved. For better results, unsteady state analysis can be carried out to predict how the intake manifold performs under real conditions. The boundary conditions for these can be obtained form 1-D software. The joints can also be made smoother to reduce pressure losses, but the eff ect of increase in plenum volume has to be correlated with 1-D software. Also if some changes to the plenum perform in order to guide the fl ow to the runners by the geometry of the plenum, the performance of intake manifold will be improved Rui B. de Campos Thiago A. Simões [7] In general, the design of intake manifold (IM) for Otto cycle engines starts with one-dimensional (1D) gas dynamics simulation which is used to define its main characteristics. The use of unsteady CFD (Computer Flow Dynamics) methodology can provide additional information not captured in 1D method, allowing a greater optimization of the IM geometry. Due to dynamic boundary conditions involved, this type of analysis increases significantly the results making the compilation more difficult and time consuming (1). This paper presents a methodology for unsteady simulation where qualitative results may provide a direction at an early stage in the design process. Examples and practical results already implemented are discussed to guide designers through IM development.

Negin Maftouni and Reza Ebrahimi [8] It is quite wellknown that a properly designed Intake Manifold is vital for the optimal performance of an IC engine. This paper will present 3-D Simulation of a XU7 Engine Intake Manifold and the results will be discussed. 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. In the present research the effect of length of runners on the volumetric efficiency has been analyzed by 3-D CFD model at different speeds. Three hypothetical models have been made that all of their runners' length is increased to 110,120 and 130% of initial value. In the model with 20% extended runners, the volumetric efficiency increases at 3500 and 4500 rpm. Finally according to the results of steady and unsteady simulations, some suggestions are recommended to improve the performance of this Intake Manifold. M. Safari and M. Ghamari [9] It is quite well known that a properly designed Intake Manifold is vital for the optimal performance of an IC engine. This paper will present 3-D Simulation of a 1.6L MPFI Engine Intake Manifold by using the FLUENT code and the results will be discussed. 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. Finally according to the results of steady and unsteady simulations, some suggestions are recommended to improve the performance of this Intake Manifold.

III. Conclusion

By using such type of design of inlet manifold for single cylinder engine gives maximum discharge and that helps to proper combustion of fuel in combustion chamber which gives maximum efficiency and maximum power.

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