

Design and Development of a Flow Based Dual Intake Manifold System

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ABSTRACT

The Torque from an engine is a very critical parameter which controls the drivability of the vehicle, better torque availability at Partially Open Throttle (POT) condition improves drivability at city driving condition and better torque at Wide Open Throttle (WOT) condition improves cruising at highway driving condition, conventionally engine produces better torque at one particular operating condition leaving poor drivability at others. The Torque characteristics of an engine depends upon the volumetric efficiency of the engine. The volumetric efficiency of a naturally aspirated engine can be improved by tuning the intake manifold. With an overall improvement in volumetric efficiency throughout the engine operating conditions better torque curve can be achieved, which facilitates improved drivability.

For improving volumetric efficiency, several technologies were developed and used, among that Dual Intake Manifold system is one where the flow of charge is channelized between longer and shorter flow path depending on the engine operating condition. Conventionally in Dual Intake manifold system, flow is channelized using valves which are actuated by external power sources. However the application of this system is limited due to increased cost, complexity in assembly, need of an external power source for actuation, and increased number of moving parts which in turn reduces the reliability of the system; also this system requires an actuation mechanism for operating the valve which further increases the complexity of the system.

In this work a novel Dual Intake Manifold system is designed and developed which improves the torque at POT condition by making the charge to flow through the longer path and at 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. In this method no valves are used to channelize the charge, no external actuation mechanism is required and no moving parts are present, which further improves the reliability of the system. Experimental results have shown more than 47% improvement in Torque and Power at POT condition without any sacrifice of performance at WOT condition.

CITATION: Saravanan, D., Gokhale, A., and Karthikeyan, N., "Design and Development of a Flow Based Dual Intake Manifold System," *SAE Int. J. Engines* 8(1):2015, doi:10.4271/2014-01-2880.

INTRODUCTION

The primary function of an Intake manifold system is to transfer the air fuel mixture from carburetor to the intake port; in addition intake manifolds have the potential to change the flow characteristics of the charge, which controls the engine performance. The length and diameter of an intake manifold helps in shifting the peak torque point in the engine operating speed range.

The volumetric efficiency of an engine can be increased by the principle of dynamic charge boosting. The sum of kinetic energy and potential energy remains constant, thus an increase in the velocity of the fluid occurs proportionately with an increase in both its dynamic pressure and kinetic energy, and a decrease in its static pressure and potential energy. By making the charge to flow through a longer manifold with

smaller diameter the velocity of the charge increases which imparts higher momentum to the charge and increases the turbulence of the charge in the combustion chamber [1].

Helmholtz resonance method can also be utilized to achieve peak volumetric efficiency at a desired engine speed, when the intake valve closes, the charge which is in motion hits the valve face and bounce back, this causes a rare-fraction wave to travel down the intake pipe to the open end and it is reflected as a compression wave. A positive tuning effect occurs when the compression wave arrives at the inlet valve as the valve is closing this can be achieved by proper design of intake manifold length [1]. The tuning peak depends on the engine operating speed.

During various operating condition of the vehicle, the torque requirement from an engine is highly variable. Good torque at lower engine speeds improves drivability at city driving condition and better torque at higher engine speeds improves highway cruising. Conventionally engine produces peak torque at one particular engine speed usually at the mid-range of the engine operating speed. Shifting of peak torque to lower engine speed by using a longer manifold, improves drivability at city driving condition but leaves poor acceleration at higher engine speeds, and also Peak torque point can be shifted to higher engine speeds by using a shorter manifold which improves highway cruising but leaves poor drivability at city driving conditions. So it is a compromise between low speed drivability and high speed cruising.

In order to achieve both low speed drivability and high speed cruising, the torque should be higher at both lower and higher engine speeds. Dual intake manifolds have the ability to produce better torque at both lower and higher engine speeds by directing the flow of charge through longer manifold at lower engine speeds and by directing the flow of charge through shorter manifold at higher engine speeds.

Conventionally dual intake manifolds have two manifolds of different length with same entry and exit points, a valve is provided at the manifold junction where it operates in directing the flow of charge through longer or shorter manifolds based on the engine operating speed.

However, usage of Dual Intake manifold system in production vehicles is very limited due to packaging constraints, complexity in operation, need for an external actuation mechanism to actuate the valve and increased number of moving parts in the manifold makes it unreliable and incurs additional cost.

This research presents a novel Dual Intake Manifold system where it precisely functions in diverting the charge through longer and shorter manifolds. Apart from conventional Dual Intake manifold system this system differs in the following

1. Valve less- no flow diverting valves are used, which reduces the complexity of system.
2. No external pneumatic or hydraulic actuation system is required.
3. No moving parts are present in the system thus increased reliability and reduced complexity in operation.
4. Highly compact and packaging is effective.
5. Functions based on Throttle position, partially open throttle condition (POT) and Wide open throttle condition (WOT).

DESIGN OF FLOW BASED DUAL INTAKE MANIFOLD SYSTEM

Engine Specification

Table 1. Engine Specifications

Engine	4-Stroke, Naturally aspirated, Single cylinder, Air cooled carbureted SI engine
Displacement	110 cc
Peak Power	6 Kw @ 7500 RPM
Peak Torque	9 Nm @ 5500 RPM
Number of valves	2
Compression ratio	9.5

Intake Manifold Tuning

By Helmholtz resonance property of air peak volumetric efficiency of an engine occurs when the natural Helmholtz resonance of cylinder and pipe is roughly double the piston frequency [2].

Speed at which resonance occurs is given by,

$$Ns = \frac{1348 \times Cs}{K} \sqrt{\left(\frac{A}{L \times V}\right)} \times \sqrt{\left(\frac{R-1}{R+1}\right)} \quad (3)$$

Where, k is a constant usually between 2 and 2.5 and it depends on the valve timing, Cs is speed of sound in m/s, A is the cross sectional Area of the intake manifold in cm², L is the length of manifold in cm, V is the effective resonator volume in cm³ and R is the compression ratio.

The engine which was selected for this research has an operating speed range from 3000 RPM to 8000 RPM. It is observed that with the existing or base manifold peak torque occurs around 6000 RPM which is at the higher operating speed range. In order to achieve two peaks in the engine operating speeds; two manifolds

1. Longer manifold for low engine speed operation which has a peak torque around 4000 RPM.
2. Existing manifold which has a peak torque at around 6000 RPM for high engine speed.

Using equation (3), the calculated length of manifold to be used to achieve a torque peak at 4000 RPM is 590mm. Taking due account of packaging feasibility in the vehicle, maximum feasible length is selected for lower engine speed range.

Conceptualization of Flow based Dual Intake Manifold system

This novel technology works based on the changes in the flow of charge during different operating conditions, Partially Open Throttle (POT) condition and Wide Open Throttle (WOT) condition.

In a carbureted engine, partially open throttle condition represents the throttle operating condition between completely closed positions at Idling to 50% of total throttle opening at middle engine operating speed range as shown in [figure 1](#). During wide open throttle condition the throttle operates between 50% of throttle opening to fully or widely open throttle condition as shown in [figure 2](#). Typically the engine operating speed during POT condition will be from 1500 RPM to 4000 RPM and from 4000 to 8000 RPM during WOT condition.

Typically during city driving condition the engine RPM will be low and POT condition prevails. At highway driving condition the engine RPM will be high and WOT condition prevails.

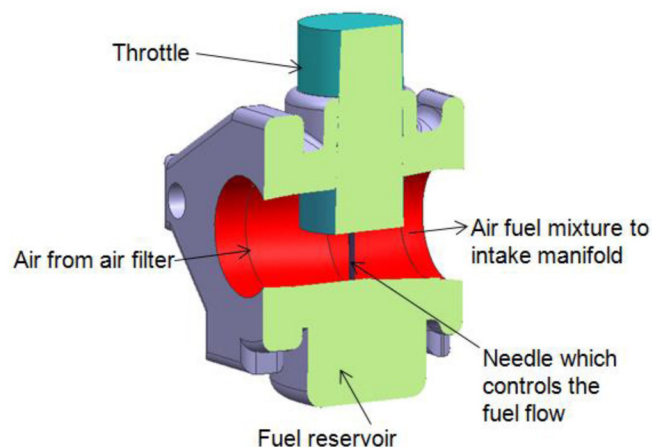


Figure 1. Cut section of carburetor showing throttle position at POT condition.

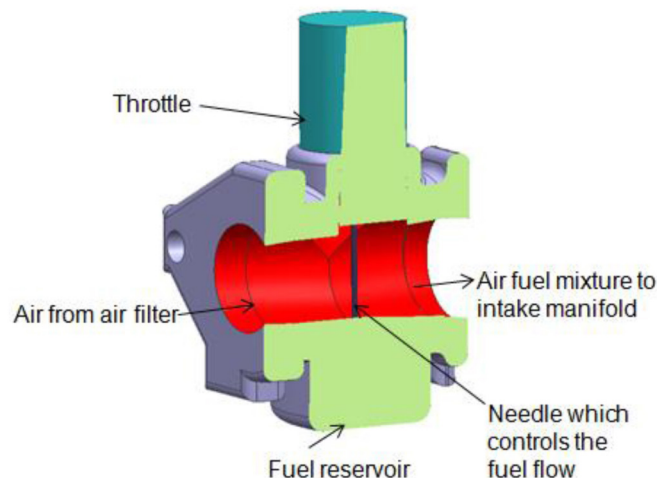


Figure 2. Cut section of carburetor showing throttle position at WOT condition.

The crux of this technology lies in making the charge to pass through the longer manifold at POT condition and to make the charge to pass through the shorter manifold at WOT condition.

The flow of charge at POT and WOT conditions are studied carefully with the help of advanced CFD tools. The flow model of charge from connecting tube till Intake Port via Manifold is prepared and simulated.

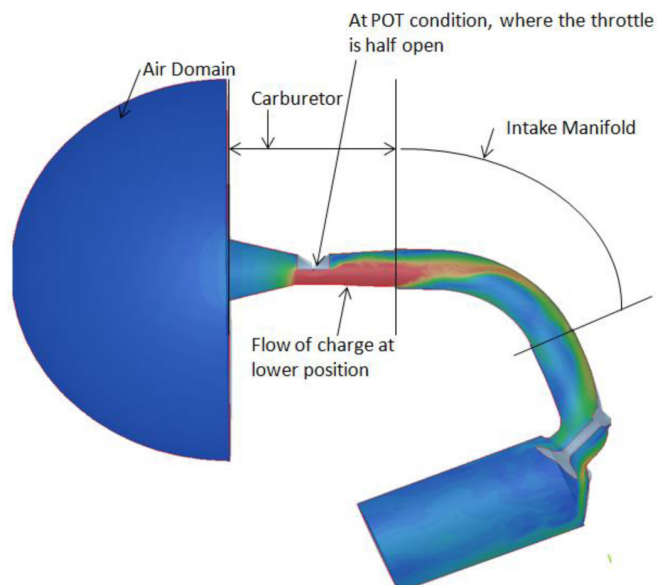


Figure 3. Flow model showing the flow of charge at POT condition.

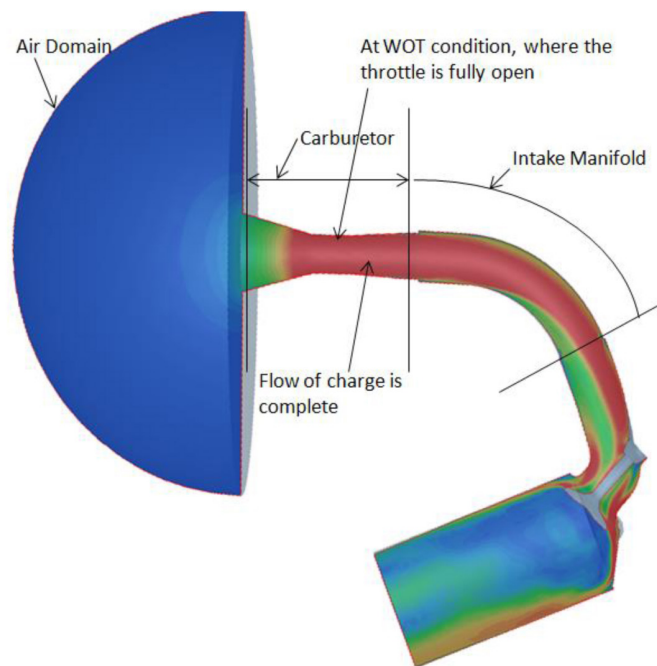


Figure 4. Flow model showing the flow of charge at WOT condition.

It is observed that at POT condition the carburetor throttle is only half open and the flow of charge is through the lower half of the carburetor (bottom side). At WOT condition the carburetor throttle is fully open and the charge flows completely through the manifold.