A review on effect of intake system flow by various designs to engine performance

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Abstract This paper presents a critical review of effect of intake manifold flow to four stroke single cylinder engine performances. Intake manifold and its components play critical role in deciding the performance of engine. Engine can be easily breathing related to flow pattern by best design of intake manifold that can contribute to performance. Flow pattern of intake manifold affect the volumetric efficiency, mass flow rate and velocity which ultimately makes impact up on the engine power & torque. This paper reviews work done by various prominent researchers in the field of intake tuning and variable intake manifold. It can be easily concluded that for getting best flow pattern of intake manifold throughout the engine operating speed the intake geometry need to be changed.

Keywords: intake port, geometrical design, flow pattern, flow characteristics, power & torque.

1. Introduction

Intake manifold is the part of an engine and piping system which deliver incoming air to the cylinders, usually made of cast metal, plastic or composite material. In most SI engines, fuel is added to the air in the intake manifold system either by fuel injectors or with a carburettor. Some intake manifolds are heated to enhance fuel evaporation. The individual pipe to a single cylinder is called runner. Other parts in intake system are air filter, intake pipe and plenum. Various injection timing, fuel delivery pressure and flow rate are the several ways in enhance the engine performance. Improving the air flow rate through intake port is one of the ways which can enhance the turbulence intensity at spark time and it will increase the stability of combustion and reducing emission. The technologies for high power include optimized combustion system. An intake flow which is generation of flow structures are related closely to the design process and performance of the 4-stroke engines. The tumble motion is necessary to increase the turbulence level which contributed proper and quick mixing of fresh charge which leads to effective combustion with reduced emission. The intake port design plays a critical role in the development of modern internal
combustion engines (ICE). Geometrical properties are importance to improve the gasoline engine performance in terms of efficiency.

2. Literature Review

M.F. Samuri et.al done experiment on 16-Valve DOHC engine which more focuses on air flow at intake port. They record and analyzed the existing data by using flow bench machine. For improvement design the polish the intake port as maximum possible and test again by using flow bench machine. Result for both design are comparing. The increase in flow from improvement design is due to the occurrence of the flow in the intake port. The larger section area of port together with small cross section near intake valve causes the velocity increase and quality of flow.

M. Eng. M Gandyk et.al in their research of combustion engine intake port design on 2015 prove that phenomena effect of geometry changing in theory and in simulated engine are similar. Shortening and increasing are of ducts makes high torque on high engine speed. Final improvement gives higher power, up to 1.5hp and about 1Nm higher torque in wide range of engine speed. The maximum power could be higher but the engine torque would be worst.

Ujwal D. Patil studied on cylinder head intake port design in his paper more focus on developing intake port geometry to meet swirl ratio required to meet emission.

Research Methodology Steps

- Provides the literature to know about flow patterns, designing parameters, types of ports to be used and methodology for design of Intake ports.
- Development efforts are focused while designing intake ports with improvement to obtain the required swirl and flow patterns.
- Defining the full valve lift 3D model and in cylinder air flow analysis through CFD package to know swirl, velocity vectors streamlines formation for full lift model.
- Validation of results by prototyping testing.

Dominic Wentworth Linton and Shian Gao in their research work were studied on the effect of intake design on volumetric efficiency which focus to selecting the best stack length for the given discipline of motorsport. Pressure and velocity contours around the valve guide show the effect of porting on smoothing the airflow into cylinder. Opening the throat of the valve port helps to smooth the airflow into the cylinder and improve the power delivery. From the result prove shorter stack length is more suited for high rpm applications while longer stack shift the bulk of the power lower down the rpm range.

The key findings from the study were:

- The valve lift dimension 3mm for low, 7mm for medium and 10mm for high valve lift.
- The stack length use 40mm, 90mm and 120mm.
- The rpm tested are range between 2500-8000rpm.

Y. bifeng Jia Hekun Liu Shengji research on “Notice of Retraction intake port of the non-road small spark-ignition engine,” state that maintaining the flow of cross-sectional area at the middle of the intake port can prevent the formation of dead air and handle the changes of structural in the corner. The tumble and swirl motion that had been naturally produced by the geometry of intake port contributed proper and quick air-fuel mixing that produced higher efficiency does increasing the engine performance. In this research, the coefficient discharge value will indicates the flow efficiency in the intake port area. When the engine is in operation, the intake valve will lift and the discharge coefficient of inlet poppet valve will occur.

The geometry of intake port for a gasoline engine has an important effect on tumble and swirl motion in cylinder. The tumble motion can generate the air and fuel to form a well mixture while Swirl can be generated by geometry of the intake port that provide a tangent components to the intake flow as it enters the cylinder. J. Rabault study on “International Journal of Heat and Fluid Flow A study using PIV of the intake flow in a diesel engine cylinder,” found that function of tumble motion is to increase the turbulence level which give good mixing of fresh charge which leads to effective combustion does increase the engine performance.
M. F. Hushim prove that the cross-section of the flow is greater at the entry point of the intake port and the smaller at the exit of the intake port. This will cause of increasing of the velocity does improving the engine performance. B. Y. Hong Han-Chi study on “Optimization of Intake and Exhaust System for FSAE Car Based on Orthogonal Array Testing,” found one of the most important subsystems of the engine is the intake port. Intake port is the entrance point for air flow into the combustion chamber. In order to increase the power output of the engine, the quantity of the air flowing into the engine, intake port must to be maximized as possible.

3. Principle of intake manifold and intake port

Air Flow Motions

The air flow motions in the intake passage are in turbulent motions. These flows help to improve the rate of transfer and mixing the fuel and air in the combustion chamber. B. M. Krishna and J. M. Mallikarjuna in their research, the rates of momentum and mass transfer also can be increased when there is the presence turbulent flow. From C.W. Hong and S.D Tarng, the term of turbulent flow will be referred as swirl when the flow enters and rotates in the combustion chamber. Organized rotations that are produced by air-flow in the intake passage are the definition of the swirl motion. From K. Lee et.al swirl also can be referred as the directional flow of air and fuel mixture that are affected by the shape of the intake port or its angle of entry into the cylinder block.

![Image](image1.png)  
**Figure 3.1:** Intake air flow motion  

![Image](image2.png)  
**Figure 3.2:** Intake Air for stationary rotation axis

The flow of swirl in the combustion chamber. The mixing of air and fuel will be more homogeneous where there is the presence of swirl motion. The swirl motion enters the combustion chamber until the ignition and the combustion process started. The swirl flow is very important where it can help to increase the air-fuel mixing and improve the combustion process. Besides, swirl also helps to minimize engine knocking, and performed the complete combustion. An optimal swirl ratio is not only good for optimum combustion, but also for an optimal emission reduction. In racing tournament, the swirl value in the cylinder block is very important in order to optimize the engine performances by A. Shamsudeen et.al. The effective combustion occurs when there is high swirl near the TDC when the ignition occurs.

Intake Port Geometry

“Full-Parameter Approach for the Intake Port Design of a Four-Valve Direct-Injection Gasoline” by T. Wang study focus on tangential port template for a four valve gasoline engine with symmetrical
arrangement. Inlet intake port must larger size to the outlet intake port. In this research also clearly classified in figure 3.3 and named each angle and area for intake port geometry in table 1.

![Intake Port Geometry](image)

**Figure 3.3:** Intake Port Geometry

| Parameter | Description | Unit |
|-----------|-------------|------|
| P1        | Outlet diameter of intake port | mm   |
| P2        | Angle between the outlet plane and the cylinder head bottom | Deg |
| P3        | Distance between the outlet center and the cylinder head bottom | mm   |
| P4        | Distance between the outlet center and the axis of the cylinder | mm   |
| P5        | Distance between the outlet center and the symmetry plane of the intake port | mm   |
| P6        | Distance between the entrance center and the axis of the cylinder | mm   |
| P7        | Distance between the entrance center and the cylinder of the bottom | mm   |
| P8        | Eight of the entrance | mm   |
| P9        | Width of the entrance | mm   |
| P10       | Fillet of the entrance (not shown) | mm   |
| P11       | Fillet of the intake port | mm   |
| P12       | Pattern draft of the part model along the parting line (not shown) | mm   |
| P13       | Diameter of the boss | mm   |
| P14       | Distance between the outlet plane and the boss plane | mm   |
| Av        | Angle between the upper wall and the outlet plane | Deg |
| Ab        | Angle between the lower wall and the outlet plane | Deg |
| Ar        | Ratio between the entrance area of one leg and the outlet area | Deg |
| Ac        | Angle between the entrance plane and the outlet plane | Deg |

**Table 1:** Parameter List
4. Conclusion

After reviewing work of different authors as above it can be easily concluded that intake geometry make considerable impact on engine performance. The main impact is on the volumetric efficiency of the engine which ultimately affects the torque & power produced at different speed. The intake port size is bigger give high torque and power to engine. Other main impact is high angle of intake port that can give high torque and power. For future study, is toward studying for geometry and angle of intake port by theoretical and experimental.

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