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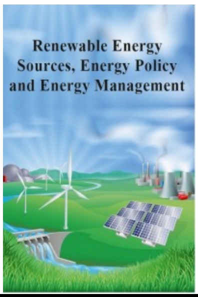

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Original Research Article

Investigation of Intake Manifold Design and Its Effect on Engine Performance

Cihangir Kaplan[1,*], Hasan Aydogan[2].

[1] *Kentpar Otomotiv, Konya, Turkey*
[2] *Selcuk University, Technology Faculty, Campus, Selcuklu, Konya TURKEY*

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* Corresponding author
kaplancihangir@gmail.com

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ABSTRACT

This review includes the basic concepts of the intake manifold. Since the internal combustion engines have a complex structure, the efficiency of the engine also interacts with these parts. One of the most important factors affecting the efficiency of the engine is the amount of air to be taken into the cylinders. The intake manifold ensures that the air to be taken into the cylinders or its fresh mixture is distributed equally for each cylinder. In internal combustion engines, attention is paid to the design of the intake manifold to meet requirements. In this study, an investigation was made on the intake manifold types, internal structure, its effect on engine performance and design inputs.

Keywords: Air intake manifold, air intake manifold design, engine performance

1. Intake Manifolds

In daily life, internal combustion engines are widely used in passenger cars, vans, motorcycles, aircraft, ships, trains. Internal combustion engines have a complex structure consisting of multiple parts. The performance of an internal combustion engine varies depending on many factors. The most important of these factors is that combustion in cylinders provides ideal combustion conditions. Ideal combustion is possible by mixing the reacted air and fuel in the cylinder in sufficient proportions. It enables the air-fuel mixture to be transported into the cylinders with the help of the intake manifold. For this reason, engine designers attach importance to the intake manifold design. The intake manifold acts as a buffer between the air-fuel system and the engine. Intake manifold designs are made taking into account the position in the engine along with the performance. This is also an important parameter. As a result, it may encounter low performance manifolds in some mass production engines [1,2].

One of the most important parameters after the design is engine efficiency. One of the most important factors affecting the efficiency of the engine is the burning of all the fuel entering the combustion chamber. This is achieved by sending the oxygen that will enter the combustion reaction with the fuel in the right amount and at the right speed and pressures to the combustion chamber [3].

Intake manifolds to be used in internal combustion engines are designed differently and in different types suitable for the engine. Depending on the engine types, the air inlet port, filling volume and suction channels are changed. The main target is to distribute the air to be taken into the cylinders evenly. Figure 1 shows the intake manifold.

Figure 1. Intake manifold view [4]

2. Intake Manifolds Parts

The intake manifold is an engine part used to transport the mixture of fuel and air to the engine. The intake manifold consists of ram pipe (manifold inlet), plenum (fill volume) and runners (pipes). It is shown in Figure 2.

Intake manifolds have high effects on vehicle engine performance and emission of pollutants [5]. The air enters the plenum with the vacuum intake manifold inlet part created by the engine. The plenum stores the air to be used during combustion as a tank and then transfers the combustion air into the cylinders with the help of runners (pipes) [6].

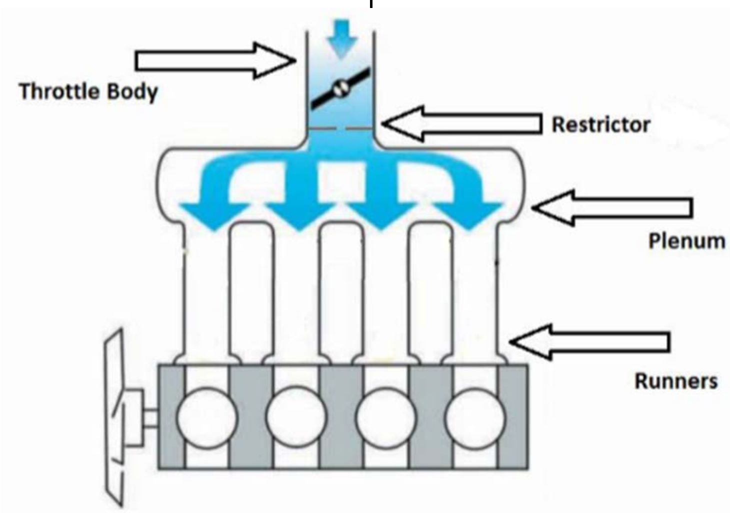

Figure 2. Intake manifold section view [7]

The task of the plenum (filling volume) is to equalize the pressure for the more uniform air-fuel mixture in the combustion chamber. Plenum sometimes works as an acoustic muffler [6]. The ram pipe is part of the intake manifold and is generally known as the critical nozzle, critical flow valve or sonic choke. Such components are often used to control the mass flow rate in the application of industries [6]. Runners (pipes) are one of the basic parts of the air intake manifold. It enables the air in the plenum to be transported into the cylinders, that is, to the combustion chamber. In this way, maximum air is carried and an increase in engine performance and volumetric efficiency is provided.

3. Intake Manifold Types

3.1 Variable Way Intake Manifold

These intake manifold designs basically feature two different airflow paths using a valve that separates them. It consists of two air flow ports, one is called the torque port and the other is called the performance port [8]. This design is used to optimize the use of the suction system.atıf. The variable intake manifold consists of two intake channels of different lengths due to production difficulties. The longer one is used for low speeds, the shorter one is used for high speeds. This variability provides good acceleration and flexibility with an ideal torque change overall. The fill volume has a huge impact on engine performance and pollutant emissions. Using variable fill volume manifolds can increase the performance of the engine. Using variable intake manifold reduces torque drops at higher speeds, and torque distribution at lower speeds is better [9].

Figure 3. Variable way intake manifold [8]

3.2 Single Zone Intake Manifold

All suction channels join together towards a general filling volume. Open-filled manifolds provide higher power than dual-zone manifolds. It was observed that the performance of single-zone intake manifolds increased more in high-speed vehicles. In single-zone intake manifolds, the air inlet into the manifold can take different forms [9,10].

3.3 Wet Flow Intake Manifold

Wet flow manifold; air and fuel flow together. These types of flow are carburetor and direct injection systems to the intake manifold. The disadvantage in these manifolds is that they rotate about 90 ° before the air comes to the cylinders. At high speeds, it becomes difficult to keep fuel and air mixed. It causes the mixture to separate at very low speeds. This situation occurs especially in large channels and low revs.

3.4 Dry Flow Intake Manifold

While air and fuel move during suction, hard edges cause speed increase during rotation. Air is lighter than fuel and makes sharper turns. When an air-fuel mixture reaches a hard turn, the fuel is separated and swung towards the outer part of the rotated edge [9,10].

3.5 Dual Zone Intake Manifold

Such manifolds have two filling volumes. This feature increases power at low rpm and increases gas response compared to other manifolds. Dual-zone manifolds are used especially in large-volume engines [9,11].

Figure 4. Dual zone intake manifold [9,11]

4. Main Features Expected from the Intake Manifold

Depending on the engine performances, sufficient air must enter the cylinders at full loads and speeds. The intake manifold must have some properties to meet these requirements. These;

- Durability
- Material quality
- Air flow
- Ease of assembly
- Burn resistance
- Acoustic condition
- Design flexibility
- Temperature performance

5. Factors Affecting Intake Manifold Performance

5.1 Pipe Geometry

In the intake manifold, importance is given to the duct geometry. The air to be sent to the cylinders through the manifold is affected by the edges, corners and lengths. For example, single-point injection and carburetor intake manifold pipes are designed to be short depending on how long the fuel gets into the cylinder.

5.2 Plenum Geometry

Fill volume size and shape are the main factors that determine manifold performance. A filling volume in the correct volume and geometry is the most important tool for the air intake to reach the cylinders at the desired speed and pressure [11].

5.3 Manifold Roughness

The intake manifold is one of the important parts of the engine that provides optimum performance. The smooth inner wall of the slides allows air to pass through the manifold at low pressure [12]. Another researcher found that the surface roughness was influenced by the friction factor and thus the flow parameters in the rough channels [13]. Increasing the inner surface roughness of the intake manifold affects the air flow and causes pressure drops.

5.4 Intake Air Duct Cross Section

Regardless of the length of the manifold body during intake, the cross sectional area of the duct affects power in a given rpm range. If the pipe is too small, this will negatively affect the flow, but if it is too large, it will decrease the speed and decrease in power. However, the wider the suction channel, the pressure waves will be less [9,11].

5.5 Manifold Temperature

Too hot the manifold causes the air to overheat and expand, thereby reducing the amount of air entering the cylinder. Due to the stated reasons, the manifold shape and temperature is an important factor in preparation for combustion [9,11].

5.6 Combined Effects

In a well-adjusted intake manifold, an extra pressure of up to 0.2 bar may occur, even exceeding this value, due to pressure fluctuations in the intake valve. As can be seen from this, this has a major impact on engine volumetric efficiency. Thus, it turns out how an atmospheric powered engine can exceed 100% efficiency [9,11].

6. Design Parameters

The main task of an intake manifold distributes the air evenly inside the cylinder. The same distribution of air to the cylinders is vital for an optimized engine. In an uneven air distribution, uneven cylinders lead to volumetric efficiency, power loss and increased fuel consumption [14].

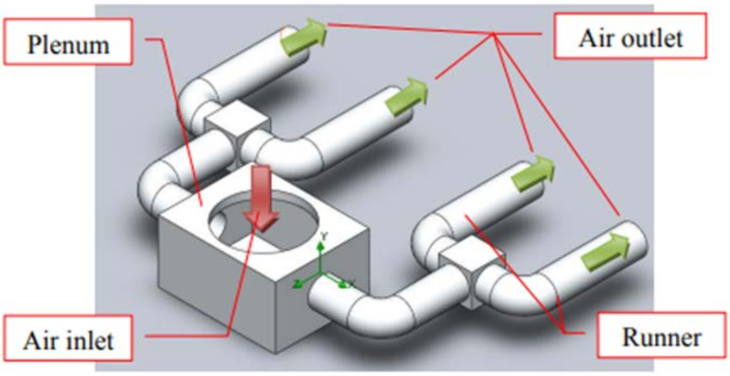

Figure 5. Schematic diagram of the air flow paths in the intake manifold [12]

Some parameters need to be considered during design to minimize problems and achieve an optimum intake manifold. These;

- Uniform distribution of air to all cylinders
- Minimum possible resistance in IM runners.
- Properly designs of IM geometry to utilize the pressure waves to improve induction process.
- Eliminate the unnecessary turbulence and eddies in intake manifold
- Chose the throttle body position correctly (often symmetrical to the plenum) [14].

The intake system of an engine regulates the air load inside the combustion chamber. The torque output from a motor is determined by its volumetric efficiency. The volumetric efficiency of the engine depends on the amount of air load present inside the combustion chamber and, in turn, controlled by the intake system. It has issues that affect the designs that affect efficiency from the entrance system. Intake manifold actuator length, diameter, intake manifold plenum volume, air cleaner volume, clean and dirty duct length. Air filter volume and dirty / clean ducts help to obtain maximum air at optimum temperature. These parts also play a vital role in the noise characteristics of the engine intake system. The system designer uses the intake manifold to adjust the torque output to the requirement [15].

Air intake, volumetric efficiency and torque-rpm graph of a current engine are taken into consideration in the intake manifold design. Volumetric efficiency is the ratio of the amount of air taken into the cylinder to the total cylinder volume (volume the piston swept). It is one of the reasons that affect engine power and torque. If this efficiency increases, engine power and torque also increase.

The amount of air to be taken into the cylinders is calculated according to the formulas specified below.

Cylinder Volume:

$$V_A = \frac{\pi x D^2 x H}{4} \quad (1.1)$$

D = Cylinder diameter (mm)
H = Stroke (mm)
n = number of cylinders

∑VA = Total cylinder volume

$$\sum V_A = V_A x n \quad (1.2)$$

Input mass flow:

$$\dot{m} = \frac{\sum V_A x n}{60 x a} x \rho_h \quad (1.3)$$

n = Revolution (d / d)
a = Number of suction valves
ρh = Air mass flow (kg / m^3)
Vg = Manifold inlet speed (m / s)

Conclusion

In this study, it provides basic information about the design of a new intake manifold according to the requirement of the engine. The design of the intake manifold appears to have a major impact on the air flow area. It is observed in the study that the manifold design has an effect on parameters such as maximum engine power, minimum fuel consumption, thermal efficiency and exhaust emission.

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