

## INVESTIGATION OF THE EFFECTS OF INLET SYSTEM CONFIGURATION ON THE AIRFLOW CHARACTERISTICS

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### ABSTRACT

The effort towards the development of an engine that is efficient and green has become one of the biggest efforts of the major part of the automotive industry. The contribution of air quality to the engine plays an important role to increase power while minimizing the exhaust emission. The main purpose of this article is to investigate the characteristic of the air intake system of a naturally aspirated engine on a steady flow bench. The experiment was conducted using an industrial flow bench apparatus where the pressure different test pressures can be set and, at every test pressure, the valve is lifted at an increment of 1mm until the maximum possible valve lift where the flow rate is obtained in terms of cubic foot per minute or CFM. The experiment process was then repeated at different configuration. The experimental result shows that the flow rate increases with each valve lift in a linear pattern until at a certain point where the value becomes constant. The result also indicated that the flow rate increases as the different pressure increases.

**Keywords:** Naturally aspirated engine, Intake system, Air mass flow, Intake stroke

### INTRODUCTION

The basic works of an inlet system is simple and that is to provide sufficient air into the combustion chamber of an IC engine for the combustion process. While the main purpose of system is simple, the science that is involved with the system is quite complicated and the effort of improving the system as a whole has been a focus of the automobile industry as the inlet system plays a vital role in improving the performance and efficiency of the engine, plus it plays a vital role in the engine's emissions.

When it comes to emissions and the efficiency of an engine, the fuel to air ratio plays a major importance where engines that operate on lean mixtures (fuel to air ratio more than 1.0) results in a cleaner and more efficient engines. This is due to several reasons, some of which are; high compression ratios, low throttling losses at part load, and favourable thermodynamic properties in burned gasses. A major part in reducing the particulate matter emissions is the design of the engine itself. One of which is the optimized air motion through the combustion chamber and the intake air turbulence that

provides adequate mixing of the air and fuel at low speeds and avoid over rapid mixing at high speeds that leads to hydrocarbons, nitro oxides and increased fuel consumption (A.Faiz et al., 1996).

The role that a good inlet system plays in the performance, efficiency and emission of an IC engine are the main motivations of this study, which, hopefully, leads to the production of an optimized and improved inlet system.

The secret to make a good inlet system design lies in making the inlet system to be able to provide the most amount of air velocity as possible into the combustion process so that the combustion process inside the engine (P.C. Vorum, 1976). For this condition to happen, the efforts that have been done are either by increasing the volumetric efficiency of the engine or through supercharging the air itself.

In an ideal intake process, the pressure of at the intake valve should be equal of that in the intake manifold. This, however, does not happen. The ideal conditions are not met due to several factors (J.M. Desantes et al., 2010), some of which are:

i) The pulsations of pressure where the pressure in the intake manifold is strongly affected by the wave effects that is created by the pulsating engine operation.

ii) The residue that is left from the combustion process as the exhaust is imperfect. This happens when the intake valve opens before the exhaust valve closes, causes the exhaust gas mixes with the intake gas.

iii) The existence of different surfaces in the different part of the intake system, namely the intake manifold, the inlet valve, the engine runners, and the cylinder wall itself affected both the heat transfer of the engine and the pressure and flow operation during the intake process. The existence of different part of an engine and how it affected the airflow during the intake process will be the main focus of this study.

The main purpose of this study is to investigate in the different factors that affect the mass flow rate of an engine's intake flow. To be more specific, this article investigates how the flow rate changes with changing valve lifts, changing pressure and different configurations.

## EXPERIMENTAL SET UP

Table 1. Specification of the SF-1020SB Flow Bench

<b>SF-1020 Specification</b>	
Calibration Test Pressure	25" of water
Range	0-1, 100 CFM
Exhaust Capacity	1,000 CFM @ 25" H <sub>2</sub> O
Power Phase	240VAC, 75A, Single Phase
Weight	480lbs (281kg)
Dimensions	48 x 33 x 43 in.

Table 2. Specification of the Honda GX120 engine

<b>DIMENSIONS AND WEIGHT</b>	<b>GX120</b>
Description code	GC01
Length X Width X Height	300 x 345 x 320 mm (11.8 x 13.6 x 12.6 in)
Dry Weight	12.0 kg (26.5 lb)
Engine type	4-stroke, overhead valve, single cylinder
Displacement (Bore X Stroke)	118cc (7.3 cu in) [60 x 42 mm (2.4 x 1.7 in)]
Max. Output	4.0 HP / 3,600 rpm.
Max. Torque	0.75 kg (5.4 ft-lb)/ 2,500 rpm
Fuel Consumption	230 g/PS h
Cooling system	Forced air
Ignition system	Transistorized magneto
PTO shaft rotation	Counter-clockwise

The experiment was conducted using the SuperFlow SF-1200 flow bench, which is an apparatus that generates a steady flow and at the same time allows for the measurements of the global flow characteristics such as; mass flow rate, velocity and pressure (SuperFlow SF-2010 Instructional Manual). Table 1 shows the specifications of the flow bench that was used during the course of the study. The specimen that was used was the cylinder head of a Honda GX120 single piston two-stroke 4 horsepower engine. Other characteristics of the engine are shown in Table 2.

The test apparatus required the engine head to be attached to the flow bench by a cylinder head adaptor that have the same diameter as the bore diameter of the tested engine as shown in Figure 2. The engine head, head adaptor and flow bench set up is held together using a type of sealant and foam tape to ensure that the leakage is as little as possible. Any small leakage that is still present is keyed into the flow bench so that the flow bench apparatus can adjust to the leakage present when it is measuring the intake flow rate.

The cylinder head was tested at the pressure of 20.095 inH<sub>2</sub>O, 40.19 inH<sub>2</sub>O, and 60.285 inH<sub>2</sub>O. At each test pressure, the valve was lifted from 0 mm at an increment of 5 mm until the valve is lifted at 11.5 cm, which is the maximum valve lift for this engine model, and at each of those valve lift, the flow rate was measured.

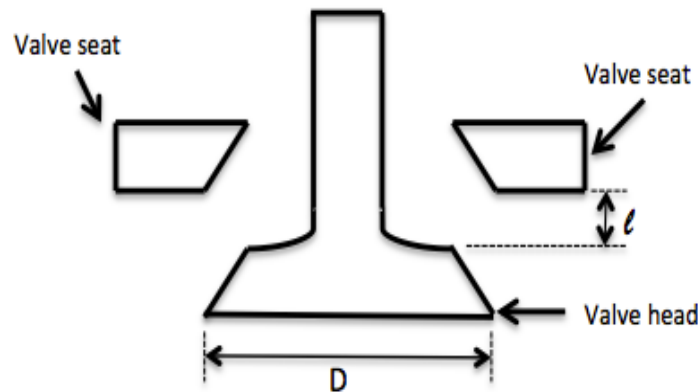
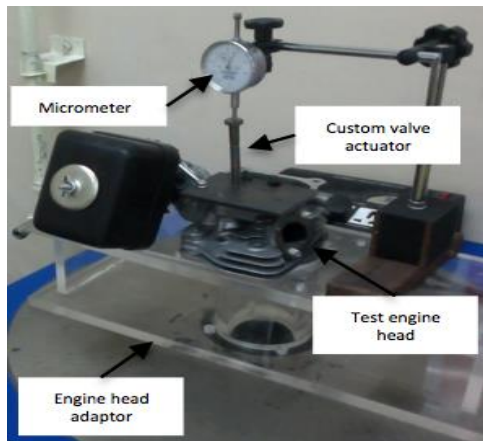


Figure 1. Diagram of the valve lift where,  $l$  is the valve lift and  $D$ , is the valve diameter.

The valve of the engine was opened, as shown in figure 1, where the valve head is lifted from the valve seat to create an opening that allows for the air to flow into the system as it was during an intake process. The valve was lifted using a manual valve actuator, which is a custom made plate that is fixed above the valve tip where the rocker arm should be. The valve is lifted by a turn of a blot that is attached to the plate, which pushes the valve open. A micrometre is fixed above the bolt to measure the actual valve lift.



(a)



(b)



(c)

Figure 2. Experimental setup (a) at full configuration; (b) removed air filter; (c) port only configuration.

The test continues with different configurations for the intake system. The first configuration was the complete configuration as shown in Figure 2(a). Second configuration was the port and the carburettor (the air filter removed) as shown in Figure 2(b) and third configuration was the intake port only configuration (without anything attached to the intake port) as shown in Figure 2(c). Each configuration was tested and the mass flow rate was recorded.

## RESULTS AND DISCUSSION

From the result that was obtained from the experiment shows that as the flow rate changes with valve lift in a polynomial pattern where the flow rate changes in a linear pattern at low valve lifts. The gradient of the flow rate to valve lift curve then changes substantially at higher valve lifts and when the valve lift reached at a certain point, the flow rate began to show low changes and at later valve lifts, there were no changes to the flow rate, even as the valve lift increases. This pattern is true for most of the

different conditions that were run during the course of this study. This pattern is due to the increase in area of the airflow gap.

The study also made a point of testing the engine at the valve lift of 11.5 mm because it is the maximum amount of valve lift allowed by the engine's current design's valve spring. While it is possible to test the engine at higher valve lift, the data shows that the flow rate will not have any significant changes beyond a certain point. Plus, the valve lift range that is used in this study is already beyond the normal operating conditions of the engine as the cam shaft design will not open the valve beyond 6mm and if the valve is opened anymore, the design will suffer a grate reduction in efficiency and increase in cost for the benefit of a very little improvement in flow intake.

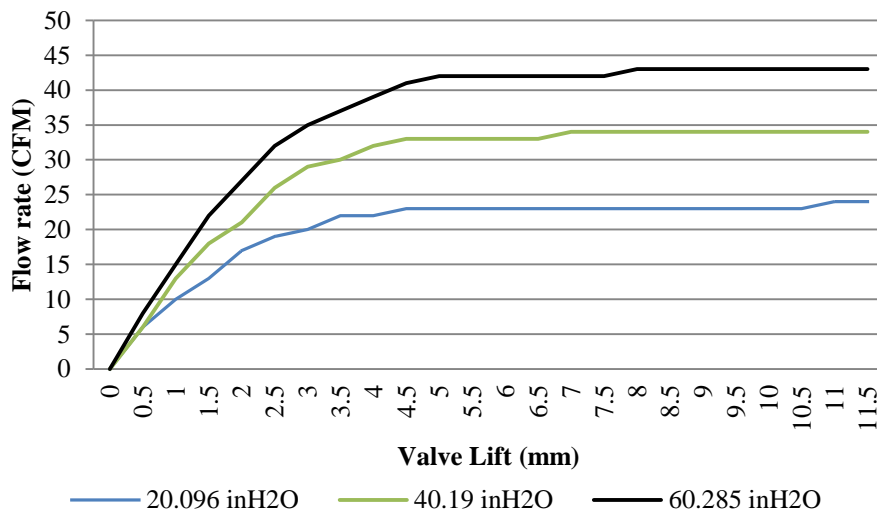


Figure 3. Mass flow rate of the tested port at full configuration at different pressure

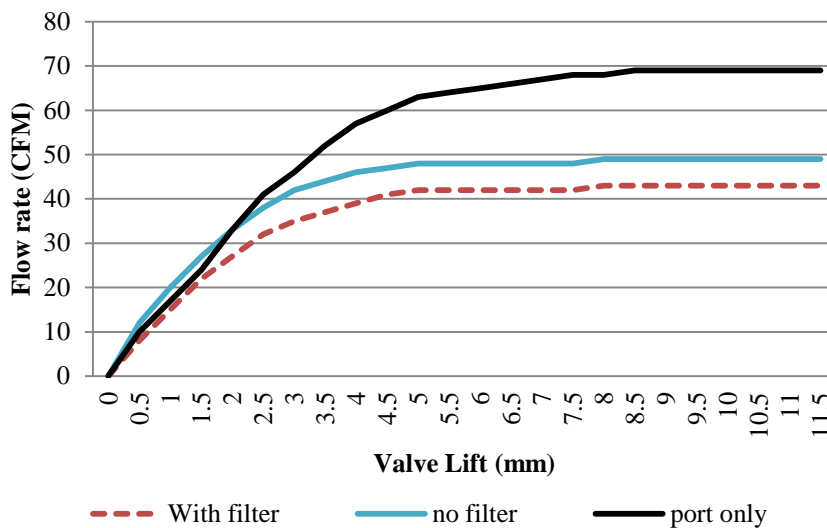


Figure 4. Mass flow rate of the tested cylinder head at 60.285 inH<sub>2</sub>O at different configuration.

Figure 3 shows how the flow rate changes with different valve lift at different pressure. As expected, with increasing pressure, the flow rate that was produced becomes greater. The different pressure does not change the pattern in which the flow rate changes with valve lift. This means that the different pressure curves do not intersect with each other at any valve lift other than the initial valve lift of 0 mm. The increment of pressure from 20.095 inH<sub>2</sub>O to 40.19 inH<sub>2</sub>O leads to an average of 45% increase in flow rate, while the increment of 40.19 inH<sub>2</sub>O to 60.285 inH<sub>2</sub>O leads to an average of 25% increase in flow rate. The increase in flow rate is attributed to the higher-pressure difference inside the inlet system and the outside atmosphere and the fact that there is a direct correlation between the pressure and flow rate for every rise in pressure, shows that no special phenomenon will occur during the intake process.

Figure 4 shows the flow rate changes with valve lift at different engine configuration. The result shows that when the engine is at its complete configuration, the flow rate is less produced. When the air filter is taken off and the engine is left at only its port and its carburettor, the flow rate exhibits an average increase of 18% and when the carburettor is removed, leaving only the engine port, the flow rate exhibits an average increase of 25%. The difference in flow rate is due to the losses that occur in the internal flow due to the changing geometry and the different surfaces that the air flows through when it is at full or port and carburettor only configuration. It is not until the air is only flow directly through the port of the engine did the flow rate exhibit a significant increase.

For both the engine at full configuration and for the engine with the air filter removed, the curve flow rate against valve lift curve seems to pattern the same way as before with the initial valve lift gives a linear correlation between the flow rate and the valve lift and the gradient of the curve decreases as the valve lift increases as to a point where there is no apparent change in flow rate. As for the case of where there is only the engine port is tested, the flow rate against valve lift curves seems to have a lower gradient at low valve lift and the gradient increases before the gradient lowers again at higher valve lifts and later on the flow rate barely changes with increasing valve lift.

It is also important to note that at lower valve lift, the port only configuration seems to have lower flow rate when compared to the port and carburettor configuration. It is not until at a higher valve lift where the port only configuration has a higher flow rate when compared to the port and carburettor configuration, which the two curves intersect at valve lift of 2 mm. This phenomenon can be attributed to the geometry of the port only configuration that creates turbulence and significant losses to the airflow. This also shows the importance of creating a laminar flow before the air enters the engine.

It is also worthy to note that the curve pattern between the full configuration and, the port and carburettor configuration seems to have similar shapes and did not show any signs of turbulence or any other unexpected losses to the internal flow. This shows that the creation of laminar flow for the intake process is not attributed only to the air filter of the engine but also to the carburettor. It is also can be argued that, from a volumetric efficiency stand point, the carburettor is enough to create a laminar flow for the intake process and the current design of full configuration engine does exhibit a problem of creating unnecessary losses.

## CONCLUSION

In this paper, it is found that the flow rate will increase with the increase of the valve lift up to a certain point before the flow rate decrease its rate and later on remains constant and as expected the flow rate increases with increasing test pressure. The full configuration will have the lowest overall flow rate followed by the port and carburettor configuration and the port only configuration exhibits the highest overall flow rate, which demonstrates the effects and losses caused by the different engine parts. At low valve lift, the port only configuration seems to have lower flow rate compared to the port and carburettor configuration due to the turbulence formed when the engine is at this configuration.

The results of the study serves as a very good baseline for further investigations especially when it comes to computer simulations. Plus the phenomenon observed at low valve lift at port only configurations begs for further investigations in the turbulence formation during the intake process of the same test engine.

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