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FLOW BEHAVIOUR ANALYSIS ALONG AN ENGINE AIR INTAKE PIPE

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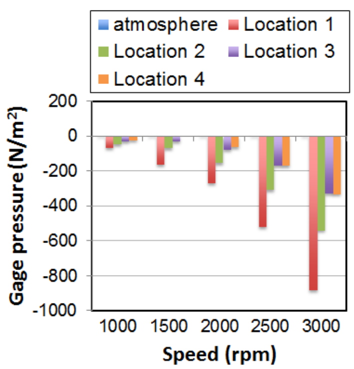
Graphical abstract



Abstract

There is a concern with the flow behaviour inside the air intake pipe that affects the desirable pressure ratio for inflow into the cylinder of an internal combustion engine. Measurements of flow along the intake pipe are required to better understand the physics of the intake system. This paper focuses on investigating the dynamics of the pressure profile along the intake pipe. The methodology involves experimental work utilising a red oil manometer to measure the pressure. Results analysis is presented as graphs of gauge pressures against engine speeds. From experimental results, the pressure profiles along the intake pipe were similar at different engine speed settings and pipe lengths. It was observed that the values of gauge pressure were lowest at the pipe entrance and it continued to rise along the pipe until it reaches the intake valve. This is a preliminary study looking into the effect of pipe geometry on the pressure dynamics.

Keywords: Air intake, intake pipe, airflow, internal combustion engine

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1.0 INTRODUCTION

Air intake system provides fresh air to internal combustion engines. There are many investigations related to the design of combustion engines in improving airflow in the intake pipe [1]. As the piston moves downward during the intake stroke, a reduction of pressure occurs at the intake valve relative to the pressure at the open end of the intake pipe. A favourable pressure ratio for inflow to the cylinder occurs when the pressure in the cylinder is lower than the pressure in the port [2]. Such favourable pressure ratio may be obtained in two ways; firstly, by the downward motion of the piston reducing the cylinder pressure and secondly, by the wave action in the port increasing the instantaneous pressure in the port [3].

When the intake valve is open, air is sucked into the cylinder, so the air in the intake pipe is moving rapidly toward the cylinder. When the intake valve closes suddenly, this air slams to a stop and stacks upon itself, forming an area of high pressure. This high-pressure wave makes its way up the intake pipe away from the cylinder. When it reaches the end of the intake pipe, the pressure wave bounces back down the intake pipe towards the cylinder [2].

If the timing of these waves is appropriately arranged, the positive pressure waves will cause the pressure at the intake valve at the end of the intake process to be raised above the nominal intake pressure and increase the inducted air mass [4]. The oscillating pressure waves caused by the opening and closing of the intake valve also affects the pressure profile along the intake pipe [5]. Single lengths of pipe feeding each cylinder separately are preferred to an intake manifold that restricts the flow path [6]. As such, the aim of this study is to investigate the flow behaviour along the air intake pipe of a simple geometry utilising red oil manometer at different experimental settings to enable a better understanding of the physics of the intake system.

2.0 EXPERIMENTAL SETUP AND PROCEDURES

A small Launtop LT160 single cylinder, four-stroke, air-cooled, naturally aspirated internal combustion engine was used in the study. The engine specifications are shown in Table 1.

As this paper is focused on understanding the air flow behaviour in the air intake pipe of a fuel injected engine, the carburetor was removed and the engine's crankshaft was attached to a variable speed electric motor to control the engine speed. This setup is akin to a direct injection engine where the fuel is injected directly into the combustion chamber of the cylinder and only air passes through the intake pipe. This means that there is no concern on the effect of fuel on the air flow in the intake pipe. The engine's intake system consists of a straight 26 mm internal diameter Perspex tube. The intake pipe was drilled and tapped at several locations along its length and pressure was taken at these locations using a red oil manometer (SG= 0.784). The experimental setup is shown in Figure 1.

The speed of the engine was varied between 1,000 rpm and 3,000 rpm and the manometer readings at the different locations were recorded. To determine the effect of intake pipe geometry on the pressure profile, two different lengths of the same diameter were utilised, a short intake pipe length of 19.4 cm and a longer pipe length of 60 cm.

Table 1 Launtop LT160 engine specifications

Type	**Single cylinder, Four-stroke, Air-cooled,**
Displacement	163 cc
Bore x stroke	68 mm x 45 mm
Compression ratio	8.5:1
Speed	3600 rpm
Continuous output	3.17 kW / 4.3 hp
Max torque	1.1 kgm / 2500 rpm

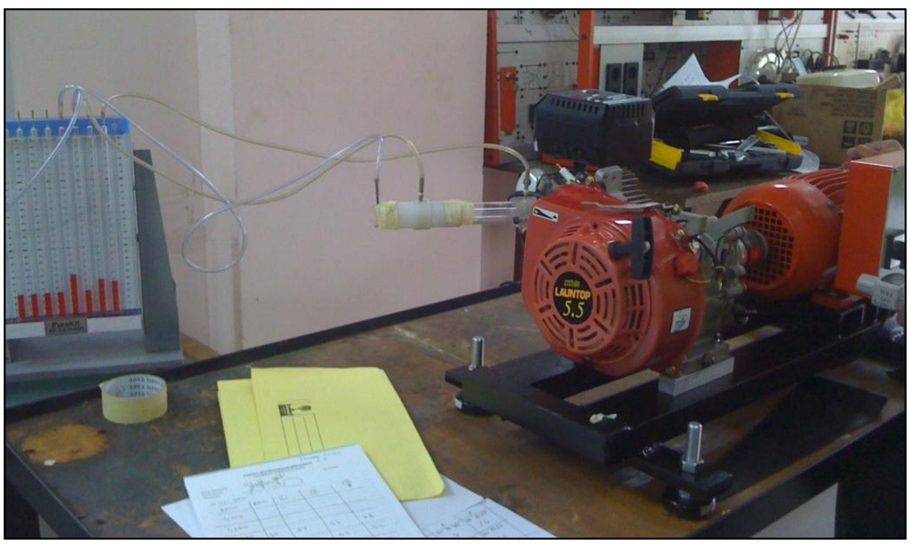

Figure 1 Experimental setup

3.0 RESULTS AND DISCUSSION

The location and pressure readings by the red oil manometer along the short 19.4 cm pipe section are presented in Figure 2 and Figure 3. Location 1 is at the pipe entrance and location 3 is at the intake valve. For the longer 60 cm pipe (Figure 4 and Figure 5), location 1 is at the pipe entrance and location 4 is at the intake valve.

The pressure profiles generated by the oscillating pressure waves along the intake pipe are similiar at different experimental settings of engine speed and pipe length with low gauge pressures recorded at the pipe entrance and the pressure continues to rise along the pipe until it reaches the intake valve (Figure 3 and Figure 5). As the engine speed increased, the rate of the intake valve opening and closing also increased, resulting a decrease in gauge pressure at the pipe entrance for both the short and long intake pipes. The highest gauge pressure was -47 N/m2 (1000 rpm, short pipe length) while the lowest gauge pressure recorded at the pipe entrance was -884

N/m2 (3000 rpm, long pipe length). An increase in the rate of the intake valve opening and closing and the extra travel length for the oscillating pressure wave may reduce the pipe entrance gauge pressure.

The highest gauge pressure recorded at the intake valve is 0 N/m2 (1500 rpm, long pipe length and -162 N/m2 at the pipe entrance) and the lowest pressure measured was -331 N/m2 (3000 rpm, long pipe length and -884 N/m2 at the pipe entrance). The result indicates that a lower gauge pressure at the pipe entrance does not contribute to a higher gauge pressure at the intake valve. For this experimental setup, the intake valve opening and closing at 1500 rpm and a longer pipe length provides an ideal condition for the oscillating pressure waves to increase the gauge pressure at the intake valve.

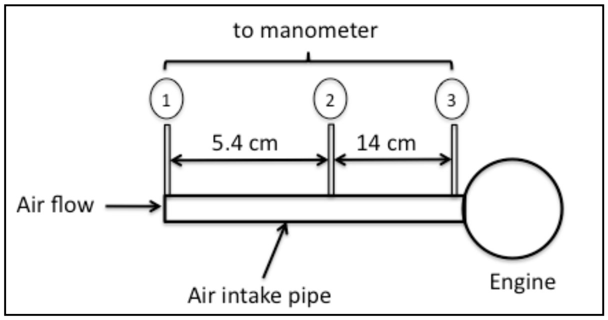

Figure 2 Pressure reading locations along the short 19.4 cm air intake pipe

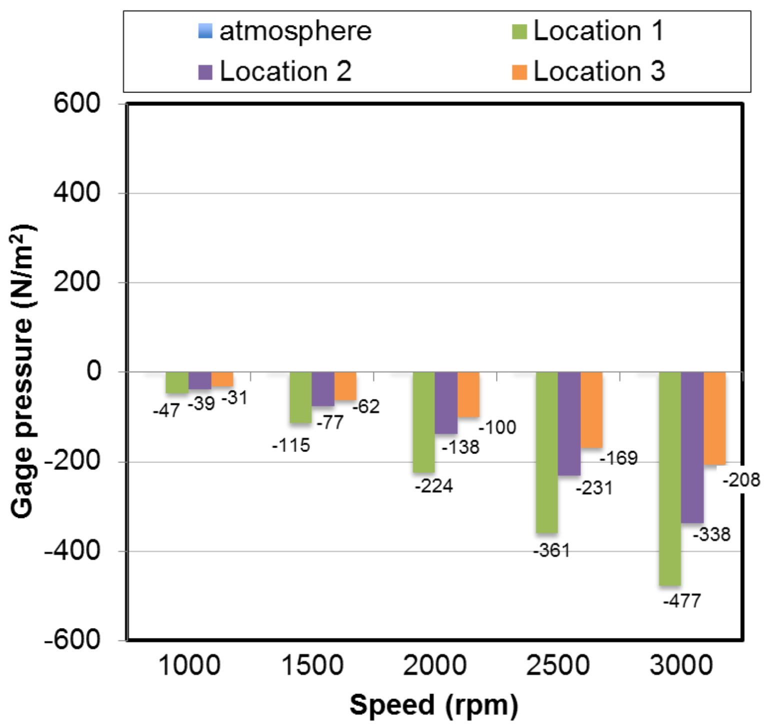

Figure 3 Pressure readings along the short 19.4 cm air intake pipe at different engine speeds

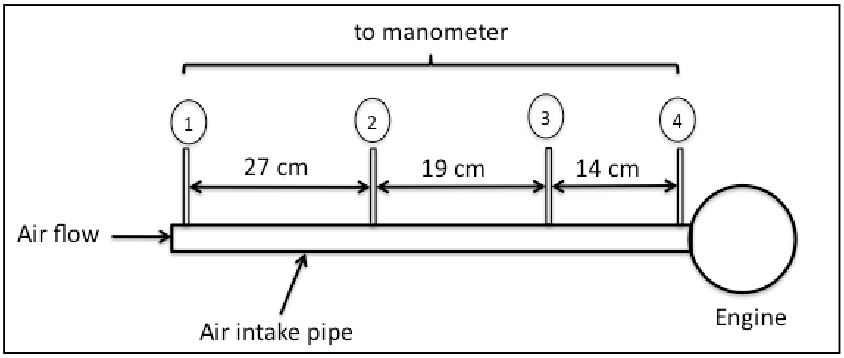

Figure 4 Pressure locations along the long 60 cm air intake pipe

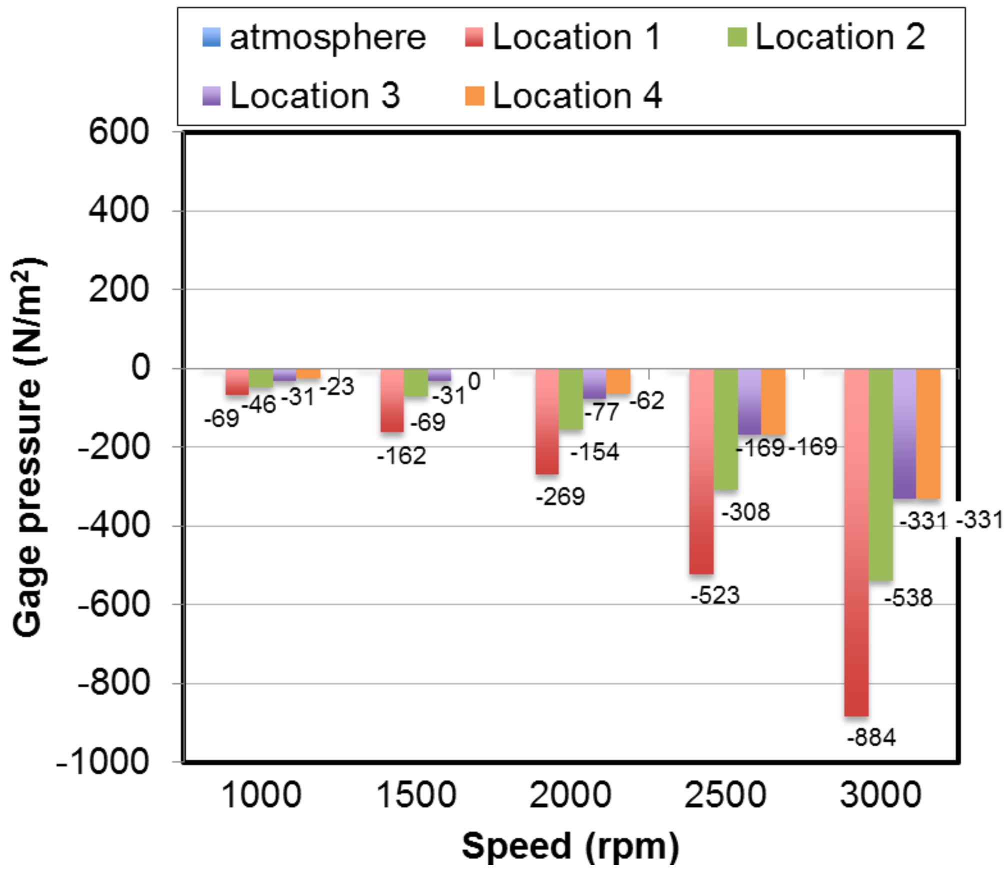

Figure 5 Pressure readings along the long 60 cm air intake pipe at different engine speeds

4.0 CONCLUSION

The experimental results showed that the oscillating pressure waves, caused by the opening and closing of the intake valve, affected the pressure profile along the intake pipe. The pressure readings using the red oil manometer indicate that a lower gauge pressure at the pipe entrance, caused by the rapid opening and closing of the intake valve at high rpm, did not result in a higher gauge pressure at the intake valve. For this experimental setup using straight pipe length geometry, the combination of the rate of opening and closing of the intake valve and pipe length has an effect on the increasing gauge pressure at the intake valve. The highest gauge pressure at the intake valve was achieved at 1500 rpm and with a longer pipe length. It was observed that the values of gauge pressure were lowest at the pipe entrance and it continued to rise along the pipe until it reaches the intake valve.

In future, intake pipes with a different geometry and cross sectional area will be installed on the engine and will be tested. The results will be compared with the cited results.

Acknowledgement

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