EXPERIMENTAL INVESTIGATION OF AN AIR ENHANCEMENT DEVICE ON THE PERFORMANCE OF A SPARK IGNITION ENGINE

(Date received: 30.3.2009)

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ABSTRACT

Air enhancement devices for air intake manifold systems of automotive engines have been widely available in the market with the claim that they can improve fuel-air mixing and thus bring more power to the engine performance and better fuel efficiency. However, there is lack of evidence to complement the claim. The objective of this study is to investigate the ability of an air enhancement device in improving the performance of a Spark Ignition (SI) engine. The investigation is performed by an experiment on a four-stroke single-cylinder engine test bed, in which the air enhancement device is installed at the downstream of the air intake manifold. The result is compared to the performance of the engine without the air enhancement device. It is shown that the brake power, brake mean effective pressure (BMEP) and torque increase significantly with the engine speed when operated at 30% to 50% of the open throttle positions. However, no distinct difference in the results is observed when the engine is running at higher throttle openings.

Keywords: *Engine, Internal Combustion, Spark Ignition, Volumetric Efficiency*

1.0 INTRODUCTION

Historically, the price for crude oil used to be USD 150 per barrel [1]. Due to the increase of fuel price, vehicle owners may consider seeking for devices that can lower their vehicles' fuel consumption without compromising the performance of the engine. One of the approaches to reduce fuel consumption is by using an air enhancement system that is mounted at the air intake manifold of the engine. Forced induction systems such as turbochargers and superchargers have been used to overcome some of the performance issues [2]. However, turbocharging does not completely eliminate the problem of "turbo lag" as it cannot produce sufficient charging pressure at low engine speed when there is little energy in the exhaust [3]. As for supercharging, it has problem with parasitic loss, which takes additional power from the engine especially at full load [4].

The amount of air that enters the intake manifold of a *Spark Ignition* (S.I.) engine depends on the pressure differential between the air above and below the throttle valve [2]. The air above the throttle valve is the atmospheric pressure, which is around 101 *kPa*. The air below the partially closed throttle valve is at less than atmospheric pressure, which is called negative pressure as created by the piston during the intake strokes. When the piston leaves top dead center (TDC) and move down the cylinders the space above the pistons gets larger. The stroke will lower the pressure in the intake manifold and creates the partial vacuum called intake manifold vacuum.

Normal engines use atmospheric pressure as a force to induce air into the intake manifold. These engines are called naturally aspirated or normally aspirated engines. At the same speed, an engine can produce more power if more air-fuel mixture is forced into the cylinders [5]. Forcing additional air-fuel mixture into the cylinders is referred as forced induction, which increases the volumetric efficiency of the engine; and this can be achieved by allowing higher pressures during the power strokes

There are many air enhancement devices available in the market recently, which are intended to increase the volumetric efficiency of the engine. One of the devices is reported to use crossed pin at a location before the throttle body of the engine to produce a swirl effect inside the manifold and consequently induce more air-fuel mixture in the cylinders [6, 7]. With a similar concept, another device, which uses a conical-shaped element, alters the pressure and velocity of the gas flow in order to improve fuel efficiency [8]. Some of these devices are reported to improve fuel efficiency for about 3-5% [9, 10]. In contrary, in a more recent work by Mohd-Abidin [11] on a similar device, it was reported that such device had a detrimental effect on engine's performance.

There is also a device that employs an air induction element with a honeycomb treatment structure to provide a uniform directional air flow pattern for reduction of turbulence and improvement of air velocity delivery to the carburetor [12]. Another device system, which is integrated with the engine air management system, consists of an electronically controlled inlet air compressor [13]. The system is claimed to use the concept of turbo charger system with the capability of improved performance without sacrificing the fuel economy.

However, for most of the devices introduced, there is lack of evidence to support the claims by the manufacturers of their advantages. Therefore a study has to be conducted to determine the most suitable method to design a modified air enhancement system.

In the present work, the mechanism and design of an airflow enhancement device or the airflow enhancer that forcefully induces the flow of air into the combustion chamber of a Spark-Ignition (S.I.) engine is studied. The manufacturer claims that the device enables cars to have better power and fuel consumption by a three-stage mechanism that results in a mixture of fuel and air molecules with separated positive and negative ions. The effects of using the airflow enhancer in terms of engine performance at various throttle positions are studied using a petrol engine test bed.

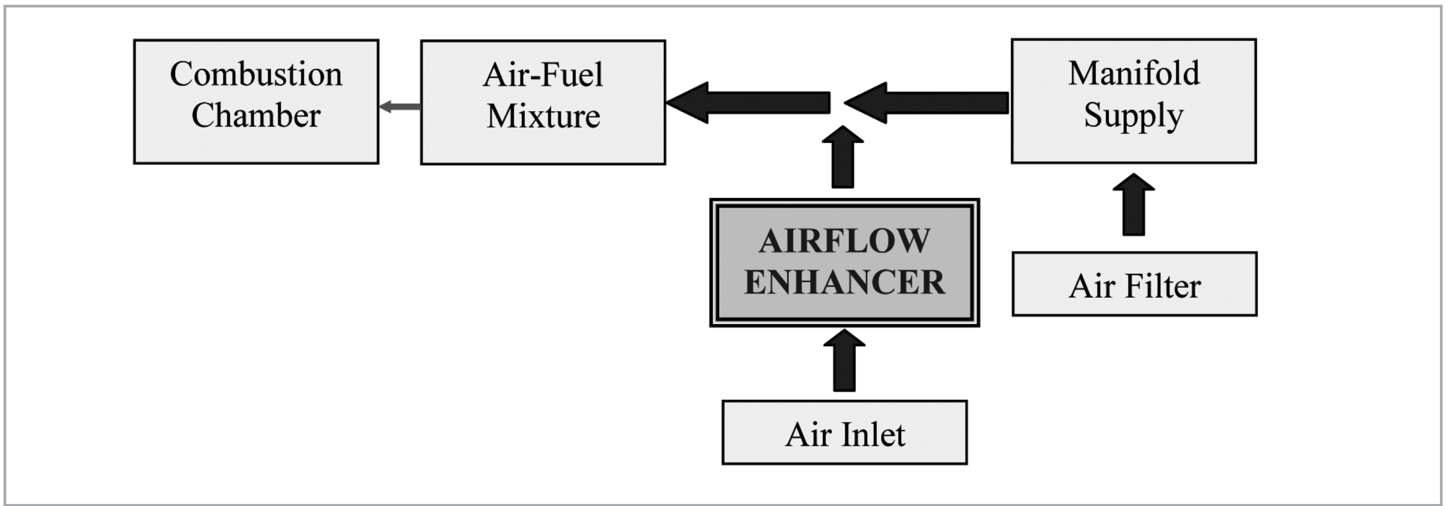

Figure 1: Mounting location of the airflow enhancer

2.0 DESCRIPTION OF THE AIRFLOW ENHANCER

The name of the air enhancement system product will not be revealed in this paper to prevent influencing consumers' judgment on a particular brand. The authors will refer the particular commercial product in generic term as the 'airflow enhancer.' For the same reason, detailed description of the device will not be disclosed. Tubular in shape, the airflow enhancer resembled a nozzle, of which the internal diameter of the inlet was about four times greater than the outlet. The airflow enhancer was installed at the intake manifold after the throttle, as illustrated in Figure 1. The mechanism operation of the airflow enhancer can be divided into three stages. In the first stage, the surrounding air will be drawn into the device inlet to pass through a built-in strainer. In the second stage, the air will pass through an array of air splitter before being directed into a nozzle for compression. In the final stage, the air accumulated in the cavity would be pressurised due to the reduction in the cross-sectional area of the airway. A Neodymium magnet was installed at a downstream point of the compressed air flow within the device. It has been claimed that the diatomic oxygen molecules that passed through the magnetic field would be polarised and would also increase the negative ions in the air to result in increases in burn time, temperature, and cylinder pressure, and consequently would increase the engine torque and power output [14].

3.0 EXPERIMENTAL SET-UP AND PROCEDURE

The experiments were conducted using an engine test bed. Shown in Figure 2 is the schematic of the engine test bed. A photograph of the test bed is shown in Figure 3. A 1.8 *litre* Ford 16-valve S.I. engine that was coupled to a dynamometer was used to determine the horsepower and torque of the engine. Table 1 shows the specifications of the engine. The dynamometer, Cusson Model SE 150, was of eddy current type with a maximum capacity of 150 *kW* and speed up to 8000 *RPM*. The fuel tank continuously fed the engine during the experiment and all the tests were conducted using Petrol RON 92 fuel, which was available and purchased from the local retailer. The air intake would pass through the air filter prior to entering the intake manifold at the body of the engine. The exhaust gas from the combustion chambers would be diverted into the exhaust pipe, as shown in Figure 2. A data acquisition system was connected to all the measurement transducers within the engine test bed to obtain the torque, brake mean effective pressure (BMEP) and brake power (accurate to ± 0.5 *kW*). The measurements were displayed and recorded by a desktop computer. The airflow enhancer was installed at the intake manifold in the arrangement as shown in Figure 1.

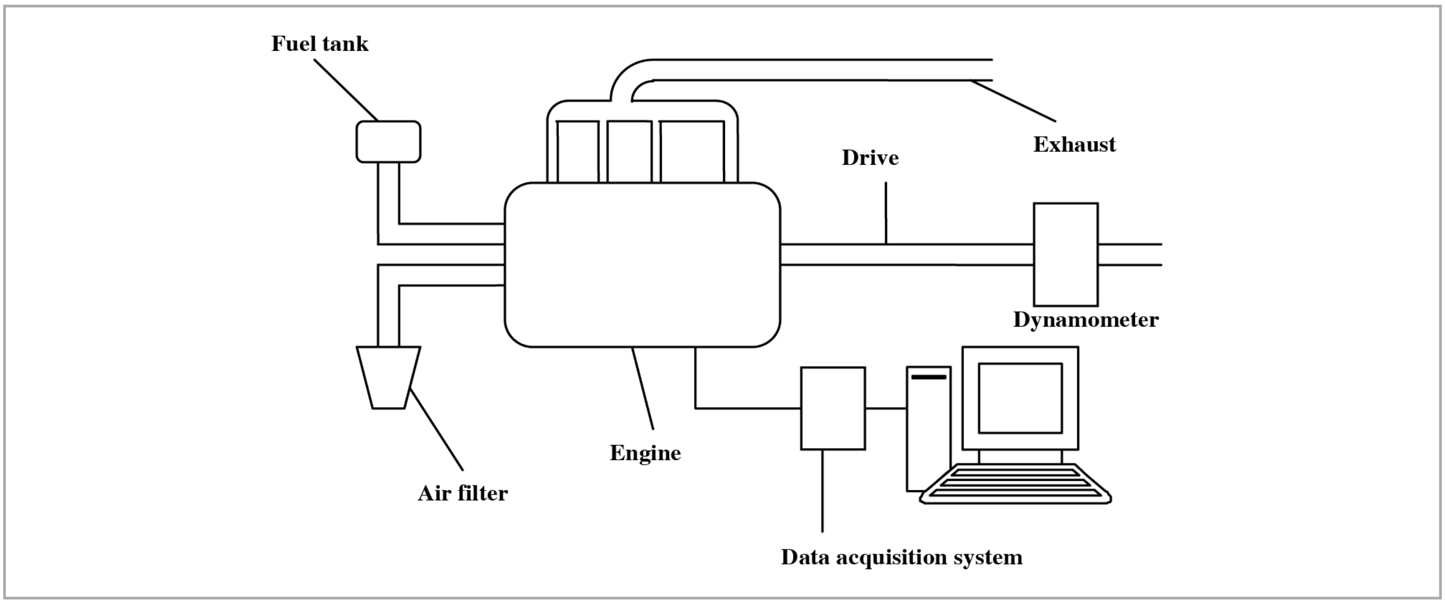

Figure 2: Experimental set-up

The engine's performance testing was conducted with and without the airflow enhancer. The engine was initially allowed to warm up. After a steady temperature within the engine's radiator was achieved, the engine was stopped to install the airflow enhancer. The engine was then restarted and the air vent-screw was adjusted to obtain the previous engine speed. A load on the engine was established to allow a starting speed of 1000 *rpm*. The experiment conditions were varied by changing the throttle opening positions and the engine speeds from 30 to 100 % and 500 to 3500 *rpm*, respectively, as indicated in Table 2. For each condition, the brake power, torque, BMEP, speed, fuel consumptions, air flow rate, and temperatures were recorded when the readings were stable. As shown in Table 2, there were experiments that could not be carried out for 30 and 40% throttle positions and at certain engine speeds. This was because the engine torque was very low that it could not run at such speeds. In other cases, instability in the measurement readings was displayed and thus it was decided that experiments were not performed under such conditions.

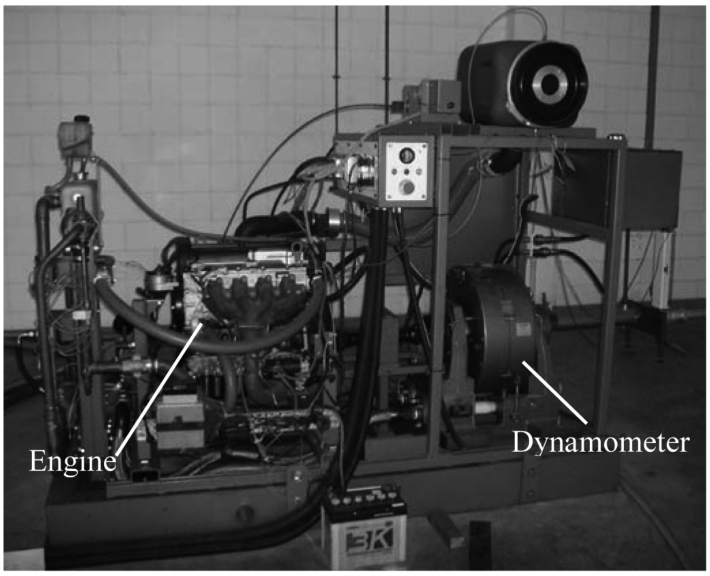

Figure 3: Photograph of the engine test bed

Table 1: Engine technical data

Specification	Data
Make	Ford
Type	SI 1.8 DOHC 16V
Emission standard	83 US
Identification code	RDA
Firing order	1-3-4-2
Bore (mm)	80.6
Stroke (mm)	88.0
Cubic capacity (cc)	1796
Compression ratio	10:1
Max. engine speed (rev/min)	5950
Power output (DIN-kW) at 5500 rev/min	77
Torque (Nm) at 4000 rev/min	153

Table 2: Experiment conditions

	Engine Speed (RPM)						
Throttle (%)	500	1000	1500	2000	2500	3000	3500
30		x	x	x			
40		x	x	x	x		
50	x	x	x	x	x	x	x
60	x	x	x	x	x	x	x
100	x	x	x	x	x	x	x

4.0 RESULTS AND DISCUSSIONS

Shown in Figure 4(a) is the variation of the measured torque with engine speed at throttle opening positions between 30% and 100%. The continuous lines represent the results for experiments with the airflow enhancer installed, and the dashed lines represent those without. In general, Figure 4(a) shows that the measured torque decreases with the engine speed, except for that of 100% opening, which exhibits gradual increase in torque with the engine speed. In Figure 4(b) the change in torque as a result of the use of the airflow enhancer is shown. Obviously, the torque increases up to 25% for experiments with low engine throttle (30% to 50%). As for 50% of the throttle opened, the increase in torque is shown only at engine speeds of higher than 2000 *RPM*. The slight drop in the graph for 30% of the open throttle at an engine speed of 2000 *RPM* is probably related to the fact that the torque at such condition was approaching a zero value. At other conditions, the differences in the results are small (<5%).

The variation of the BMEP with engine speed is shown in Figure 5(a), for the same experiment conditions as described for Figure 4 and with the same representations of symbols and lines. It is shown in Figure 5(a) that the BMEP decreases with the engine speed. However, this is an exception when operated at 100% opening position, in which the engine experienced a gradual increase in BMEP with the engine speed. Although at an engine speed of between 3000 and 3500 *RPM*, the BMEP starts to drop slightly, it is uncertain of whether it would further drop at a much higher engine speed.

In Figure 5(b) the change in BMEP as a result of the use of the airflow enhancer is shown. The trend of the graph is similar to that of Figure 4(b), in which the BMEP increases up to 25% for experiments with low engine throttle. As for 50% opening, the increase in BMEP is shown only at engine speeds of higher than 2000 *RPM*. At other conditions, the differences in the results are very small; *i.e.* less than 5%.

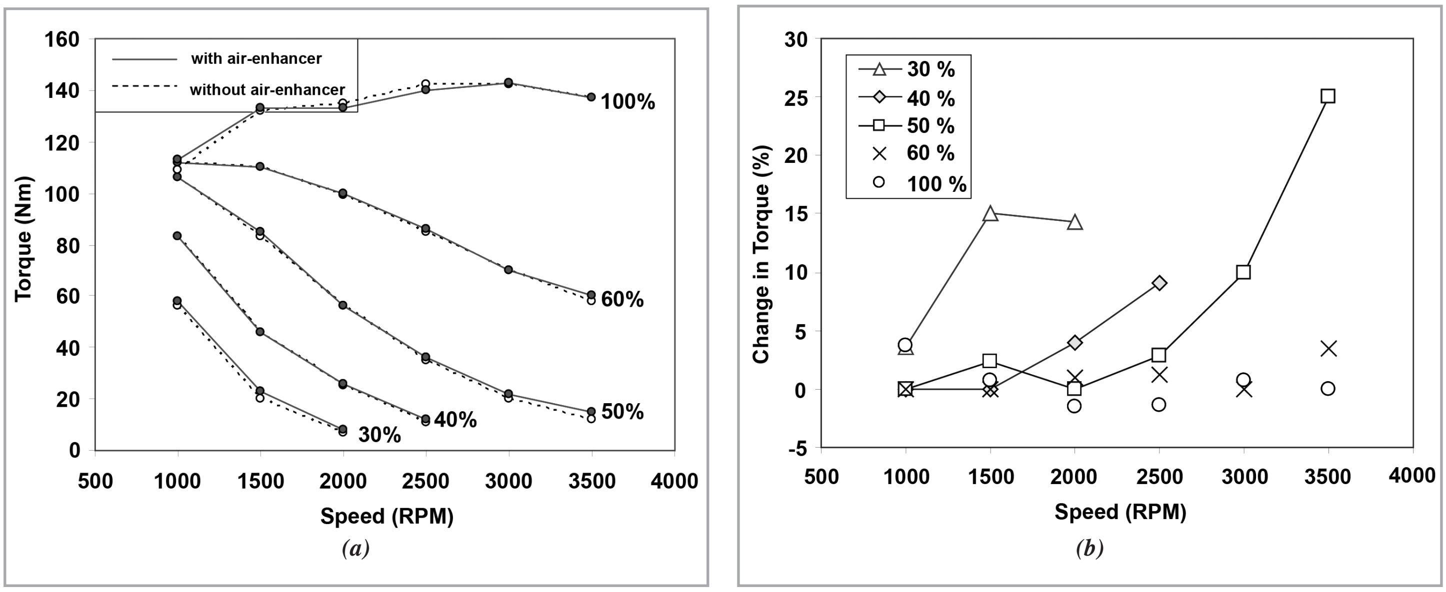

Figure 4: Variation of the measured torque with engine speed at different throttle opening positions with and without the airflow enhancer, (b) changes in the torque

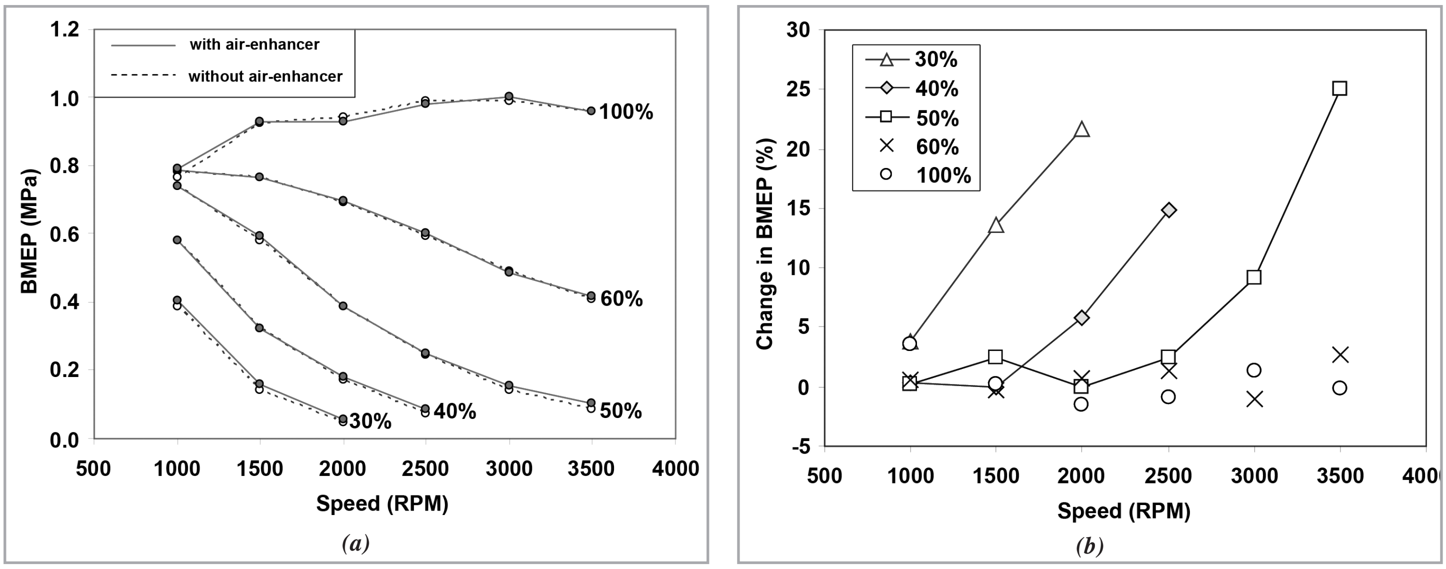

Figure 5: Variation of the measured BMEP with engine speed at different throttle opening positions with and without the airflow enhancer, (b) changes in the BMEP

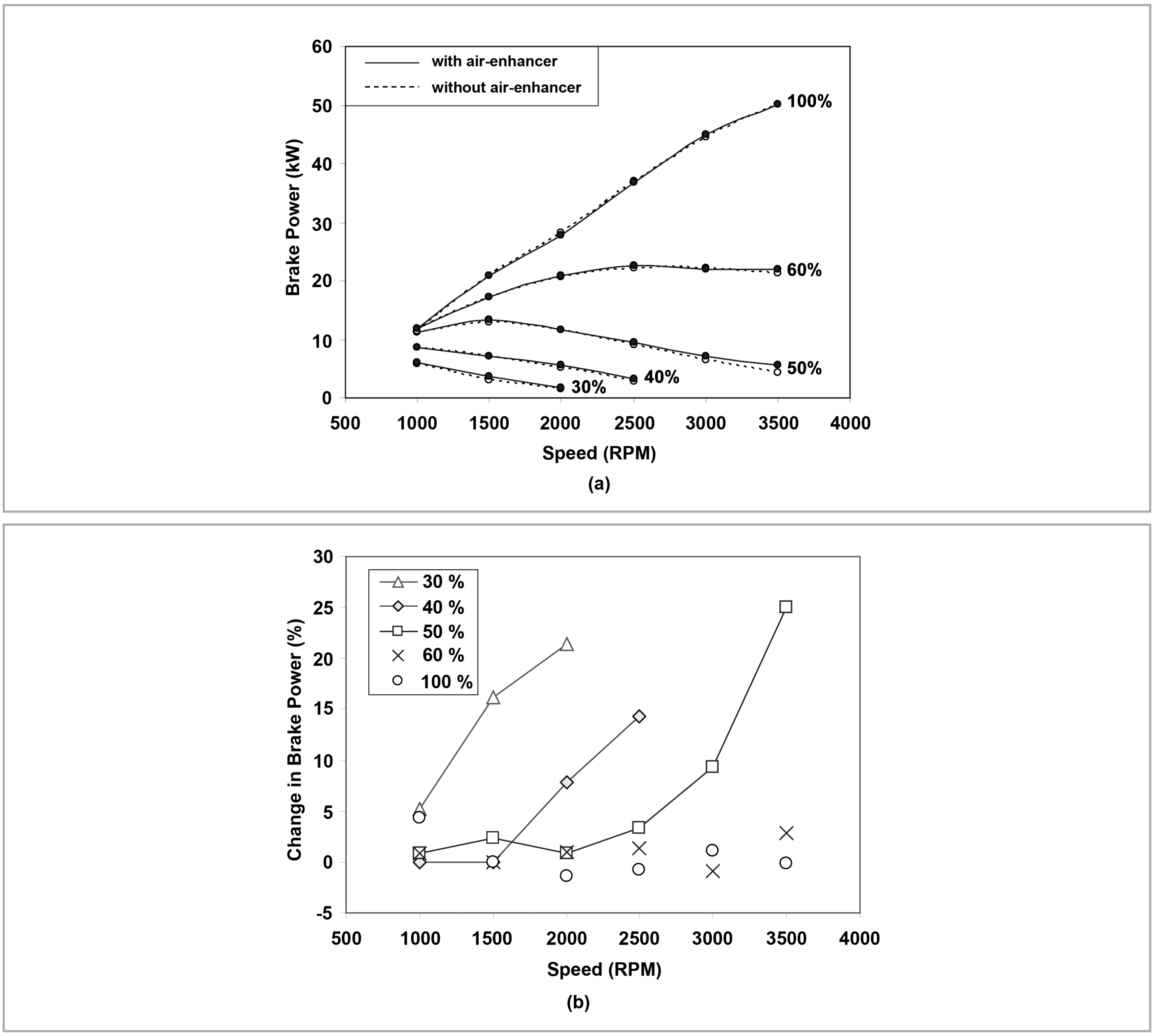

Figure 6: (a) Variation of the measured brake power with engine speed at different throttle opening positions with and without the airflow enhancer, (b) changes in the brake power

Shown in Figure 6(a) is the variation of the brake power with engine speed for the same experiment conditions as described for Figure 4 and with the same representations of symbols and lines. It is shown in Figure 6(a) that the brake power decreases with the engine speed when operated at 30% and 40% opening. The same trend is exhibited for experiments with 50% and 60% opening; however each displays an increase in brake power at lower engine speeds. For 100% opening, it is clear that the brake power increases with the engine speed. The change in the resulting brake power as a result of installing the airflow enhancer is shown in Figure 6(b). Similar to the graphs in Figures 4(b) and (b), the brake power increases significantly for experiments with low engine throttle (30%, 40% and 50%), although for 50% opening, the increase in BMEP is only demonstrated at engine speeds of higher than 2000 *RPM*. At other conditions, the effect of the airflow enhancer is shown to be negligible.

In general, the results show improvements in the torque, BMEP and brake power at some conditions when the air intake system of the engine was installed with the airflow enhancer. These are however limited to operations at 30%, 40% and 50% throttle open positions. The increases in torque, BMEP and brake power are proportional to the engine speed. The reason behind this is due to the higher number of intake stroke, which creates vacuum condition that enabled the airflow enhancer to induce more air into the combustion chamber. Obviously, the present work demonstrates that the airflow enhancer does not produce any effect when operated at 60% and 100% opening. This is probably because the volume of air induced by the normal operation (without airflow enhancer) is large and enough for the engine to reach the highest performance. During the normal operation, the volumetric efficiency is already high and no additional air can further be added.

5.0 CONCLUSIONS

The engine performance, as a result of installing an air-enhancing device at the air intake system of a spark ignition engine, was investigated in order to verify the claims made by its manufacturer. The use of such a device, which operated by mean of forced induction, was studied to determine its capability to enhance engine performances. The manufacturer claimed that by connecting the airflow enhancer to the manifold supply air inlet, extra air could be induced into the combustion chamber, which would then enhance the performance of the engine by improving its volumetric efficiency. The investigation was conducted by an experiment using a four-stroke single-cylinder engine test bed with and without the air-enhancing device. It was demonstrated that the brake power, brake mean effective pressure (BMEP) and torque increased significantly with the engine speed when operated at low load (30% to 50% of the throttle opened), although these were limited to a certain range of engine speeds. Nevertheless, at larger throttle openings, the device demonstrated insignificant effect to the engine's performance. ■

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