PAPER • OPEN ACCESS

The two-stroke poppet valve engine. Part 1: Intake and exhaust ports flow experimental assessments

To cite this article: M Kamili Zahidi *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **257** 012023

View the article online for updates and enhancements.

The two-stroke poppet valve engine. Part 1: Intake and exhaust ports flow experimental assessments

M Kamili Zahidi[1]***, M Razali Hanipah**[1, 2]**, D Ramasamy**[1, 2]**, M M Noor**[1, 2]**, K Kadirgama**[1, 2]**, M M Rahman**[1, 2]

[1]Automotive Engineering Centre (AEC), Universiti Malaysia Pahang, 26600, Pekan, Pahang, Malaysia.
[2]Automotive Engineering Research Group (AERG), Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600, Pekan, Pahang, Malaysia.

*Corresponding author: kamili.zahidi@gmail.com

Abstract. A two-stroke poppet valve engine is developed to overcome the common problems in conventional two-stroke engine designs. However, replacing piston control port with poppet valve will resulted different flow behaviour. This paper is looking at experimental assessment on a two-stroke poppet valve engine configuration to investigate the port flow performance. The aims are to evaluate the intake and exhaust coefficient of discharge and assess the two-stroke capability of the cylinder head. The results has shown comparable coefficient of discharge values as production engine for the intake while the exhaust has higher values which is favourable for the two-stroke cycle operation.

1. Introduction

Engine downsizing concept has been adopted by most automotive manufacturers to increase the power to weight ratio [1]. Engine downsizing are done by reducing the weight of the engine using smaller capacity and intake air boosting to increase the power.

Two-stroke engine cycle has been known to have higher power to weight ratio. However, the conventional two-stroke engines use piston control port which poses several problems. The first problem is bore distortion caused by an asymmetric temperature of the cylinder liner. Bore distortion is increasing the wear rate or worst case it will lock-up the piston[2]. The second problem is lubricant oil easily enter combustion cylinder via intake port resulting in higher pollutants in the exhaust emission[3].

Two-stroke poppet valve engine has been proposed by several researchers to eliminate the problem and at the same time increase the engine performance [4-7]. Each researcher has experiment different specification and design of two-stroke poppet valve engine. Nakano, et al reported the converted four-stroke engine into two-stroke poppet valve engine produce better power than original engine when compare at the same engine speed [8]. While, Sato, et al has design shrouded intake valve to overcome two-stroke poppet valve problem. The problem is short-circuit phenomenon during scavenging process [2, 3, 9].

In this paper, a production four-stroke cycle engine is converted into a two-stroke cycle engine. Then, the port flow performance is investigated by using flow bench.

2. Engine specifications

The investigation is conducted on a 65cc four-stroke gasoline engine. The bore of the engine is 50mm and stroke is 33mm while the compression ratio is 9.5:1. In terms of valves specifications, it has

maximum valve lift of 4 mm, intake valve diameter of 20mm and for exhaust is 18mm. The engine specification is as shown in Table 1.

Table 1. The engine specification.

Parameter	Value
Displacement volume	65 cm^3
Bore	50 mm
Stroke	33 mm
Compression ratio	9.5:1
Maximum valve lift	4 mm
Intake valve diameter	20 mm
Exhaust valve diameter	18 mm

The head design is shown in Figure 1. The valve design is straight at 90° from the horizontal axis. It has one valve is for intake and another valve is for exhaust. The left valve in Figure 1 is exhaust valve and the right valve is intake valve.
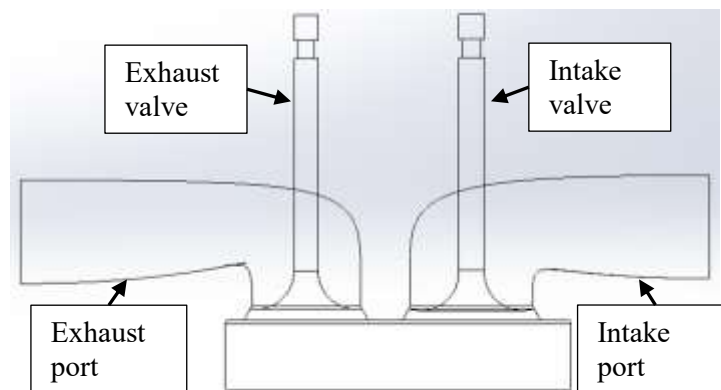

Figure 1. The engine design.

3. Experimental investigations

The experimental investigation is conducted into two phases. First phase involves experimental setup preparation and second is the experimental procedure. The preparation involved is the design and fabrication of adapter to place an engine head on a flow bench. Then, the experiment was run and the data is being calculated to find the coefficient of discharge. There are two types of testing mode; the intake test by setting the flow bench to draw the air from surrounding into flow bench through intake port. Exhaust test is for exhaust by setting the flow bench to blow the air through the exhaust port. Flow bench is an equipment used to measure air flow rate through orifice plate by means of differential pressure. The flow bench is capable of measuring velocity, temperature, and volume flow rate [10] with relevant sensors installed on the equipment during testing.

3.1. Experimental setup preparation

There two components need to be fabricated. First is engine the head adapter to mount engine head on SuperFlow SF-1020 flow bench. The flow bench can be used to test a wide range of cylinder bore diameters. Thus, the adapter is necessary to fit engine head with the flow bench standard sized bore. The adapter also to ensure there is no air leakage. The second part is valve pusher to vary the valve lift during the experiment. The experiment setup is shown in Figure 2. In the setup, dial gauge was used to measure the valve lift.
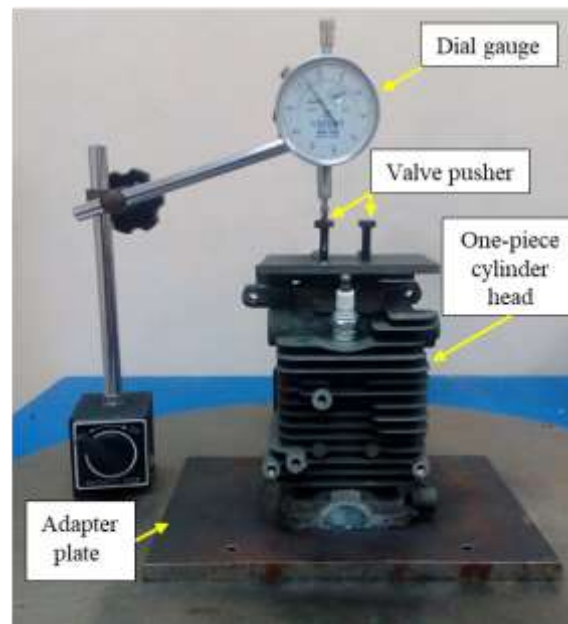
Figure 2. Engine head setup on flow bench.

3.2. Experimental procedure

In this paper, the engine head was tested without manifold or surge tank. The experiment started with intake port test during which the exhaust valve remains closed and the pump was set into suction mode. The data was recorded at every 0.5mm valve lift from 0mm until the maximum lift of 5mm. Next, the experiment resumed for exhaust port test where blowing mode was selected and the intake valve closed. Data were taken at similar valve lift intervals and the procedures were repeated five times for consistencies. The results are presented in terms of L/D ratio as it is an universal ratio used elsewhere [10]. The formula for L/D ratio is given in equation (1) and the results are shown in Table 2.

$$L/D \ ratio = \frac{Valve \ lift \ (L)}{Valve \ diameter \ (D)} \qquad (1)$$

Table 2. Intake and Exhaust L/D ratio.

Valve Lift (mm)	Intake L/D ratio	Exhaust L/D ratio
0.5	0.025	0.028
1.0	0.050	0.056
1.5	0.075	0.083
2.0	0.100	0.111
2.5	0.125	0.139
3.0	0.150	0.167
3.5	0.175	0.194
4.0	0.200	0.222
4.5	0.225	0.250
5.0.	0.250	0.278

From the experimental data, the coefficient is calculated in order to assess the efficiency of air flow [11]. The higher the coefficient value results better air flow into the engine. Thus, the coefficients give practical advices to engine designers and tuner on sizing and location of ports and valves[12]. The coefficient of discharge, C_D can be calculated by using equation (2).

$$C_D = \frac{\dot{m}_a}{\dot{m}_t} \qquad (2)$$

Where $\dot{m}_a$ is actual mass flow rate and $\dot{m}_t$ is theoretical mass flow rate. The actual mass flow rate can be calculated by using equation (3).

$$\dot{m}_a = Q\frac{P}{RT} \qquad (3)$$

Where Q is volume flow rate, P is the local pressure, R is a gas constant of air and T is air temperature. While the theoretical mass flow rate can be calculated by using equation (4).

$$\dot{m}_t = \rho_s A_k V_s \qquad (4)$$

Where ρ_s is the air density, A_k is the valve seat area and V_s is flow velocity. The flow velocity can be calculated by using equation (5).

$$v_s = \sqrt{\frac{2\gamma}{\gamma-1}RT[1-(\frac{P_2}{P_1})^{\frac{\gamma-1}{\gamma}}]} \qquad (5)$$

Where P_1 is upstream pressure, P_2 is downstream pressure and γ is an index of isentropic expansion. As long as the flows remain in the subsonic region no choked flow occurs in the design.

The flow coefficient, C_f has same equation with C_D. But, it has different area calculation for $\dot{m}_t$ in equation (4). For flow coefficient, the area is at the valve throat area.

4. Results and discussion

The result from flow bench experiment is volume flow rate data of intake and exhaust port. Then the experimental result is calculated with theoretical equation of coefficient. The result from coefficient calculation is compared against small block Chevrolet (SB Chevy) engine coefficient.
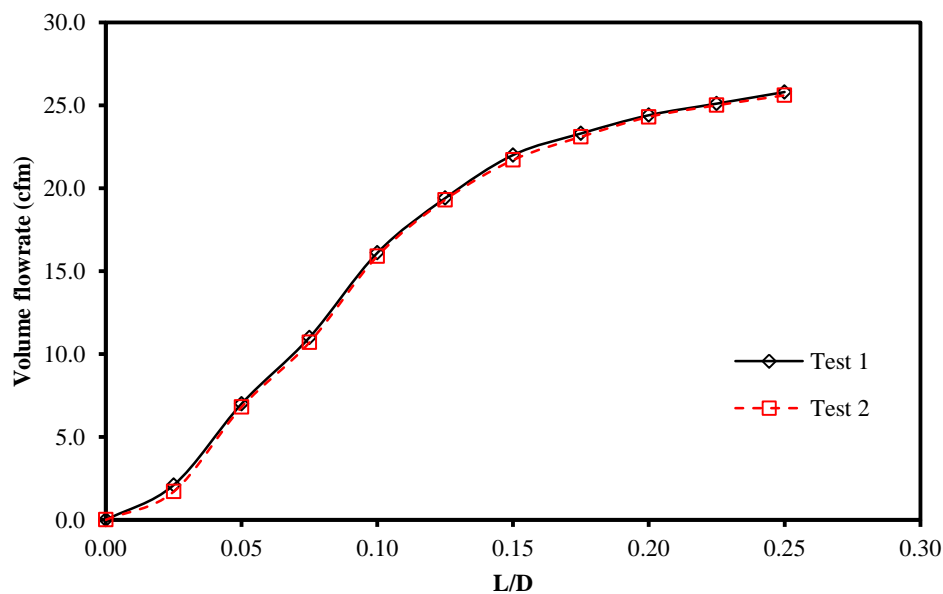

Figure 3. Volume flow rate through intake port.

Figure 3 shows the two result of the air volume flow rate through the intake port. Both results show a small different value of air volume flow rate. The volume flow rate is 0 cubic feet per minute, CFM at 0 L/D ratio. Then it increases gradually until 25.8 CFM at 0.25 L/D ratio.
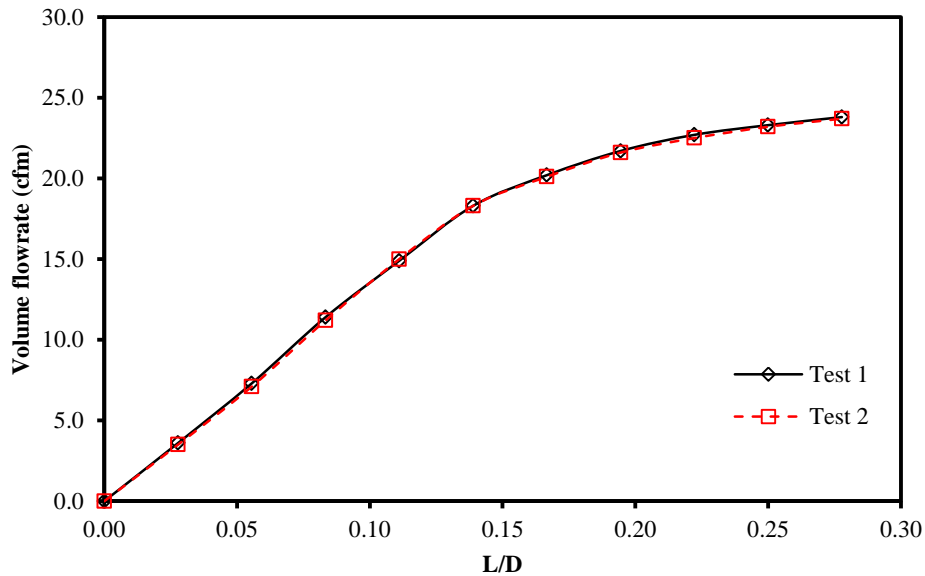

Figure 4. Volume flow rate exhaust port.

Figure 4 present the two result of the air volume flow rate through the exhaust port. The both results also have small different value. The volume flow rate at 0 L/D ratio is 0 CFM and increase gradually to 23.8 CFM at 0.278 L/D ratio.
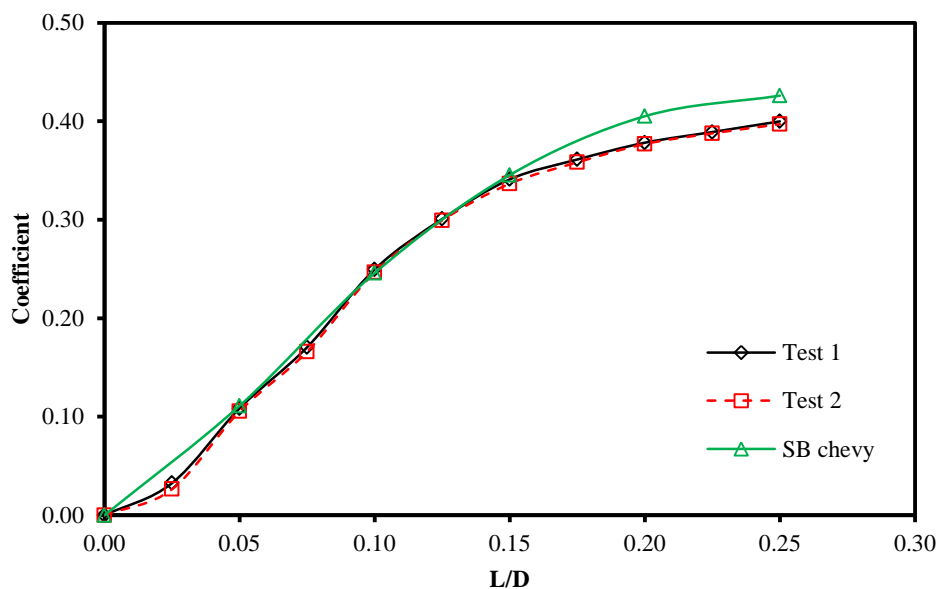

Figure 5. Flow coefficient of intake port.

Figure 5 shows the flow coefficient of intake port two-stroke poppet valve engine and compare with SB Chevy. The figure shows the intake port flow coefficient did not have much different with SB Chevy. The coefficient is 0 at 0 L/D ratio and increases gradually to 0.4 at 0.25 L/D for two-stroke poppet valve engine. While SB Chevy coefficient is 0 at 0 L/D and increases gradually to 0.42 at 0.25 L/D ratio.
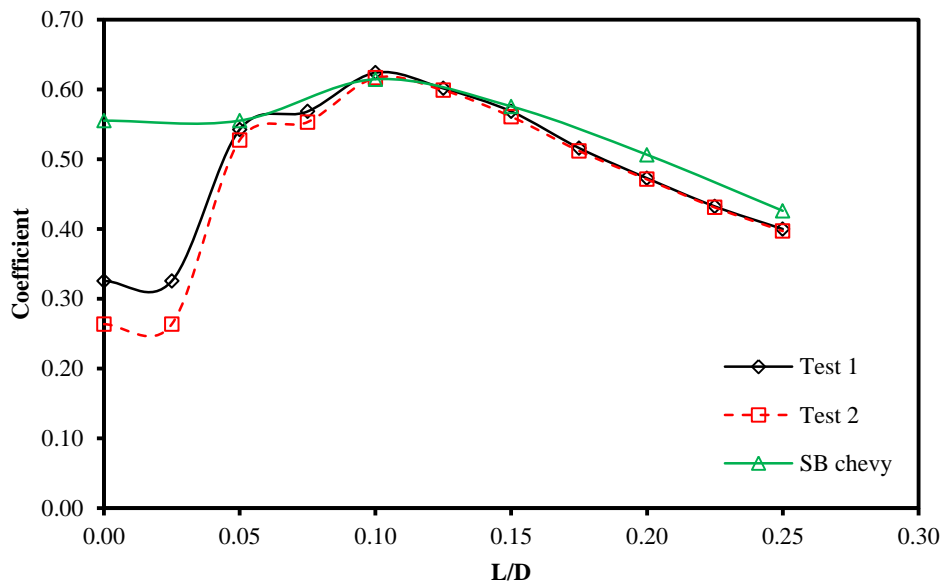
Figure 6. Discharge coefficient of intake port.

Figure 6 present discharge coefficient of intake port for both head engine. The result shows SB Chevy has higher coefficient at 0 until 0.05 L/D ratio. At 0 L/D ratio, SB Chevy has 0.55 coefficient and two-stroke poppet valve engine is 0.32 and 0.26 coefficient. Then the coefficient for both engine head have similar values at 0.05, 0.1 and 0.15 L/D ratio with 0.54, 0.61 and 0.57 coefficient respectively. The highest coefficient value is at 0.1 L/D ratio. Then, the values decrease gradually until 0.25 L/D ratio with 0.4 coefficients for two-stroke poppet valve and 0.42 coefficients for SB Chevy. The result show the intake port coefficient of two-stroke poppet valve engine is almost same value with SB Chevy. It is show the two-stroke poppet valve intake port is comparable with SB Chevy.
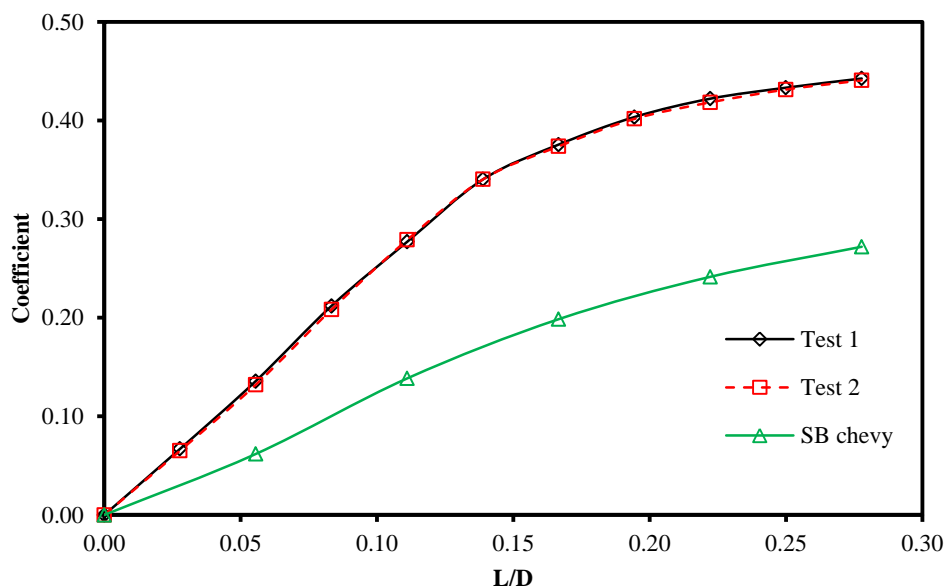

Figure 7. Flow coefficient of exhaust port.

Figure 7 shows flow coefficient result of the exhaust port. It shows two-stroke poppet valve has high coefficient value compare to SB Chevy. Both heads start with 0 coefficients at 0 L/D ratio. But at last or 0.278 L/D ratio, the two-stroke poppet valve has 0.44 coefficients and SB Chevy has 0.27 coefficients.
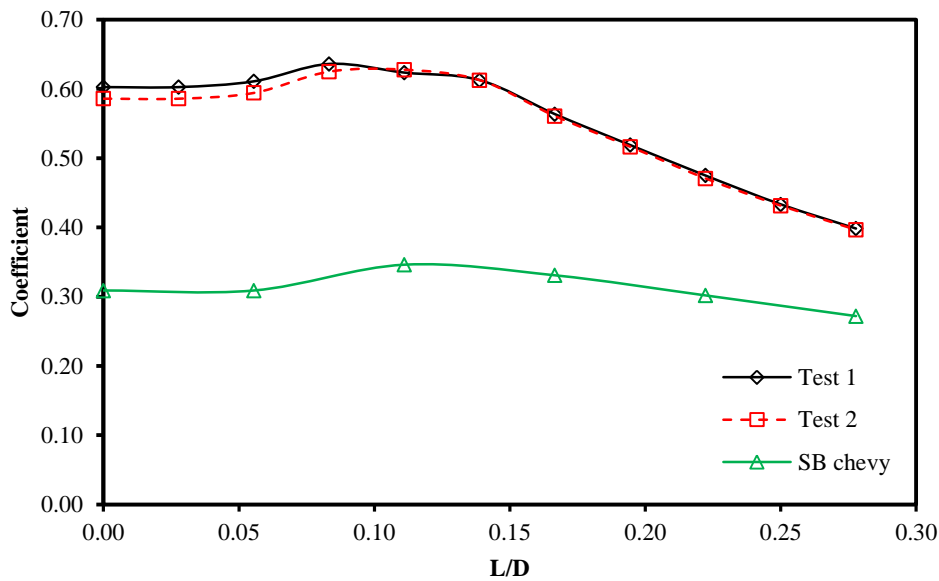
Figure 8. Discharge coefficient of exhaust port.

Figure 8 present discharge coefficient of the exhaust port. It also shows the two-stroke poppet valve has higher discharge coefficient compare to SB Chevy. The two-stroke poppet valve engine has 90% higher coefficient between 0 until 0.05 L/D ratio. Then the percentage of coefficient different is reducing gradually until 46% at 0.279 L/D ratio. The result show the coefficient of two-stroke poppet valve engine exhaust port has better coefficient compare to SB Chevy. The higher coefficient show the exhaust gas can release faster at limited time in two-stroke cycle duration.

5. Conclusions
The port flow experimental investigation of the two-stroke poppet valve has highlighted the following results: The flow and discharge coefficient of the intake port has similar values for two-stroke poppet valve and SB Chevy. Except at zero L/D ratio of intake C_D, the SB Chevy has 89% higher value than the two-stroke poppet valve. The flow and discharge coefficient of the exhaust port for the two-stroke poppet valve has higher values than SB Chevy. Thus, it is possible to operate two-stroke cycle on the head as the flow performance through the exhaust valve is higher at lower lift. Further, the flow is capable of maintaining the subsonic flow without choking as illustrated by the low lift performance trend.

References
[1]   Golloch R and Merker G P 2005 Internal combustion engine downsizing *MTZ worldwide* **66** 20-2
[2]   Zhang Y 2014 Experimental investigation of CAI combustion in a two-stroke poppet valve di engine. Brunel University)
[3]   Nora M D 2015 Experimental and numerical study of a two-stroke poppet valve engine fuelled with gasoline and ethanol. In: *Department of Mechanical, Aerospace and Civil Engineering*: Brunel University)
[4]   Stokes J, Hundleby G E, Lake T H and Christie M J 1992 Development Experience of a Poppet-Valved Two-Stroke Flagship Engine. SAE International)

[5]   Nomura K and Nakamura N 1993 *Development of a new two-stroke engine with poppet-valves Toyota S-2 engine*: Editions OPHRYS)

[6]   Dunn P F N F, AU), Rutherford, Robert Matthew (Nundah, AU) 2003 Two-stroke engine. (United States: Rotec Design Ltd. (Queensland, AU))

[7]   Rebhan M and Stokes J 2009 Two-stroke/four-stroke multicylinder gasoline engine for downsizing applications *MTZ worldwide* **70** 40-5

[8]   Nakano M, Sato K and Ukawa H 1990 A Two-Stroke Cycle Gasoline Engine with Poppet Valves on the Cylinder Head. SAE International)

[9]   Sato K, Ukawa H and Nakano M 1992 A Two-Stroke Cycle Gasoline Engine with Poppet Valves in the Cylinder Head - Part II. SAE International)

[10]   Abdul R. Ismail R A B, Semin 2008 An Investigation of Valve Lift Effect on Air Flow and Coefficient of Discharge of Four Stroke Engines Based on Experiment *American Journal of Applied Sciences* **5** 9

[11]   S.A.Sulaiman, S.H.M.Murad, Ibrahim I and Karim Z A A 2010 Study of flow in air-intake system for a single-cylinder go-kart engine *International Journal of Automotive and Mechanical Engineering (IJAME)* **1** 14

[12]   Algieri A 2011 An Experimental Analysis of the Fluid Dynamic Efficiency of a Production Spark-Ignition Engine during the Intake and Exhaust Phase *ISRN Mechanical Engineering* **2011**