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The two-stroke poppet valve engine. Part 2: Numerical investigations of intake and exhaust flow behaviour

M Kamili Zahidi[1]*, M Razali Hanipah[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 presents the model and simulation result of three-dimensional (3D) port flow investigation of a two-stroke poppet valve engine. The objective of the investigation is to conduct a numerical investigation on port flow performance of two-stroke poppet valve engine and compare the results obtained from the experimental investigation. The model is to be used for the future numerical study of the engine. The volume flow rate results have been compared with the results obtained experimentally as presented in first part of this paper. The model has shown good agreement in terms of the flow rate at initial and final valve lifts but reduced by about 50% during half-lift region.

1. Introduction

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

The two-stroke engine is known to have a 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[2]. Bore distortion is increasing the wear rate or worst case it will lock-up the piston. 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 experimented 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 the short-circuited phenomenon during scavenging duration[9].

The first part of this research has covered the experimental work of the intake and exhaust ports assessments. In this paper, the flow through intake and exhaust valves is visualised through three-dimensional (3D), computational flow dynamics (CFD) tool. Both qualitative and quantitative results are evaluated.

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2. Engine specifications

The investigation is based on a 65cc four-stroke gasoline engine. The base engine is running on a four-stroke cycle utilising two-stroke lubrication and intake crankcase compression system [10]. The engine stroke is 33mm and the bore is 50mm. Then the compression ratio is 9.5:1. While the maximum valve lift is 4 mm. The valve diameter for the intake is 20mm and for exhaust is 18mm. The engine specification is as shown in Table 1.

Table 1. The engine specification.

Parameter	Value
Capacity	65cm^3
Bore	50mm
Stroke	33mm
Compression ratio	9.5:1
Maximum valve lift	04mm
Intake valve diameter	20mm
Exhaust valve diameter	18mm

The engine model is as shown in Figure 1. The valve is designed to be at the vertical position. 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.

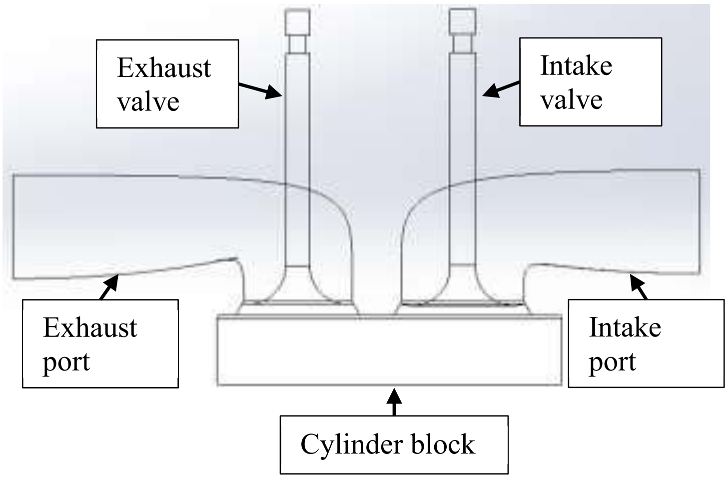

Figure 1. The engine model.

3. Method

The numerical investigation begins with the 3D model construction. The model for port flow simulation is as Figure 2 and Figure 1. Then, the model is imported into Ansys port flow IC engine simulation. The engine model is added with plenum box at bottom of cylinder block.

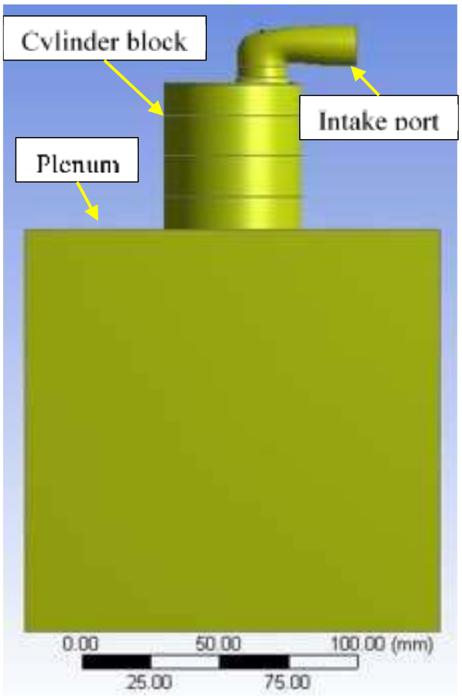

Figure 2. The engine geometry model.

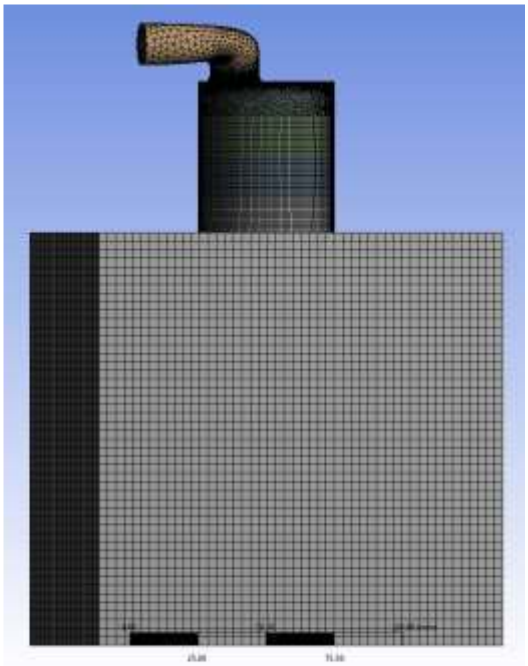

Figure 3. The mesh for port flow investigation.

The complete model has undergone meshing process. The model meshed with hybrid type, which is the combination of tetrahedron and hexahedron. The hexahedron mesh is used at plenum box and three-quarter of cylinder block as present in . Figure 3. While the tetrahedron is used at port and top quarter of cylinder block as shown in Figure 4. The mesh total nodes are 1,430,193 and elements are 3,383,208.

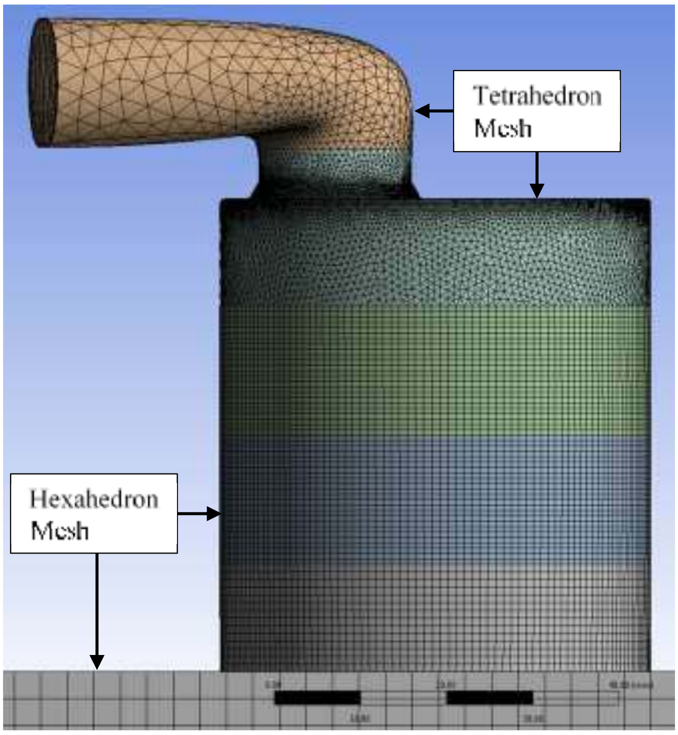

Figure 4. The mesh at engine head and block.

After meshing, the investigation continues with flow simulation. The flow simulations were run based on Navier-Stokes equations and k-ε two equation turbulent model at steady state condition.

4. Results and discussion

The successful simulation run produces various data regarding the flow through the ports. However, the main relevant outcome of the numerical investigation is the volume flow rate data which is necessary for comparing the flow obtained from the experiment.

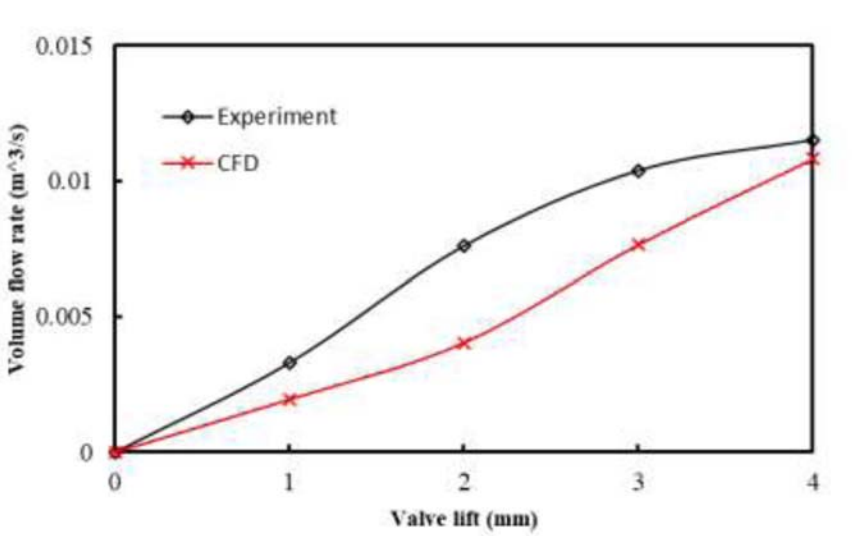

Figure 5. The comparison of numerical and experimental result.

Figure 5 shows the comparison between numerical simulation and flow bench experimental results of the volume flow rate through the intake port. The results show the experimental result is higher than CFD simulation result. Similar trends are observed but the CFD shows 50% lower flow rate during half-lift. It shows the model necessary to be tuning for a comparable result with flow bench experiment.

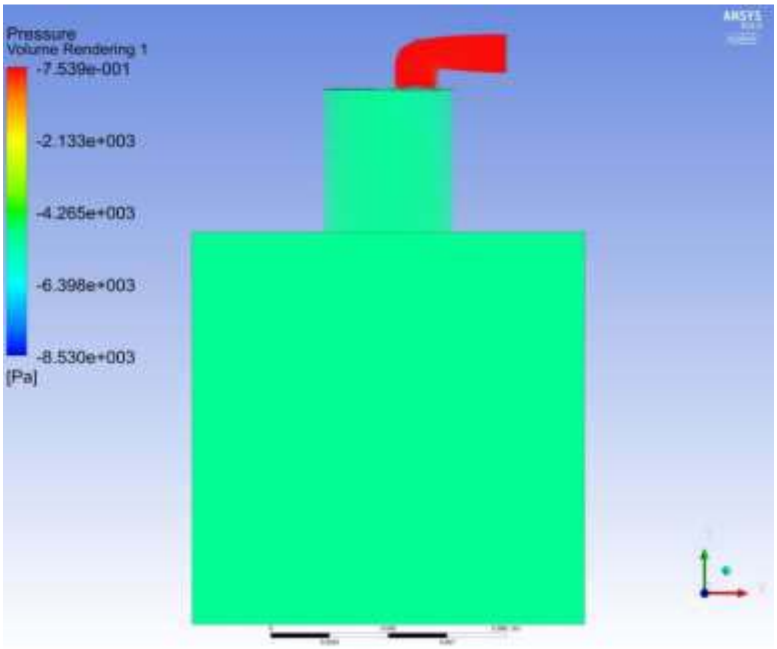

Figure 6. The Pressure contour.

Figure 6 shows the pressure rendering. It is present the pressure is highest at intake port compare to the cylinder block and plenum box. The pressure is -75.3 Pa. The value is negative because of the air suction simulation and the flow of air from upstream to downstream.

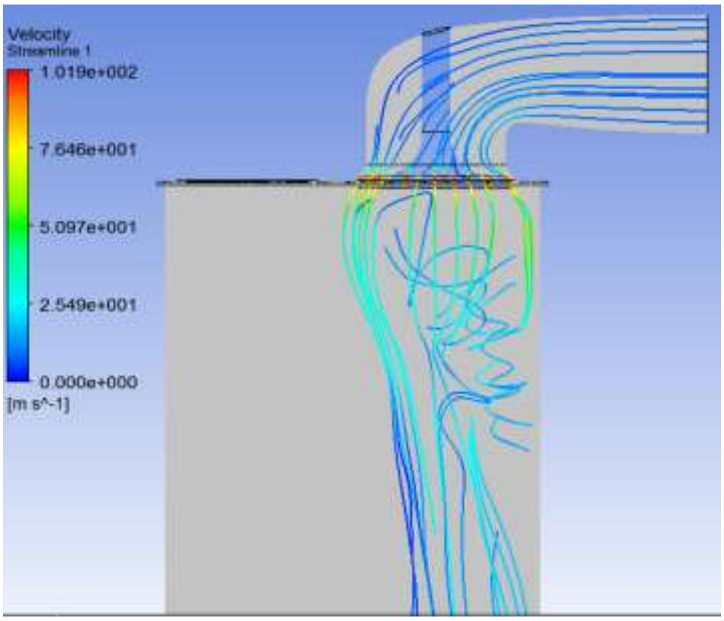

Figure 7. The velocity streamline.

As can be seen in Figure 7, the line is representing the velocity streamline. The streamline shows the air is swirling below the valve during port flow simulation.

5. Conclusions

This paper has presented the numerical model construction and flow investigation of the two-stroke poppet valve engine. The volume flow rate results have been compared with the results obtained experimentally as presented in part 1 of this paper. The model has shown good agreement in terms of the flow rate maximum lift but reduced by 50% at half-lift. The experimental results have higher value than numerical simulation result on several points but apparent trend is observed. Based on the findings from part 1 of the paper, the flow rate is sufficient for the two-stroke engine operation.

Acknowledgement

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