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Effect of The Maximum Valve Lift to the Flow Velocity at the Intake Valve of Gasoline Engine

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Abstract: Intake valve lift height value plays a very important role in ensuring the power and performance of the internal combustion engine (ICE). Computational fluid dynamics (CFD) analysis was conducted to determine the optimum valve lift value that gives the highest air velocity into the combustion chamber for 23 mm and 27 mm intake valve. For 23 mm intake valve diameter, increasing valve lift beyond 6 mm will not improve fluid flow in the combustion chamber. For 27 mm intake valve diameter, increasing valve lift beyond 4 mm will not improve fluid flow in the combustion chamber. In conclusion, increasing the valve lift beyond the maximum valve lift value will not give any additional flow of fluid into the combustion chamber.

Abstract (Malay): Tinggi bukaan injap masukan memainkan peranan yang amat penting dalam memastikan kuasa dan prestasi enjin pembakaran dalaman. Analisis CFD dijalankan untuk menentukan nilai bukaan injap optimum yang memberikan halaju udara tertinggi ke dalam ruang pembakaran pada diameter injap masukan 23 mm dan 27 mm. Bagi injap masukan diameter 23 mm, bukaan injap melebihi 6 mm tidak meningkatkan halaju bendalir ke dalam enjin. Bagi injap masukan diameter 27 mm, bukaan injap melebihi 4 mm tidak meningkatkan halaju bendalir ke dalam enjin. Kesimpulannya, bukaan injap melebihi nilai optimum tidak meningkatkan halaju bendalir masuk ke dalam enjin.

Keywords: Computational Fluid Dynamics, Internal Combustion Engine, Valve Lift, Intake Valve

1. Introduction

ICE is an engine that uses fossil fuel to convert chemical energy into mechanical energy. Most internal combustion engines are reciprocating engines (Pulkrabek, 1955). Four-stroke engines use valves to open and close at certain timing depending on engine cycle. The cams push the valves for a certain amount of time during each intake and exhaust cycle. Valve opening timing throughout the piston movement is very important in determining ICE performance (Antonelli et al., 2014; Fontana & Galloni, 2009; Hong et al., 2004; Jia et al., 2011).

Valve lift is the amount of the valve is lifted off from its seat (Fig. 1). High valve lift enables more air-fuel ratio to enter the combustion chamber, improving the performance of gasoline engine. Maximum valve lift is the highest intake valve opening that provide highest fluid flow to combustion chamber. However, increasing the valve lift beyond the maximum valve lift value will not give any additional flow of fluid into the combustion chamber. Higher lift often requires longer camshaft duration and increase valve train work, which can affect the performance and durability of the engine (Fontana & Galloni, 2009). Determining the optimum valve lift value is crucial to maintain the effectiveness and performance of the gasoline engine.

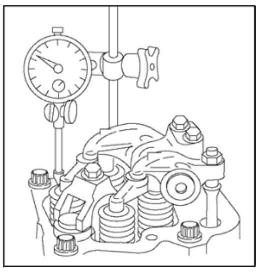

Fig. 1 - Valve Lift Measurement.

CFD is a popular method for solving the fluid problem involved in the engine. The use of CFD allows researchers to identify the fluid characteristic throughout the process inside the engine. However, the CFD method is a complex process, time consuming, and vulnerable to computation errors (Roberpj, 2018, Nigro et al., 2017).). However, the CFD method is a complex process, time consuming, and vulnerable to computation errors. The CFD method involving the use of very small mesh in large quantities in geometry causes a high

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computation load to the computer system (Yusof et al., 2016). Normally, simplified 3D modeling is needed to ensure the simulation process can run perfectly (Sridhar et al., 2004).

In the port flow analysis, engine components are frozen in the desired position during the engine cycle. Simulation and analysis of fluid movement in engine cavity is done on 3D model produced in this condition. Since the analysis is only done on a particular position of the engine, port flow analysis reduces the computational load to the computer and the time required to obtain the simulation results. To study the turbulence effect in the engine, the Reynolds-averaged Navier-Stokes (RANS) analysis is sufficient to be used during the simulation.

In cold flow simulation, an analysis is performed to study the movement of the fluid during engine operations. At this point, fluid movement, fuel injection and air-fuel mixing process can be analyzed without involving any chemical and combustion processes. The purpose of this simulation is to investigate the movement of the fluid inside the engine during the engine's operation. Through this analysis, flow characteristics around intake and exhaust valve during opening and closing can be observed (Giannakopoulos et al., 2017). In addition, the turbulence effect in the engine volume can also be seen during the movement of the piston.

2. Methodology

Port flow analysis was used in the simulation. Through this method fluid studies were conducted during the maximum intake stroke of the gasoline engine. At this point, the piston is located at the bottom dead centre (B.D.C) while the intake valve is at maximum lift. Cold flow analysis method was used in the simulation. Through this method, air properties were used as fluid without the involvement of air - fuel mixture properties.

Engine models are taken from real engine specifications and developed into 3D models for the simulation. A 100-centimeter cubic (cc) capacity of four-stroke, single cylinder, single overhead cam engine with 50 mm bore and 49 mm stoke was used as the engine model. Only the air cavity from intake manifold, inlet valve and cylinder are developed. To reduce computational burden, simulation was carried out with only half of the model (Fig. 2). The simulation was done with the section face as symmetry plane.

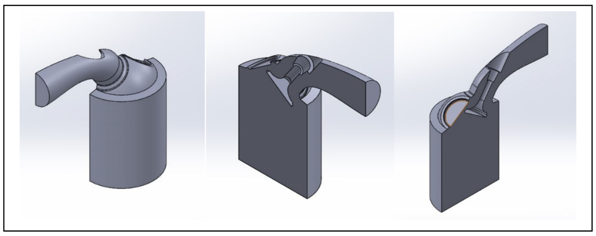

Fig. 2 - Air Cavity of Model Engine.

Two different engine`s cylinder head with 23 mm intake diameter valve size (Fig. 3a) and 27 mm intake diameter valve size (Fig. 3b) were tested in the simulation. Each valve size profile was tested with nine (9) different valve lift height profile from 1 mm valve lift to 9 mm valve lift. Fluid flow velocity at the intake valve opening of each valve height configuration was evaluated in each simulation. The fluid velocity changes and velocity profile in each valve configuration were analyzed.

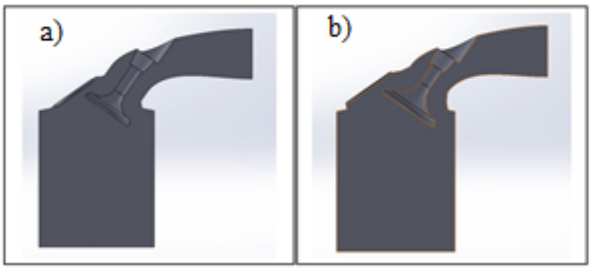

Fig. 3 – (a) 23 mm Intake Valve and (b) 27 mm Intake Valve.

3. Results and Discussion

Fig. 4 shows the intake flow velocity around intake valve at valve lifts from 1 mm to 9 mm for valve 23 mm diameter intake valve size.

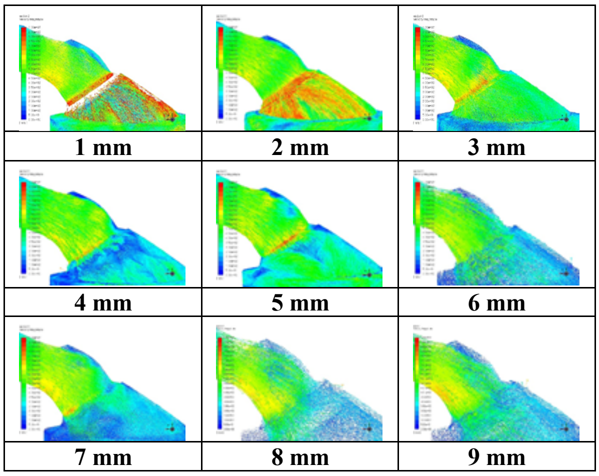

Fig. 4 – Flow Velocity Around 23 mm Intake Valve.

From the simulation results, for 1 mm up to 5 mm valve height indicates the fluid around the intake valve opening has a velocity mixed from low velocity to high velocity. This condition can be seen in a variety of mixed colors that represent the fluid velocity in the valve openings. At 1 mm valve opening, there are many red high velocities particles, indicating the presence of turbulence flow. When the valve opening is increased, the presence of this high velocity particle is decreasing, indicating that fluid flow was less restricted. Fluid velocity is also seen increasingly evenly between one another. When the valve opening reaches 6 mm, the presence of red high velocity particles around the intake valve opening has completely disappeared. Fluid velocity at valve openings is seen more uniformly from one another. This condition is constant and remain unchanged at higher valve openings of 6 mm, 7 mm, 8 mm and 9 mm. The result shows that lifting intake valve more than 6 mm will not furthermore improve fluid flow onto combustion chamber. In conclusion, 6 mm lift is the optimum valve lift value for 23 mm diameter Intake Valve.

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Fig. 5 shows the pressure contours results for 23 mm intake valve simulation. Further analysis was conducted to study the changes in pressure that occurred from the intake chamber and the combustion chamber.

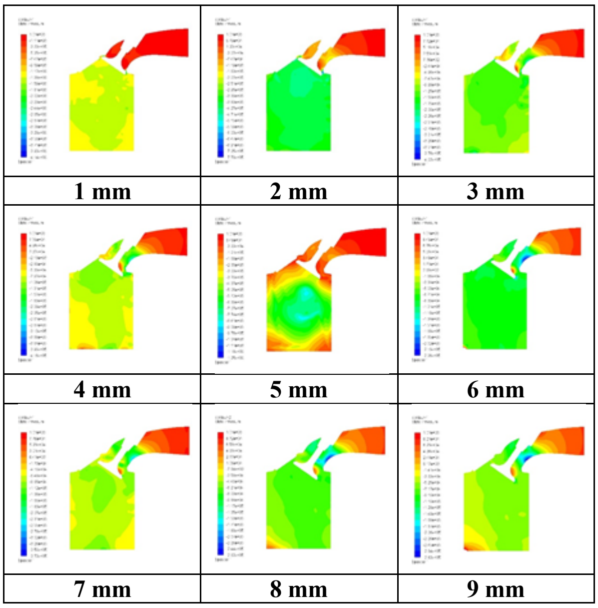

Fig. 5 – Pressure Contours of 23 mm Intake Valve.

Fig. 6 shows the value of the pressure within the combustion chamber. From the data, it is found that the pressure value is negative for all valve lift values. At 1 mm valve lift shows the lowest pressure value. When the valve opening is increased between 1 mm to 5 mm, the pressure in the combustion increases significantly. The intangible change pattern can be observed when the valve opening is between 6 mm and 9 mm. In this range, it is found that the increase in valve lift does not significantly increase the combustion chamber pressure.

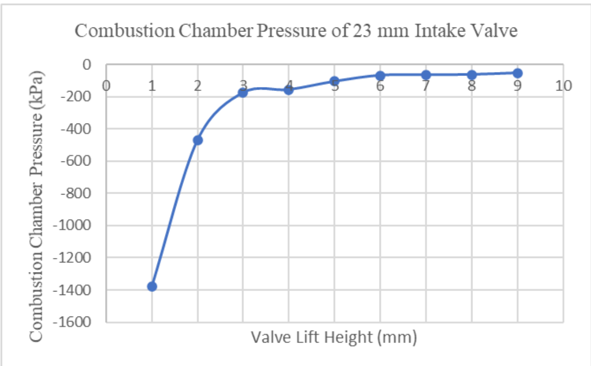

Fig. 6 - Combustion Chamber Pressure of 23 mm Intake Valve Diameter.

Fig. 7 shows the simulation results for the 27 mm intake valve diameter. The flow velocity profile for each valve lift height profile will be analyzed. The simulation results for 1 mm up to 3 mm valve height indicate the fluid around the intake valve opening has a velocity mixed from low velocity to high velocity. This condition can be seen in a variety of mixed colors that represent the fluid velocity in the valve openings. At 1 mm valve opening, there are many red high velocities particles, indicating the presence of turbulence flow. When the valve opening is increased, the presence of this high velocity particle is decreasing, indicating that fluid flow was less restricted. Fluid velocity is also seen increasingly evenly between one another. When the valve opening reaches 4 mm, the presence of red high velocity particles has completely disappeared. Fluid velocity at valve opening is seen more uniformly from one another. This condition is constant and remain unchanged at higher valve opening of 4 mm, 5 mm, 6 mm, 7 mm, 8 mm and 9 mm. The result shows that lifting intake valve more than 4 mm will not furthermore improve fluid flow onto combustion chamber. In conclusion, 4 mm lift is the optimum valve lift value for 27 mm diameter Intake Valve.

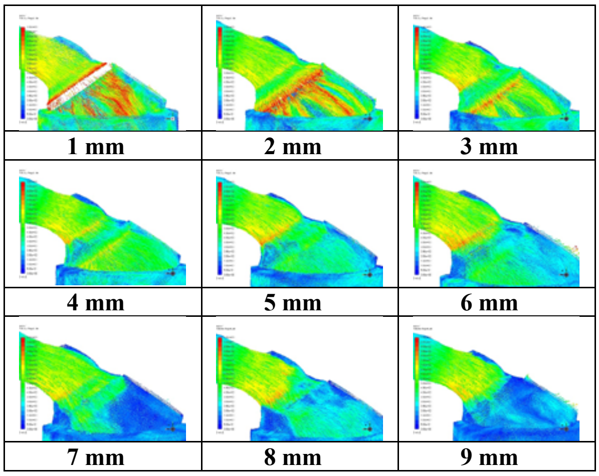

Fig. 7 – Flow Velocity Around 27 mm Intake Valve.

Fig. 8 shows the pressure contours results for 27 mm intake valve simulation. Further analysis was conducted to study the changes in pressure that occurred from the intake chamber and the combustion chamber.

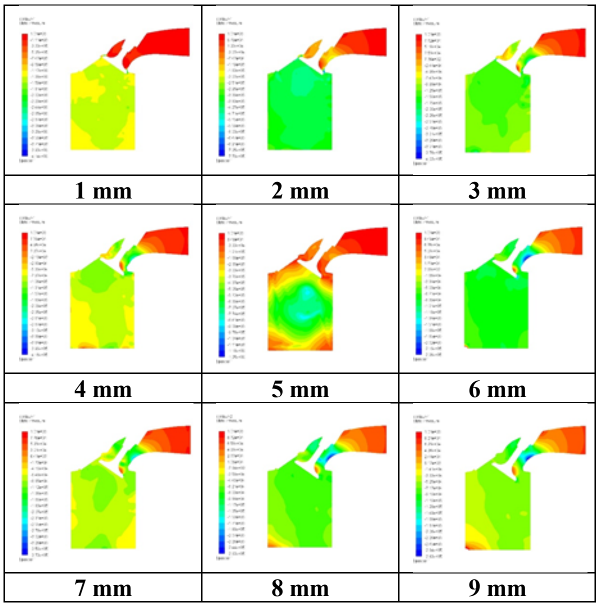

Fig. 8 – Pressure Contours of 27 mm Intake Valve.

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Fig. 9 shows the value of the pressure within the combustion chamber. From the data, it is found that the pressure value is negative on all valve lift values. At 1 mm valve lift shows the lowest pressure value. When the valve opening is increased in between 1 mm to 3 mm, the pressure in the combustion increases significantly. But the intangible change pattern can be observed when the valve opening is between 4 mm and 9 mm. In this range, it is found that the increase of valve lift more than 4 mm does not significantly increase the combustion chamber pressure. In conclusion, increasing valve lift beyond 4 mm will not improve fluid flow inside combustion chamber. The optimum valve lift value for 27 mm diameter Intake Valve is 4 mm.

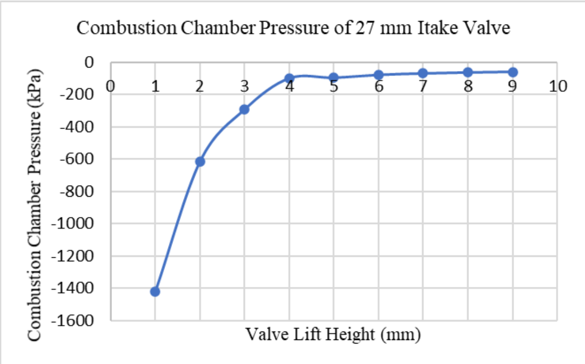

Fig. 9 - Combustion Chamber Pressure of 27 mm Intake Valve Diameter.

4. Conclusion

The research project that has been carried out has met the desired objectives. Through the results obtained, it is found that the valve lift affects the velocity of the fluid into the engine combustion chamber. Through an air pressure analysis, it is found that the valve lift value also affects the pressure inside the engine cylinder. However, the study also found that cylinder pressure was also heavily influenced by the valve lift value. When exceeding the optimum valve lift height, it is found that the pressure in the cylinder has no significant change even though the height of the valve lift is increased. From the computational fluid dynamic simulations, it was found that, for 23 mm diameter valve size, the optimum valve lift required was 6 mm. When the valve lifts lower than 6 mm, it will restrict fluid entrance into the combustion chamber. However, increasing the valve lift exceeds the 6 mm value does not significantly increase the amount of fluid entering into the engine cylinder during the intake stroke of four-cycle gasoline engine. For 27 mm diameter valve size, the optimum valve lift required was 4 mm. When the valve lift lower than 4 mm it will restrict the fluid entrance into the combustion chamber. However, increasing the valve lift exceeds the 4 mm, it does not significantly increase the amount of fluid entering into the engine cylinder during the intake stroke of four-cycle gasoline engine.

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