ABSTRACT

Optimizing airflow performance during intake valve process is the main purpose for this project. Research had using two previous works as guidance and starting point to setting and achieving targeted limit of optimized airflow, 0.0201075 m^3/s. modifications on inlet valve, inlet port of intake system had been done, and original cylinder head Ex5 geometry had been used before turning into 3D modeling as to achieve objective. Analysis was done in CFD simulation and experimental using SuperFlowbench machine. This analysis also reported differentiation that occurs during both analyses around 0.045 % in average where experimental result cannot achieve targeted limit due to some realistic condition. Fabrication of intake valve and intake port also were made to do analysis on experimental based on the modify design. This being done after simulation analysis, modeling design was using to be fabricated and analyze the model on flow bench machine to verify simulating result. This analysis could be used to increase efficiency of volumetric flow rate and maximizing usage of air fuel in combustion process, which reduce emission to environment. Even though air flow have been optimized on its intake valve and port, but still intake system could be improve by considering other parts of Ex5 engine such as intake manifold.

ABSTRAK

Pengoptimisan aliran udara masuk sewaktu melalui injap masuk proses merupakan matlamat utama projek ini. Kajian telah menggunakan dua projek yang sebelum ini sebagai panduan dan titik permulaan sebagai arah dalam mencapai target limit kadar isipadu udara, 0.0201075 m^3/s. modifikasi ke atas injap dan laluan masuk bagi kemasukan system telah di jalankan dan geometri asal bagi kepala silinder Ex5 digunakan sebelum ditukarkan dalama bentuk 3D model. Analisis boleh didapati dalam CFD simulasi dan eksperimen analisis yang menggunakan mesin SuperFlowbench. Kajian turut menunjukkan perbezaan antara kedua-dua analisis yang wujud dengan perbezaan sebanyak 0.045% secara purata di mana nilai ekperimen tidak dapat mencapai sasaran limit disebabkan oleh beberapa keadaan realistik. Injap dan laluan masuk telah direka dan dihasilkan untuk eksperimen proses berdasarkan modifikasi baru rekaan. Analisis ini dapat digunakan untuk meningkatkan kadar kemasukan isi padu udara ke dalam silinder dan memaksimumkan penggunaan udara-minyak dalam proses pembakaran yang ternyata mampu mengurangkan pencemaran. Walaupun pengoptimisan telah dilakukan, namun secara keseluruhan bagi sistem kemasukan bagi enjin masih boleh di perbaiki dan dipertingkatkan dengan mengambil kira komponen lain seperti kemasukan manifold.

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º	Degree
%	Percentage

LIST OF ABBREVIATIONS

P_{atm}	Pressure at atmospheric condition
D	Diameter
Al	Aluminium
CFD	Computational fundamental domain
mm	Milimeter
m^3/s	Meter cubic per second
CAD	Computer-aided design
3D	Three dimensional
RPM	Revolution per minute
HP	Horse power
CRC	Curvature refinement criterion
RFC	Refining fluid cells
cm	Centimeter
IC	Internal combustion
CFM	Cubic feet minute
CNC	Computer numerical controll
OVI	Opening valve intake
OVE	Opening valve exhaust

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

On four-stroke engine on single cylinder engine like Honda EX5, a process happened called as gas exchange process through the internal combustion engine that often informally referred to as intake, compression, combustion, and exhaust strokes. The purpose of the exhaust and inlet processes is to remove the burning gases at the end of the power stroke and admit the fresh charge for the next cycle. Increasing performance of engine contribute to the deliberation of air-fuel mixture into intake system. Internal combustion engine have similarity concept with air pump, the more air could be pump, and the more power will be produce.

Performance intake air-fuel system directly related to the cylinder head. A substandard cylinder head will deliver substandard power. Air streams into the intake valves by ways of ports. The shape and size of these ports control flow pattern and velocity. These are the two critical components of port design. The optimum design will yield the highest flow (volume) of air while maintaining the highest velocity. Reducing the restriction means letting more air into the cylinders. By having more air, more fuel could be adding. The result will increase in horsepower.

In order to gain power, irregularities such as casting flaws are removing and with the aid of a flow bench, the radius of valve port turns and valve seat configuration can be modifying to promote high flow efficiency. This process called porting, and can be work through hand, or via CNC machine. Basic porting does not attempt to correct any design or engineering deficiencies. Interesting fact on basic porting is that in many cases, greatest performance gain per dollar spent comes upon application of basic porting procedures to a production cylinder head.

Cylinder head porting refers to the process of modifying the intake and exhaust ports of an internal combustion engine to improve the quality and quantity of the gas flow. Porting the heads provides the finely detailed attention required to bring the engine to the highest level of efficiency. Unfortunately, it cost much of money, time, and professional skills to attempt best basic porting. Using simulation analysis covers this weakness of basic porting.

Using computational fluid analysis to determine head porting modification is necessary because it will reduce more time and save the cost in every change of design porting. Besides that, analysis goes more on flow pattern of air fuel intake port that use fundamental CFD, CosmosFlowork a friendly user software.

1.2 PROBLEM STATEMENT

Resulting from previous work, performance of airflow intake valve for four-stroke engine was increasing during its lift by modifying design of inlet valve, which is fillet radius valve. Airflow rate started to increase at 3.4mm and stopped at maximum lift, 5.3mm. [2]

Even though lift is increase, airflow fixed due to choke flow position that occurs when valve is fully opening. In order to increase the performance of airflow intake port to maximum volume at its maximum lift, some modifications on head porting being done in order to increase the maximum flow rate at maximum opening through simulation and experimental analysis.

Some of parameters suggested from previous work are modifying through face valve angle, seat valve and stem. One of the parameter used ahead of is by changing geometry of valve, which fillet radius. Through the changing in the fillet radius, it is proves that volume flow rate can be increased due to maximum lift where performance of air flow into intake port actually increased by 0.01mm higher than the original volume flow rate. This condition continues until the choking crop up at the maximum lift.

Throughout this project, new concern of modification the designs are being developed in order to get higher lift than the previous result by reaching targeted limit, in range 0.0201 m^3/s volume flow rate even though it is already in maximum lift. Geometry of intake valve could be modifying to increase the flow rate air due to the limitation of opening valve at intake port.

This based on the theory that higher flow rate caused on higher lift and lower pressure intake valve involved. Performance of flow air fuel for intake system is fully depend on shape and design of intake valve where a bigger space for air flow entering intake port is due to its lift. Analyze through simulation that is better will be constructed in order to achieve the best recital of airflow before it being using into real application.

1.3 OBJECTIVES

Basically the main purpose in accomplishing this task are stated below

i. To evaluate the air-fuel mixing process
ii. To optimize the maximum flow process for intake valve maximum opening

1.4 SCOPES

The scope of this project focusing on

i. Literature review
ii. Valve design and porting modification
iii. Intake air flow simulation
iv. Design modification for optimization

1.5 HYPOTHESIS

During this project, it is expected that volume flow rate of airflow could be optimize into limit setting at maximum lift.

1.6 METHODOLOGY

i. Stage 1: Literature study

    Make review on literature study based involving title project

ii. Stage 2: Modification 3D modeling design

    Stating modification setting on intake valve and port design using CAD software

iii. Stage 3: Simulation boundary condition setting

    Set up boundary condition for simulation analysis.

iv. Stage 4: Simulation analysis using CFD software

    Simulation analysis using Cosmos Flowork software.

v. Stage 5: Analysis of simulation result

    Analyze result from simulation.

vi. Stage 6: Fabrication design

    Fabricate design produce from analysis.

vii. Stage 7: Experimental using Super Flow Bench machine

    Experiment the fabricate product using Super Flowbench machine.

viii. Stage 8: Data verification

    Analyze experimental and simulation result to verify the analysis.

1.7 PROJECT FLOW CHART

Progress work and research is described in form of flow chart below. The chart contains Final year project, 1 and 2 which also have been divided due to time constraint. The task also could be referring in APPENDIX E.

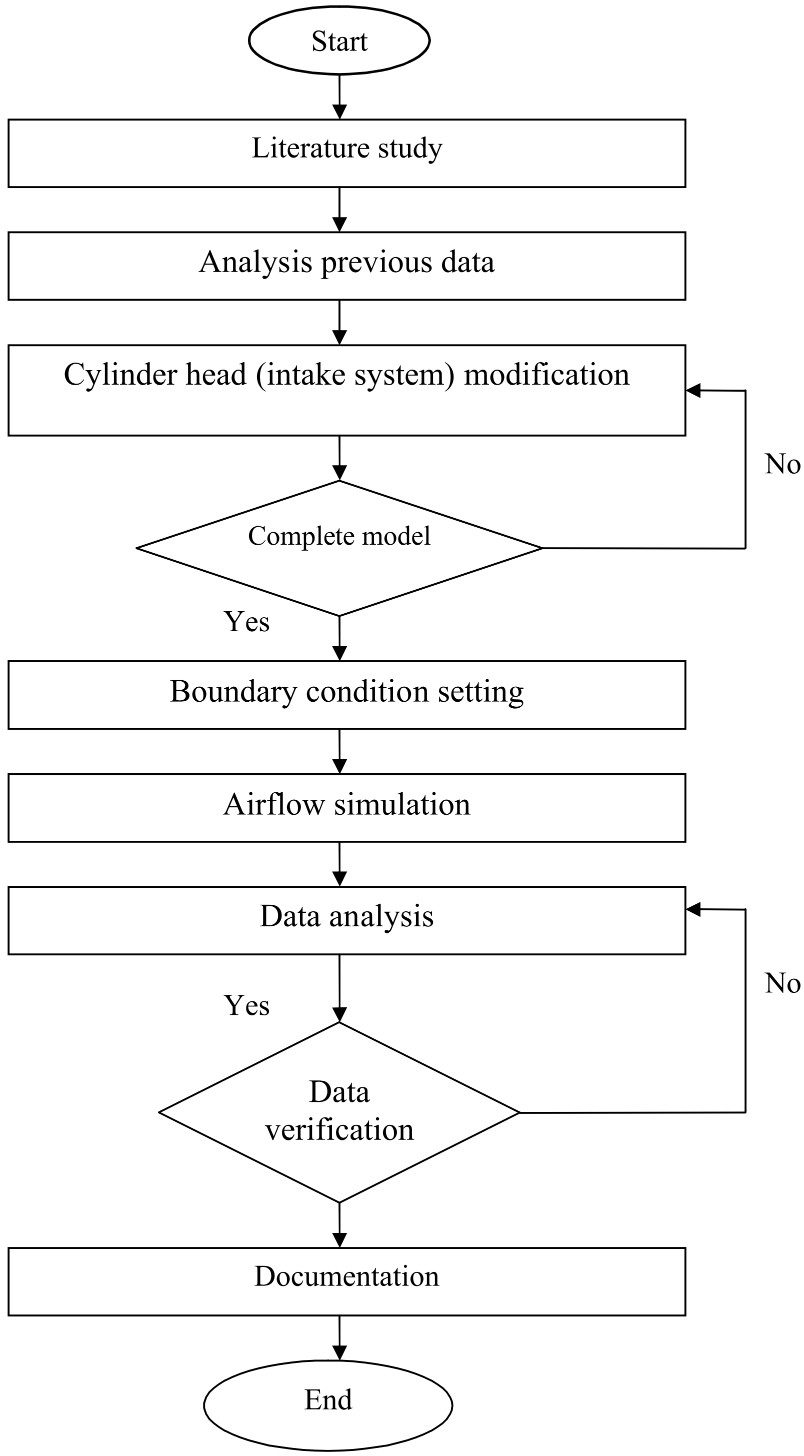


Figure 1.1: Project flowchart

CHAPTER 2

LITERATURE REVIEW

This chapter will be discussing more on elements involved that can improved the flow pattern performance and increasing maximum volumetric flow rate due to maximum valve opening or valve lift.

2.1 GENERAL DESIGN OF INTAKE VALVE

Valves come in a lot of types design with main function to control the volume of flow and pressure of fluids. Valves are use in many areas of commercial application, domestic and process application, automobiles, hydraulic presses, medical equipment and many more. Most internal combustion engine use poppet valve. The position of this valve is the top of the cylinder head. Several types of valve are used: a poppet, rotary, disc and a sleeve. The most common valve is the poppet valve. The poppet valve is inexpensive and has good sealing properties, making it such a popular choice. The following evaluation will assume poppet valves used for both the inlet and exhaust ports.

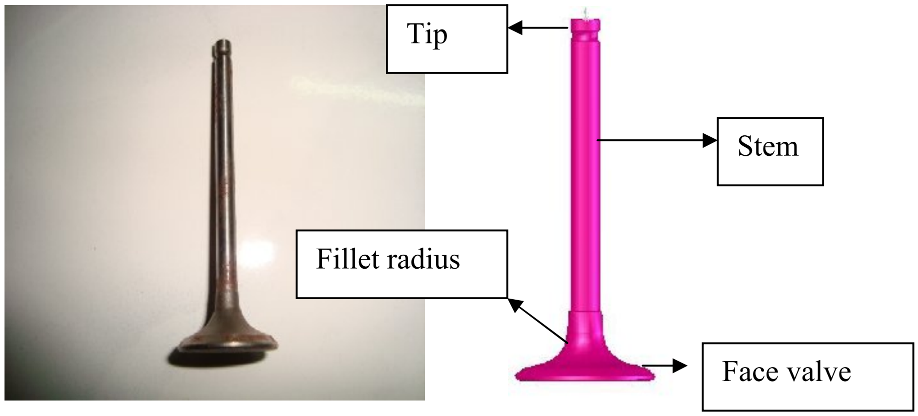


Figure 2.1: Original inlet valve Ex5 and in 3D modeling design

Poppet Valves are using to control the flow of exhaust and intake gases in automobiles. These valves are controls by the camshaft and other devices and need to be very accurate and durable over extended use at high temperatures.

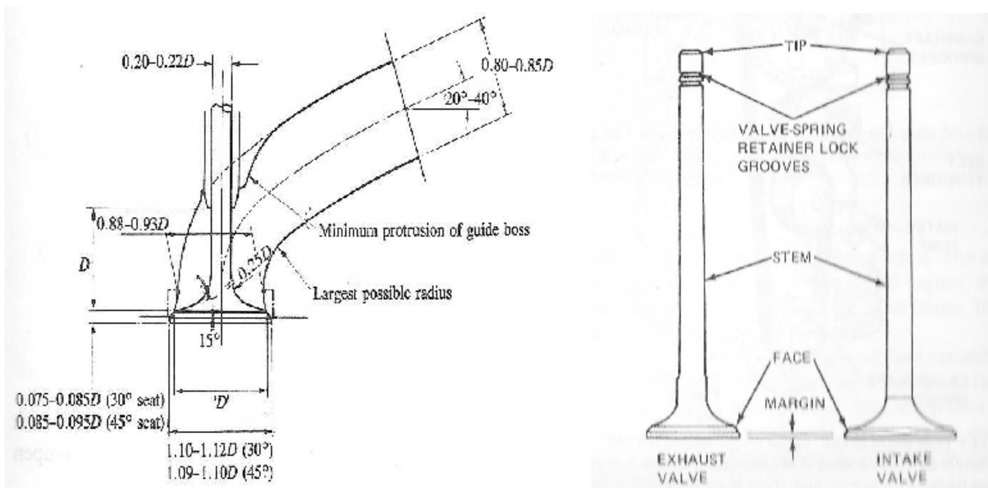
Inlet valve opening (IVO) typically occurs at 15º to 25º BTC. Engine performance is relatively insensitive to this timing point. It occurs sufficiently before TC so that cylinder pressure does not dip early in the intake stroke. Inlet valve closing (IVC) falls in range 40 to 60º after BC, to provide more time for cylinder for filling under condition where cylinder pressure is below the intake manifold pressure at BC. IVC is one of factor that determines high-speed volumetric efficiency; it also affects low-speed volumetric efficiency due to backflow into the intake. [5]

Mostly used in piston engines to open and close the intake and exhaust port in the cylinder head. The valve is usually a flat disk of metal with a long rod known as the valve stem out one end. The stem used to push down on the valve and open it, with a spring generally used to close the valve when the stem is not being pushing on. [11]

The intake valve is usually larger than the exhaust valve. The reason is that when the intake valve is open, the only force moving air-fuel mixture into the cylinder is atmospheric pressure. [3]

2.2 GENERAL DESIGN OF INTAKE PORT

Intake port generally related with valve shape so both could work out together in supplying the airflow. The inlet port is generally circular, nearly cross-sectional area is no longer than required to achieve the desired power output. Although a circular cross section is still desirable, a rectangular or oval shape is often essential around the guide boss area. [11]



(a) (b)

Figure 2.2: (a) Intake and exhaust valve. Source: Heywood (1988) and (b) intake valve design geometry. Source: William and Donald (1993)

The angle of valve surface at the interface with the valve seat is generally design to give minimum flow restriction as the airflow around the corner the stream lines separate from the surface and the cross section area of flow is less than the passage area. Usually valve angle of intake is 30º for give flow restriction and give more flow to the cylinder. The actual flow area to the flow passage area called valve discharge coefficient. Shape and angle of valve surface are sometimes design to give special mass flow pattern to improve overall engine efficiency. Besides that, more design of two or three valve in cylinder head is to give more flow area and less flow resistance. [6]

The valve seat is generally 45 º. Seat angles of 30º and 20º maybe. However, it also be selected to reduce valve seat wear. Small seat angles are indispensable in gas-fired engines. The differential angle between the valve seat and the seating ring achieves initial sealing along a line of contact, thus creating better seal of the face against the combustion chamber. Attention needed to ensure that the valve seat width is greater than the seating ring contact width. [24]

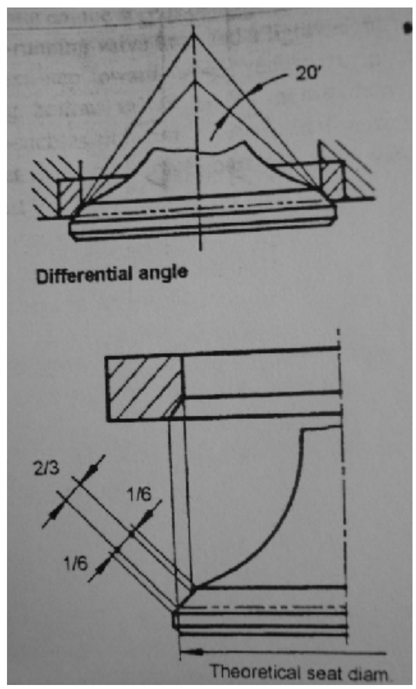


Figure 2.3: Differential angle and valve seat width. Source: Richard Van Basslauysen,, 2004

Considering the flow through the intake port as a whole, the greatest loss must be downstream of the valve due to the lack of pressure recovery (or diffusion). This loss is unavoidable on intake ports due to the nature of the poppet valve. On the exhaust ports, the opposite condition exists and we are able to control the geometry down stream of the highest speed section, namely the valve seat. This allows the possibility of good pressure recovery and is the reason exhaust ports flow better than intake ports of equal size do. [10]

Air has mass and does not like to hug a port wall around a short-side turn. That is why purpose-built race heads have steeply down-drafted ports. However, when heads have to fit under low hoods, port angles have to come down. Low-angle ports, the air (at mid and high valve lifts) does not follows shape around the short-side turn very well. As a result, most of the air goes out of the long-side turn. This situation becomes more exaggerating when the higher the lift becomes. As a result, the streamlining of the port on the long side needs to provide for low, medium, and high lifts, while the seat approach on the short side needs only to deal with the requirements of low-lift flow. [9]

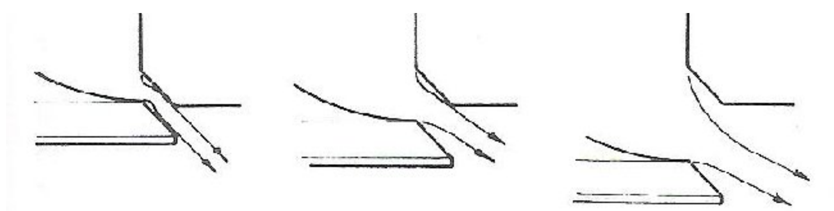
2.3 AIRFLOW CONDITION IN INLET PORT

Air flows into the valves by ways of ports. The shape and size of these ports control flow and velocity. These are the two critical components of port design. The optimum design will yield the highest flow (volume) of air while maintaining the highest velocity (speed). By thinking port as a straw, when diameter is increased the flow will increase but with the same input pressure, the velocity will have to decrease. The result of flow and velocity might also be thought of as low RPM verses high RPM performance. Velocity needed at low engine speeds to produce HP but if the volume is not there at the high RPM, the engine will not achieve maximum horsepower and torque .[6]

The characteristic of flows through valves is a parameter valve head and valve seat. The flow of velocity of fresh mixture in the intake manifold port and valve would give an effect to the volumetric efficiency by giving different discharge coefficient. In inlet valve, the discharge coefficient based on valve curtain area is discontinuous function of the valve lift or diameter ratio. If the lift is low the discharge coefficient is higher and will decrease when it lift was in intermediate but it will increase back when the lift is higher and it was because the flow separates from the inner edge of the valve seat. [2]

The lift and the discharge coefficient both vary with the crank angle. The discharge coefficient is determined experimentally. This coefficient accounts for the real gas flow effects. The discharge coefficient decreases slightly with lift since the jet fills less of the reference curtain area as it transforms from an attached jet to a separated free jet. [2]

So the performance of inlet valve assembly is influencing by the factor of, valve seat angle and fillet radius. For seat angel it will affect the discharge coefficient in the low lift regime the rounding the upstream corner of valve seat is to reduce the tendency of flow to break away. This entire factor is to generate a rotational motion inside the engine cylinder during induction process. [9]



(a) (b) (c)

Figure 2.4: (a), (b), and (c) flow pattern through the intake valve seat at different lift. Source: David Vizard, (2008)

When air flows towards the valve seat axis, the air is having a flow pattern, called swirl motion when passing face valve and seat angle. Swirl defined as the directional effect imparted to the inflowing gas by the shape of the inlet port or its angle of entry into the combustion chamber. Swirl assists eventual combustion by causing the mixture to be mixing and homogenously distributed in the cylinder. At the end of every exhaust cycle, there always a certain amount of exhaust gas that left unscavenges in the cylinder. If this exhaust gas allowed to be collecting into a pocket, it will retard the ignition flame travel, even preventing quite an amount of the fuel or air mixture from burning. [5]

Swirl generation significantly reduces the valve and port flow coefficient. Changes in seat width affect the L_v/D_v at which the shifts in flow regimes. C_d increases as seat width decreases. While seat angle, affect discharge coefficient in the low-lift regimes. Rounding the upstream corner of the valve seat reduces the tendency of the flow remains attached; increasing Reynolds number decreases the discharge coefficients. [5]

By having shrouded intake valve during intake system, swirl generations are developing well in the cylinder and this result with higher swirl ratio rather than un-shrouded valves. [27]

Good swirl will prevent this pocket of exhaust gas from forming by evenly mixing the fresh mixture coming into cylinder with unscavenges exhaust gas. All the time this action is taking place, the fuel droplets broken down into smaller more readily combustible particles and charge temperatures are being even out. With hot and cold pockets, minimized combustion is more complete, so power automatically rises. This also with less potential for violent combustion from hot spots or hot gas pockets, the way may be opened to run a little more spark advance or a few points higher compression ratio. This could add power, particularly in the midrange and widen the engine's effective power band. [9]

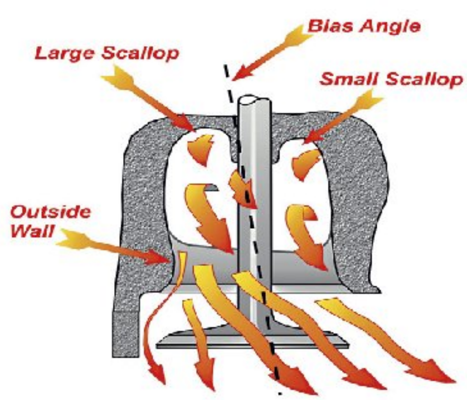


Figure 2.5: Flow pattern trough the intake port with bias angle. Source: David Vizard, (2008)

Figure 2.4 above explaining how bias angle of porting influencing flow pattern passing through intake port. By creating some biases on the port, it causing the flow "windows" towards the center of cylinder which helps to generate swirl motion during intake system process at high velocity.

Generally, the engine manufacturer offsetting the port from the valve centre creates swirl. Any tendency of the port to curve and produce swirl should be encouraged because port straightening reduces swirl, causing poor mixture distribution, with poor combustion being the result. [9]

2.4 LIMITATION DURING INTAKE PROCESS FLOW

Flow moves through a valve due to differences between upstream and downstream pressure called pressure drop. If piping size is identical both upstream and downstream from valve and velocity is consistent, valve must reduce fluid pressure to create flow by way frictional losses. A portion of valve's frictional losses attributed to friction between the fluid and valve wall. [11]

Many valves are designed to allow a portion of valve to be narrow than the piping so they can easily provide this restriction within body. [11]

2.4.1 Valve shrouding

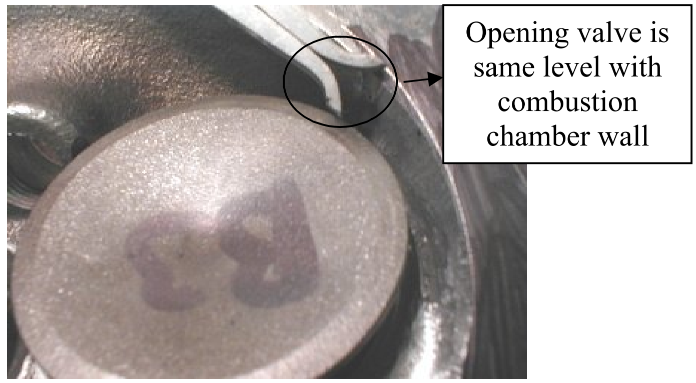


Figure 2.6: valve shrouding. Source: David Vizard, (2008)

Valve shrouding occurs when the edge of a valve is in close proximity to the combustion chamber wall, making for a tight squeeze for air to travel around the valve in this area. Some riders will try to increase this gap for better airflow in this area. Valve shrouding will usually restrict flow through the valve at some point in the valve lift, but not always. [10]

During mid lift point to something equal to say 35% of seat diameter (0.35D), airflow can be expected a big increase in flow. If the valve lifted, even further to say 100% of it's diameter it has become sufficiently far remove from the seat to be about out of the sphere of influence of the seat. This situation makes some assumptions. The first is that the air approaches the back of the valve from a near optimal direction and secondly that there are no further impediments to flow once the air has passed the seat. Unfortunately, these circumstances might not represent the real world. By re-assemble sectioned port with the part that houses the guide, air is now constrained to approach the seat area in an arc.

At higher lift, figures that the air on the floor of the port, with the short side turn, is going too fast top through around the turn. This results in skipping across the back of the valve and attempting to go out on the top (the long side) side of the port. This means the short side and the valve circumference in the immediate area is under-utilized. This situation called valve shrouding. Only by lifting the valve to extreme lift values can the head shown here avoid the restriction cause by this shrouding. [25]

In addition to valve lift, performance of inlet valve assembly is influenced by the following factor: valve seat width, valve seat angle, rounding of the seat corners, port design, cylinder head shape. In many engine designs the port and valve assembly are used to generate a rotational motion (swirl) inside the engine cylinder during induction process, or the cylinder head can be shaped to restrict the flow through one side of the valve open area to generate swirl. [5]

2.4.3 Choked flow

Choked flow in gases and vapors when velocity of a process fluid achieves sonic speeds in the valve reaches the valve restriction, pressure decreases, and specific volume increase until sonic velocities are achieve. When choked flow occurs, the flow rate is limited to the amount of flow that can passes through the valve at that point and cannot be increase unless the services condition are changed. [11]

When the flow is fully choked, the flow rate does not increase when the pressure drop is increased. The relationship of flow to $\sqrt{P_1 - P_2}$ is linear until cavitations begins to form at the point of incipient cavitations. As more cavitations forms, the more the flow curve bends until it is horizontal and fully choked with the flow not increasing with additional pressure drop. [26]

A valve normally lifted to the point where the open curtain area surrounding the valve is equal to the valve diameter. What this means is that if the valve seat was zero width, opening the valve any further than 0.25 of its diameter will not present any more breathing area to the cylinder. However because the seat occupies space under the valve, practice shows that the curtain area reaches the effective area under the seat and minus the valve stem at about 22.5% of the valve diameter. [25]

In liquid application, presence of vapor bubbles caused by cavitations or flashing significantly increases the specific volume of the fluid. This increase rises at a faster rate than that generated b pressure differential. In gas application, the velocity at any portion of valve or downstream piping is limited to the flow that achieved at sonic velocity in the valve's trim or the downstream piping. [11]

At high engine speeds, unless inlet valve is of sufficient size, the inlet flow during part of the induction process can become choked (reach sonic velocity at the minimum valve flow area). Choking substantially reduces volumetric efficiency. [5]

2.5 REVIEW OF PREVIOUS WORK

Through literature, briefing background on previous work involving modification intake valve and inlet port need to be considered. At this stage, the related study continues with analyzing previous work to understand focus on this project. In order to identify problem, previous data result were use to obtain a references point and guidance.

Figure 2.6 below describe modification madden on EX5 intake valve design had influencing the volume airflow rate that goes in into cylinder. Based on the graph, two types of modification on the valve had been made and being compared with the original design. A little changes madden on fillet radius valve dimensional had affecting the amount of airflow rate through intake system.

Using 6mm of radius fillet valve, result gives the increment value of the airflow rate compared to original design. Previous analysis also had stated that airflow rate is increase proportionally with opening valve during intake system process based on experimental madden. Lift values obtained during previous experimental, 3.4mm, 4.3mm, and 5.3mm had been use as main parameter to determine result of volume flow rate through simulation analysis. [2]

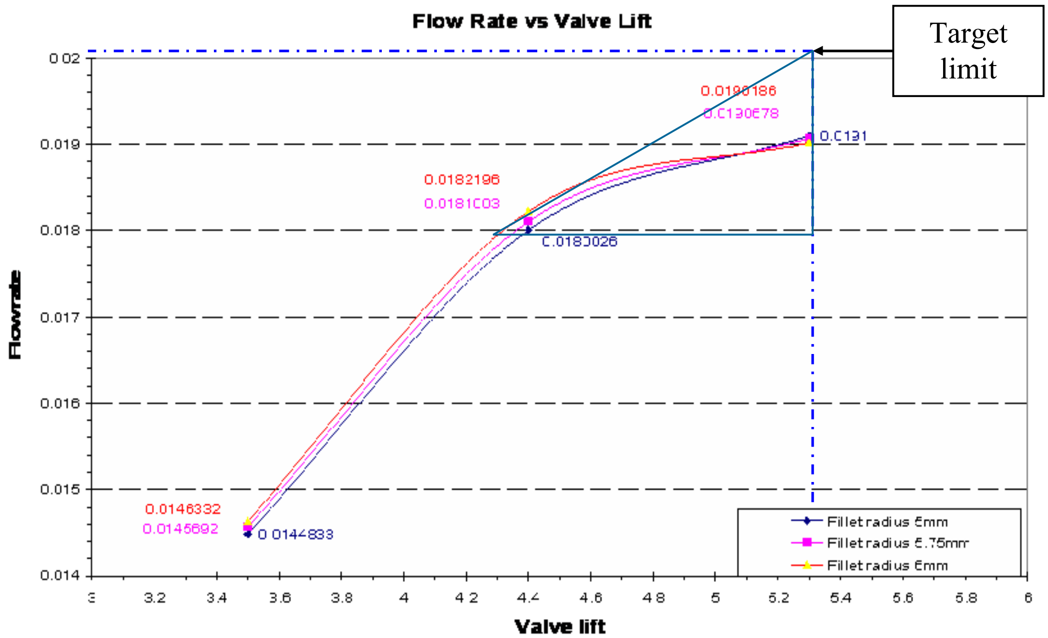


Figure 2.6: Result from past year integrated design valve product. Source: Umar b. Yunos (Nov 2007)

In order to optimize the airflow rate in cylinder head EX5, the previous data is use to identify the value of maximum airflow rate during its maximum lift. From the graph, a straight line is made until reaching the maximum lift. This is a method to setting the limit of optimization process so that objectives in this project could be achieving. Value of the setting limit is in range 0.0201 m^3/s. This could be assume as reference point which functioning as targeted limit for this project in order to analyze the new design.

2.6 MODIFICATION CONSIDERATION

A studies of the flow into and out of the cylinder of a two-valve engine shows that the principle direction of entry or exit is either toward (for the intake), or away (for the exhaust) from the center of the cylinder. In order to increase flow during intake system, modification on intake port, which normally called basic porting, is done by making some changes on geometry design of intake port and valve.

Consequences during modifying the inlet system must be considered during defining parameter that has the potential to improve airflow into intake system. **Table 2.1** and **2.2** below summarize the beneficial when modifying inlet port and valve.

Table 2.1: Advantage and disadvantages modifying intake valve design

Parameter	Advantages	Disadvantages
Face valve	• Biasing angle with valve seat to produce valve throttling flow • Discourage backflow into inlet port.	• Seat wears on the edge head.
Fillet radius	• Backcut angle and large the tulip shape reduce the seat width • Increase in discharge coefficient • Discourage backflow mixture into the inlet port	• Cause seat wear on back-head valve during high speed engine.
Stem	• Thinner valve means lighter weight • Better airflow produce	• Increase seat wear and poorer gal seal. • May fatigue and drop the valve head
Valve head diameter	• The bigger valves head present breathing area to the cylinder faster. This is about the same as a smaller valve opened at higher acceleration rate.	• Overlapping area increase too much • Losses in flow during low speed engine. • Swirl motion not

	• No valve shrouding effect occur • Suitable with high-speed engine.	generate well.

Table 2.2: Advantages and disadvantages modifying port cylinder head design

Valve guide holder	• Undercut the holder create more airflow path	• May fatigue the stem valve during high speed.
Diameter port	• Increase the diameter with short side turn creates throttle neck for airflow path. • Air flow increase with lower speed	• Backflow may happen on low speed engine
Draft angle port	• Generate high speed airflow • Swirl generation • Reduce backflow of mixture in intake port	• Not effective in low speed engine. • Produce stress on the side turn
Valve seat	• Must parallel or matching with valve angle • Produce neck throttle if undercut the angle	• Backflow of mixture in intake port may occur
Throttle area	• Shorten the side turn on valve throttle neck improves airflow path	• Seat wear occur