THE CHARACTERISTIC OF THE IN-CYLINDER FLUID FLOW OF 1.6L PETROL ENGINE

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**A report submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering**

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this project report entitled “The Characteristic of The In-Cylinder Fluid Flow of 1.6l Petrol Engine” is the result of my own work except as cited in the references.

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Date	:	…………………………………..

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature	:	…………………………………..
Supervisor's Name	:	Dr Ahmad Kamal Bin Mat Yamin
Date	:	…………………………………..

DEDICATION

I would like to dedicate my project to my beloved mother and father, who gave me never ending affection, love, encouragement and pray of day and night throughout this Final Year Project.

ABSTRACT

The main objective of this project is to study the effect of the Discharge of Coefficient, Swirl and Tumble in the inlet manifold on the block engine performance of 1.6 liter 16 Valve DOHC MIVEC engine. This project was conducted to investigate the behavior of engine air breathing performance between Discharge of Coefficient, Swirl and Tumble. This experiment was tested by opening valve lift with different adapter to show the different behavior of air flow. The experiment has been done on cylinder 2 of the engine at 25” H_20 test pressure. Also, this experiment using Superflow® SF-1020-SB flowbench machine. In this study, an experiment approach has been performed in order to investigate the flow distribution of intake port that will affect the performance of the engine when the valves lift ratio increases. The discharge of coefficient mostly affected by the boundary layer, surface roughness and flow separation. The swirl flow was performed with asymmetric valve lift with 2 cases. The difference in valve lifting is 0.17cm. The tumble flow was measured by lifting in half and full lifting. Results from all experiments were recorded and have been discussed in this report. Discharge of Coefficient (Cd) increases gradually with valve lift ratio (L/D). Swirl test in this engine showed that the fluid motion does not swirl and there is also no swirl at the engine design. Tumble flow shown the zig zag trend on the graph. Head orientation at 120-degree was produced high speed of tumble.

ABSTRAK

Objektif utama projek ini adalah untuk mengkaji kesan Pelepasan Pekali, Pusaran dan Guling dalam kemasukan yang berlipat ganda ke atas prestasi blok enjin 1.6 liter 16 injap DOHC MIVEC. Projek ini adalah untuk mengkaji tingkah laku prestasi pernafasan udara enjin di antara Pelepasan Pekali, Pusaran dan Guling. Eksperimen ini diuji dengan membuka injap menggunakan penyesuai yang berbeza untuk menunjukkan kelakuan aliran udara yang berlainan. Eksperimen ini telah dijalankan ke atas silinder yang ke-2 enjin Mivec pada tekanan 25" H_20. Di samping itu, eksperimen ini menggunakan mesin *flowbench* Superflow® SF-1020-SB. Dalam kajian ini, pengagihan aliran bahagian pengambilan yang akan menjejaskan prestasi enjin apabila nisbah angkat injap meningkat. Pelepasan pekali kebanyakannya terjejas disebabkan oleh lapisan sempadan, kekasaran permukaan dan pemisahan aliran. Aliran putaran telah dilakukan dengan menggunakan dua cara ketidakselarian injap. Perbezaan pengangkat injap ialah 0.17cm. Aliran guling diukur apabila diangkat secara separuh dan secara penuh. Hasil keputusan dari semua percubaan telah direkodkan dan dibincangkan dalam laporan ini. Pelepasan Pekali (Cd) meningkat secara ansuran dengan nisbah angkat katup (L/D). Ujian putaran dalam enjin ini menunjukkan pergerakan bendalir tidak berputar dan juga tiada putaran yang berlaku pada reka bentuk enjin. Aliran guling menunjukkan bentuk zig zag pada graf. Pada sudut 120-darjah aliran guling menghasilkan aliran yang paling tinggi

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr Ahmad Kamal bin Mat Yamin from the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for essential supervision, support and encouragement towards the completion of this project.

I would also like to express my deepest gratitude to Mr Azwan, the technician from the Test performance engine laboratory for their assistance and their effort in all laboratory and analysis works. Also my team mate, Faiz Syazwan who helps me during do the experiment test.

Special thanks to all my peers, my late mother, beloved father and siblings for their moral support in completing this degree. Lastly, thank you everyone who had been to the crucial parts of realization of this project.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

The first part of this chapter consists of the project background and aim of the project. The next part focus on the detailed problem statement that lead to the research. The objectives of the project were stated at the next part of the chapter. The objectives that helped the researcher to finish the research or project.

1.1 Project Background

This thesis focuses on the intake system flow which are pressure drop, swirl and tumble using flow bench machine or more specifically the Superflow® SF-1020-SB Flow bench machine. For this experiment, the block engine of 1.6 L 16 valve DOHC MIVEC engine has been choosing to analyze. The main function of the experiment is to determine the behavior of air flow intake system of engine. Swirl and tumble motion of the air can be determined using the swirl meter.

Nowadays, internal combustion engine is a one of the important aspect to make a vehicle. A day to days, development of the internal combustion engine very high demand on our industry. This is because, every company of the engine is chasing each other to make the top in industry. Internal combustion engine is a mixing of air and fuel in the cylinder to provide a homogeneous charge to make some power to the engine. The perfect of mixing between air and fuel, temperature rising to make the high power during combustion and the combustion in the manifold. In the spark ignition of combustion engine, there are 4 working principles of engine which are intake – compression – expansion – exhaust.

There are many characteristics of the in-cylinder fluid flow in the engine manifold. Which are pressure drop, swirl and tumble. First, pressure drop is created by the suction air in the piston when the piston push down. This behavior is very dependent on engine speed and load, flow resistance of different element in the system. Second, swirl flow is a parallel rotation to the cylinder axis. It will be generated by parallel flow rotation through the cylinder to the intake flow of the engine. Swirl flow will be effected by 3 components which are intake manifold, valve ports and the piston surfaces. Lastly, tumble flow is air flow circulating direction in the cylinder. This flow behavior will be generated turbulence flow by little effect on the tumble process. This flow can be light the engine combustion when it completes near the end of the compression stroke. This flow is very dependent on the shape of the piston surface, location of the piston cavity, orientation of the intake manifold, compression ratio and engine speed.

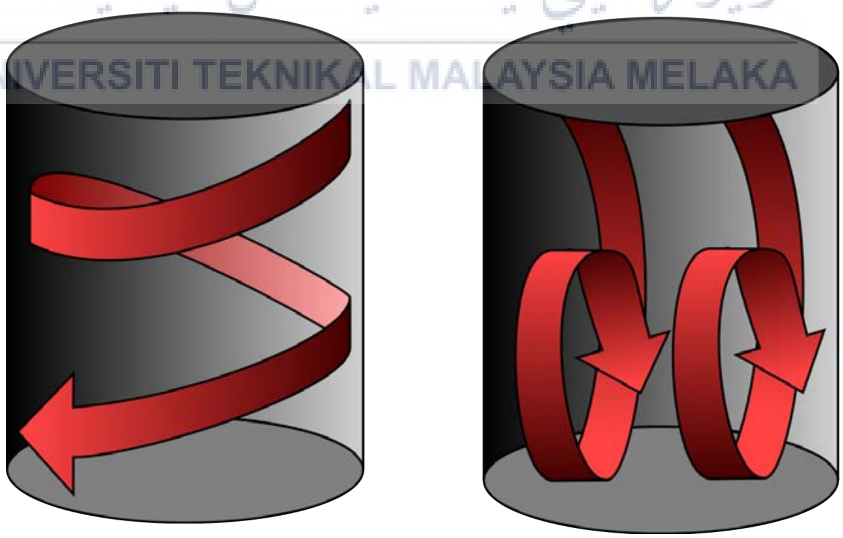

Figure 1.1: Swirl and Tumble motion

Air flow is an important part in the combustion chamber. Behavior of the engine is depending on the air flow motion in the manifold. The Discharge of Coefficient (C_d) is a ration of actual discharge to ideal discharge. Discharge of Coefficient (C_d) are widely used to monitor the flow efficiency through various engine components and are quite useful in improving the performance of these components. Since the value of C_d is higher, the efficiency is increase and more efficient the air flow in the manifold.

Mixture of the fuel and air is important in the combustion. The behavior of the combustion is depending on the mixing of fuel and air. The mixture of them makes the swirl and tumble motion during the combustion. Since the mixture between fuel and air is well, the combustion of the engine will be more efficient and make the power on the engine performance.

In the large displacement engine, it has high value of combustion between small displacement engine. It is because large displacement has two valves of intake port and exhaust port. It will be more efficient between one valve of intake port and exhaust. The fluid flow characteristic between small and large displacement also different. This study to investigate the air flow, swirl and tumble motion of a large displacement engine and get the exact value using the flow bench machine.

1.2 Problem statement

Car intake system allows the car to breathe easier and create more power in the engine. The flow efficiency of the intake system can give more power of the engine. This project has three of the objectives to be achieved, first is to analyze the pressure drop in Mivec intake system, second is to analyze the swirl behavior in intake system and the last is to analyze the tumble behavior in intake system.

1.3 Objectives of the project

The objectives of the project are:

a) To investigate the cylinder head Discharge of Coefficient (C_d) at range of inlet valve lift

b) To analyse the Swirl motion and Tumble motion of combustion air at a range of inlet valve lift

1.4 Scopes of Project

a) Study the detailed of intake port cylinder head of a Mithubitsi Mivec 1.6L engine.

b) Operate the Superflow® SF-1020-SB Flowbench machine to determine the air flow through the intake port, determine the coefficient of discharge (C_d), swirl and tumble readings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 1 discussed about an explanation of introduction to background of study, detailing of motivation for engine performance and improvement of the Automotive industry to achieve this. The air flow that occurring in an internal combustion engine perfected with the some of the uniqueness technology automotive was also introduced in this chapter.

The introduction strategies presented, identifying the relevance of the previous work. The flow through the valves will be explained further because the intake valve has an influence on of the retrieval system before entering the cylinder. In-cylinder air flow behavior is discussed and considering the pressure drop, swirl and tumble flow. For measurement and analysis, the air flow behavior in combustion engine was reviewed. It is highlighted where the existing understanding may be extended.

2.2 Variable Valve Timing

Internal combustion engine has two valves to control the intake flow and exhaust flow that control the combustion chamber respectively. Each industry of automotive has different of Variable Valve Timing (VVT) like as Mitsubishi named is MIVEC (Mitsubishi Innovative Valve timing Electronic Control system), Honda named is V-TEC (Variable Valve Timing & Lift

Electronic Control) and others. Every technology of Variable Valve Timing (VVT) used has a advantages itself and capacity to increase the power and torque output of the engine performance.

It was discovered as early as the 1992’s that it may advantage to enhance performance, economy and emission has been improved. In 1924 Csandy and Woydt [1] claim to use the inner and outer cam to file a patent for a method of varying the timing. Variable Valve Timing (VVT) was related that all of the system or technology with the same objective to achieve the best performance due the timing of the intake and exhaust depend on the engine cycle location. Valve opening and closing, maximum lift and minimum lift and some system are related on parameter of interest the behavior.

Butcher.D stated that he best tuning of engine design is a crucial part of parameter to seek the further develop the efficiency of their engines.

Figure 2.1: Mivec engine

2.3 Flow bench

Flow bench is a device used to test internal combustion of engine and other components. Before passed to public, various industrial and commercial devices must be checked by manufacturer. For example, in the design phase the flow-bench engine is used to measure the amount of air that can pass through various components (intake and exhaust port, intake and exhaust valves, etc.) related to the Internal Combustion Engine. Total horsepower that the internal combustion engine that can be produced is limited by the amount of air that can be passed and out of the combustion chamber. A flow bench can also be used to evaluate any component that is used to flow a gas such as air filters manifolds, carburetors, exhaust manifold, intake manifold, valve, etc. Flow bench such as that described by Wayne Helmer, it can be used for the study of many other types of fluid mechanics problems and can be a valuable teaching tool in engineering education.

Characteristic diameter and valve lift (L/D) can be specified by ratio and the actual dimension in decimal inches or mm. Almost of the experiment used valve head diameter. Normally engines have an L/D ratio from 0.0 up to a maximum of 0.35. Valve should be set at L/D (0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35) for flow testing.

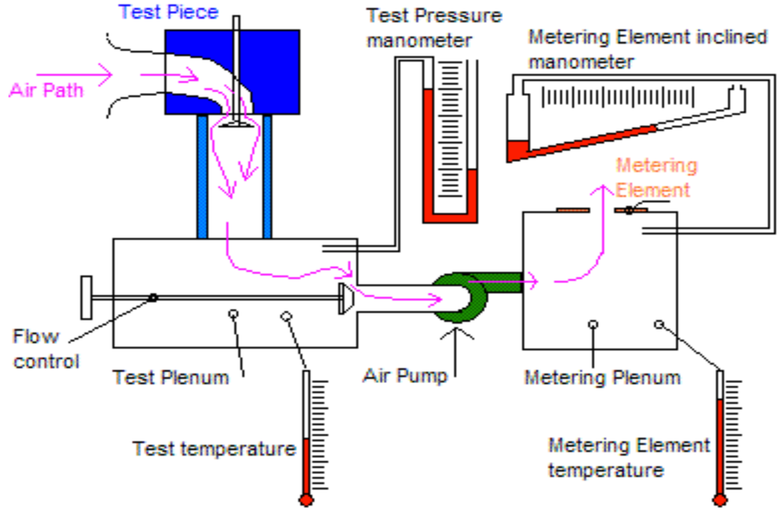

Figure 2.2: Typical Flow Bench schematic

Figure 2.3: SuperFlow SF-1020 SB

2.4 Pressure Drop

One of the very crucial part is cylinder head for automotive engine because it can affect the performance of the engine behavior, fuel assumption and emission of engine. The major of the research area in SI engine is a designing and developing of intake port. Power output and emission are depending on the thermodynamic properties of cylinder. Intake air motion should be increased in the combustion in order to achieve higher thermal efficiency and better emission control. The design of cylinder head is a one of the important aspect to deliver the air fuel mixture to the combustion.

Port and valve design determine the Discharge of Coefficient (C_d) of the port and consequently the volumetric efficiency of the engine. Discharge of Coefficient (C_d) describes the behavior of all real flows contract in area as they pass through any restriction in engine. Amount of air entering the combustion chamber are determining the performance of the engine. The more air was entering the combustion chamber, the higher of the performance of engine and improve its quality.

$$C_d = \frac{TestFlow}{PotentialOrificeFlow}$$

2.5 Swirl

Organized rotation of the charge about the cylinder axis is a usual define of swirl. Swirl is created by bringing the intake flow into the cylinder with an initial angular momentum. Friction occurs during the engine cycle, intake generated swirl through the compression, combustion and expansion process create some decay in swirl motion flow. Mohiuddin [2] claims that swirl is used in diesels and some stratified-charge and the injected fuel and to speed up the combustion process in Spark Ignition (SI) engines.

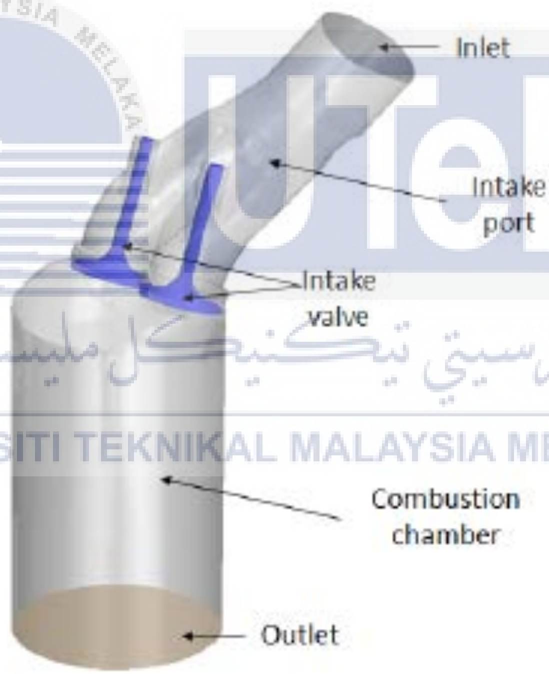

Figure 2.4: In-cylinder simulation

Swirl is also crucial for efficient soot oxidation in the late-cycle mixing controlled combustion phase. For twin port design, the swirl asymmetry is initiated by the asymmetrical orientation of intake ports. There exists a great interest in predicting the flow asymmetry in the late compression stroke. It can help deciding the optimum injector location for minimum asymmetrical mixture preparation. Swirl is a rotational motion of a bulk mass in the cylinder and also make shaping and contouring the intake manifold, valve port and piston face. Swirl air flow enhances air fuel mixing and helps to spread the flame during combustion occur described by Aizad Sazrul [3].

Prior the inlet of air entering the intake cylinder, it has a few methods that was applied for generating of swirl motion in Internal Combustion Engine. Swirl flow was widespread in Compression Ignition (CI) engine because the more of air flow is allowed entering in-cylinder and the air quickly mixing between the injected fuel. Swirl also can be found in Spark Ignition (SI) engine to enhance the combustion and improve mixing of the air and fuel injected. [4]

Figure 2.5: In-cylinder swirl motion

By forcing the intake air with the enhance of the air speed intake and control the angular momentum to rotate the air about the axis of in-cylinder using positioning of the valves. Meanwhile both of the valves offset and orientation can enhance the swirl motion described by Uzkan et. al. [5]

To produce more swirl flow in the chamber, helical port is capable used between the direct port at low lift. However, the design used are suitable to enhance the swirl flow but at the volumetric efficiency. [6]

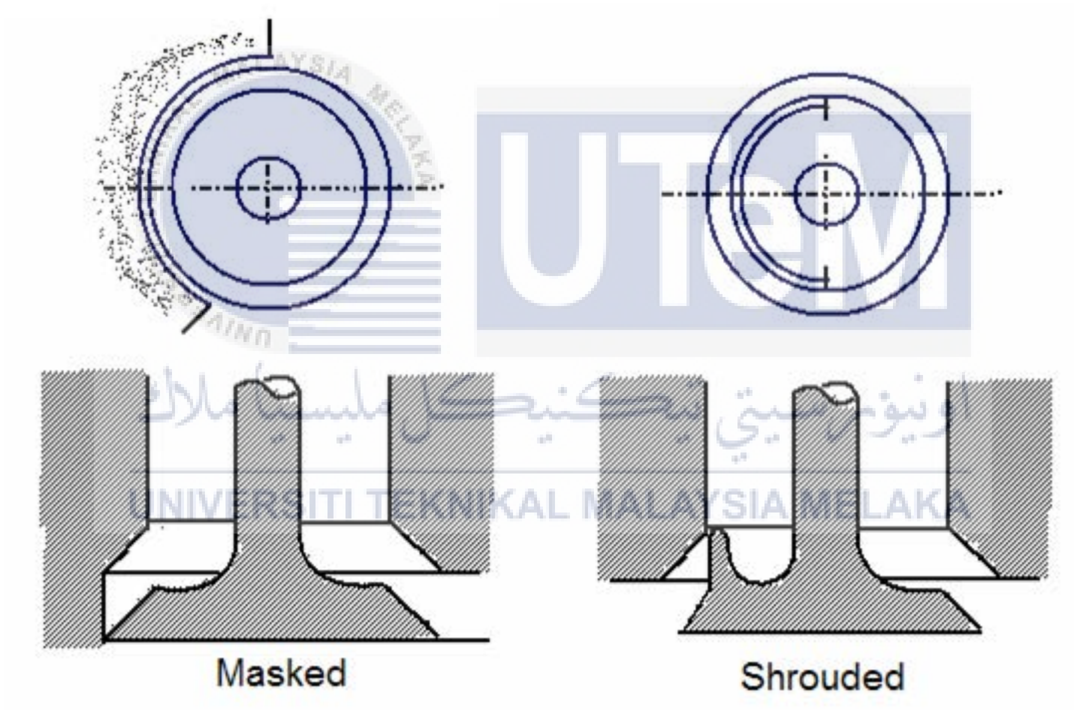

Figure 2.6: Different between head-masked and head-shrouded

Shrouded valve is a usually used device to enhance the speed of the swirl during the intake flow. It is non-uniform manner result in angular momentum with the direct intake flow [4]. Position of the head valve is a vital to determine the swirl motion. Khalighi et. al [7] found the head shrouding valve can be approximately 30% of swirl by directing the flow tangentially to the cylinder. No significant swirl flow in engine cycle at latter shrouding position.

2.6 Asymmetric valve Timing

The asymmetric valve intake lift operates by having one of the intake valve operate at higher lift compared with the other valve by Aizad Sazrul et al [3]. When the air flow strikes the valve the swirling motion will be increased. Asymmetric valve timing is to generate turbulence flow in the combustion chamber and make homogenous mixture of air flow. Mixture of the air can improve combustion process with enhancing the flame front speed. Muhd Farid et al. [3] uses Computational Fluid Dynamic (CFD) to assess the asymmetric valve lift performance towards swirl flow motion characteristic. To analyze the case study, CFD simulation domain was setup.

Case name	Valve 1	Valve 2
Base	2mm	2 mm
Case 1	4mm	
Case 2	6 mm	
Case 3	8 mm	

Figure 2.7: Asymmetric valve lift configuration case study

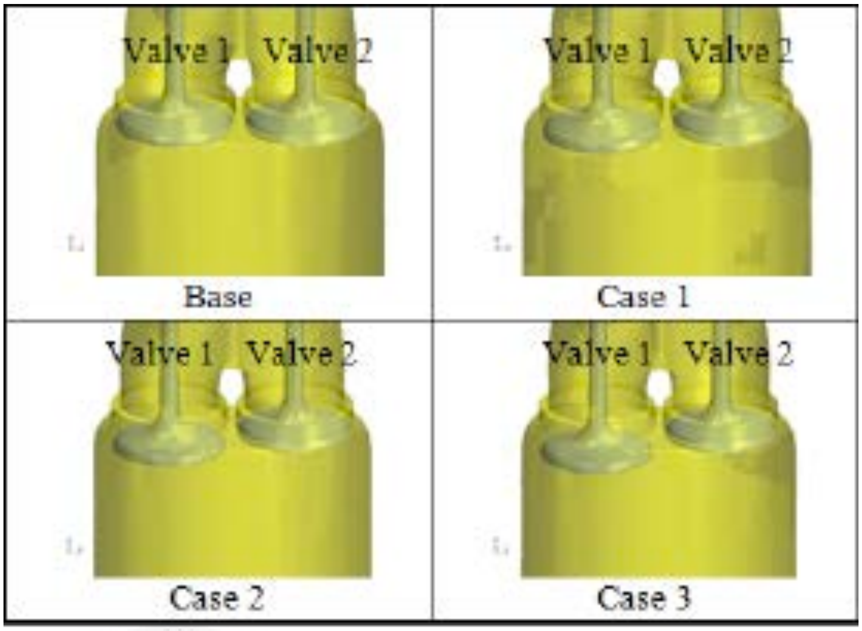

Figure 2.8: Visualization of the asymmetric intake valve lift configuration of model

2.7 Tumble

Tumble motion was described a rotational motion about an axis which is parallel to the cylinder. There are 3 axes of air motion was measured by flow bench which are pressure drop, swirl motion and tumble motion. Air flow was directed from the valve, across the head before it flows through the cylinder. During the compression stroke, the large proportion of the tumble motion was broken down into the smaller scales of swirl motion.

Figure 2.9: In-cylinder Tumble motion

The beneficial effect on the combustion in Spark Ignition (SI) engine is enhance of tumble motion in cylinder. Both of the motion like tumble and swirl will improve the stability of combustion whilst the tumble motion can greatly reduce the burn angle and also delay angle described by Floch et. al.

Kiyota et. al. shows that comparison of four stroke engines which are with tumble and without tumble. The experiment was concluding that increases the early rate of flame propagation with enhanced the tumble motion. An increase the NOx production concept lead was found.

The majority of the flow enters over the top of the intake valve will increase the tumble motion in the cylinder. For example, modified the inlet port face gasket which masked off the lower portion of the inlet port show by Reeves et. al. Tumble was increase without significantly reducing the flow rate using this possible method [8]. The higher case of tumble will found by using the PIV technique to measure the dynamic barrel swirl ratio. The compression stroke before decaying is possible for tumble motion to persist late.

Stansfield [9] was investigate the power of engine performance which is 750, 2000 and 3500 RPM. These parameters have been investigated to make their effect on in-cylinder. Some investigation of the engine by Singh & Gadekar et. al [10,11], that found as similar results which is smaller range of engine speed 1200 & 1800 RPM. Some recent work by Singh, the effect of intake air temperature to be neglected.

2.8 Quantification of Swirl and Tumble

Swirl and Tumble is a dimensionless parameter to quantify the rotational movement of motion in the cylinder. The common parameter to quantify the amount of swirl and tumble is a ratio of the angular velocity of the swirling motion and the engine speed. The enhance of overall charge velocity at higher engine speed are crucial compared to motion relative and engine speed. The equation the swirl and tumble ratio is given by

$$R_S = \frac{\omega_S}{2\pi N} \quad (2.10)$$

$$R_T = \frac{\omega_T}{2\pi N} \quad (2.11)$$

where ω is a motion angular, R is the ratio of the motion, N is the engine speed

Laser based techniques is a common method to evaluate and measure the swirl and tumble ratios in the engine. Several techniques have been developed to test the performance of cylinder head, intake manifold and device outside of the engine as described by Xu [12]

2.9 Intake Port

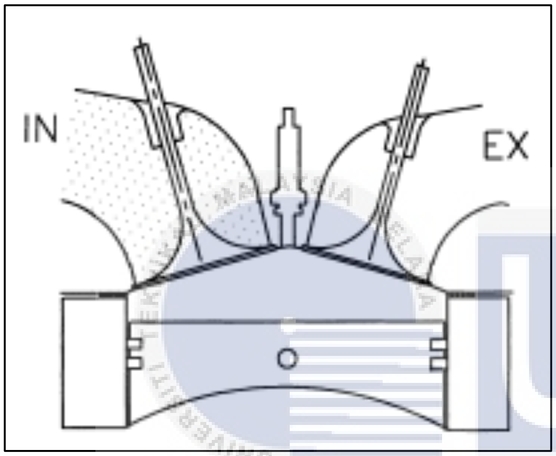

Figure 2.10: Horizontal Intake Port

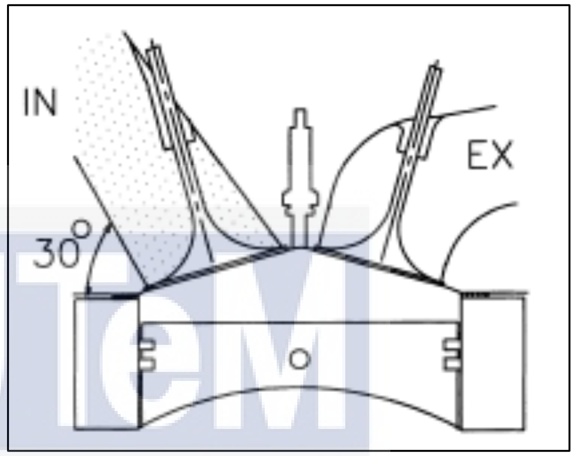

Figure 2.11: Upright Straight intake port

In the engine system, there are 2 type of the intake port which can control the airflow enter the combustion chamber. Each type of airflow most affect with the engine performance. The first is upright straight intake port and the second is horizontal intake port. Upright straight intake port efficiently directs the airflow down into the combustion chamber. The airflow behavior enters into the chamber and make a strong tumble for optimal fuel injection.

Gasoline Direct injection (GDI) technology most focuses on the Lean Burn Technology, where it different with the Rich Burn Technology. Lean burn technology is a more air excess in the engine and the amount of air needed to complete the fuel combustion is twice. While the Rich burn, technology is an enough air needed to burn all of the fuel. Upright straight intake port use the Gasoline Direct Injection (GDI) while the Horizontal intake port use Conventional engine.

The upright straight intake port used the Gasoline Direct Injection Technology. Direct fuel injection usually can be used in diesel engine and use the Lean Burn Technology. There are two advantages for the Gasoline Direct Injection (GDI), which is when the fuel was injected under high pressure directly into the combustion chamber, this can allow the precise control of charge stratification vital to ignite ultra-lean air. The second advantages of the direct injection is also dispenses with the need for a throttle, so eliminating the pumping loss associated with drawing air around a conventional engine butterfly valve.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will explain about the methodology used to accomplish this project. The methodology of the research is covered based on the information from the literature review. In conducting a research, planning is required in order to avoid any problem during the research period. Therefore, several steps and procedures need to be assessed to ease the research process alongside getting the amazing result such as experimental data. All the process that have been used to fulfill this experiment being discussed in this chapter, in order to complete the objectives and scopes of this experiment.

3.2 Flow the project

The project began with a problem statement, objectives and the scope of the experiment. All these three things are very important to determine flow and progress of the project to be carried out. Our project was divided by three part which are Pressure Drop, Swirl and Tumble motion.

3.2.1 Discharge of Coefficient (Cd)

i) Clean the block engine

Before starting the experiment, the earlier step is cleaning process need to be done onto the cylinder head. This is because, this experiment involved the air flow throughout the intake port, so the port need to be cleaned and free from residues and dust. Cleaning process is using mixture of diesel and detergent to make it easier to get rid dust and dirt in the cylinder head. In cleaning process, do not use the wool to polish the engine block because it makes hard effect on the engine block.

DESCRIPTION	SPECIFICATION
Valve mechanism	16-Valve DOHC MIVEC
Total displacement	1590cc
Bore	75.0 mm
Bore pitch	93.0 mm
Stroke	90.0 mm
Max output	115 hp (86 kW ; 117 PS) at 6000 rpm
Max torque	154 N.m (114 lb.ft) at 4000 rpm
Compression ration	11.0 : 1
Fuel type	Petrol

Table 3.1: Specification of MIVEC 1.6L

ii) Measure

Before beginning a test, record the head description, and measure the valve stem and the valve diameter. The net valve area is the valve area minus the stem area.

Net valve area= 0.785 (valve diameter^2 – stem

In earlier measurement is valve diameter by using the Vernier caliper to get the accurate measurement. Measurement of the valve diameter to make sure the flow bench not run out of the capacity. All engine valve tests should be performed at the same ratio of valve lift to valve diameter, or L/D ratio. Then the flow efficiencies of any valves can be compared, regardless of size. Multiply the valve diameter with seven L/D ratios (0.05, 0.10, 0.15, 0,20, 0.25, 0.30, 0.35) to obtain the valve lift test point value.

L/D ratio	Valve Lift (mm)
0.05	1.7
0.1	3.4
0.15	5.1
0.2	6.8
0.25	8.5
0.3	10.2
0.35	11.9

Table 3.2: Test point value

Figure below shown that, the Valve diameter vs Flow range. Based on the measurement of the valve diameter, the suggested flow range for 35mm is Range 3 – 100 cfm (47 lps)

Valve Diameter	Suggested Flow Range for 25" (63.5 cm) Test Pressure
1.00" (25 mm)	Range 3–100 cfm (47 lps)
1.50" (38 mm)	Range 4–150 cfm (71 lps)
1.50" (38 mm)	Range 5–200 cfm (94 lps)
1.75" (45 mm)	Range 6–300 cfm (142 lps)
2.00" (51 mm)	Range 7–400 cfm (189 lps)
2.25" (57 mm)	Range 8–500 cfm (236 lps)
2.50" (63 mm)	Range 8–500 cfm (236 lps)
2.75" (70 mm)	Range 9–700 cfm (330 lps)

Figure 3.1: Valve diameter vs Flow range

Second, measure the valve height on the block by using the Vernier caliper to get accurate measurement. Measure the height of valve when steady state and measure the height of the valve when the valve push down. When the valve in steady state is 39.5 mm and height of the valve when push down is 28.1 mm. The different when push down and steady state is a 11.4mm.

Figure 3.2: Measure the valve diameter

Figure 3.3: Measure the diameter of cylinder head

iii) Install the spring valve

The spring valve selected must be carefully matched in the valve train. In the experiment, spring valve selected is different with the actual spring valve. It is because the original spring valve used hard quality of stiffness but for the experiment spring valve used is a light spring.

iv) Install the gasket

Gasket is a very important part to install the engine to prevent air from leaking during the combustion. This gasket installed in between the cylinder head and cylinder adapter. It is because to ensure and prevent air from escaping during running of the flow bench.

Figure 3.4: Cutting the gasket

v) Clamp the engine block

Before experiment started, the cylinder head must be attached with the cylinder adapter. For this project, G-clamp are used to attach the cylinder head and cylinder adapter. The adapter consists of a tube approximately 4” (10 cm) long with the same bore as the engine and adapter on one end. The lower of the adapter is bolted to the flow bench, and the upper of the adapter is clamped to the engine block. Besides, to avoid the scratch on the surface of engine block and the clamp moved from its original position during testing, double-side tape is used.

Figure 3.5: Clamp the engine block with the adapter

vi) Attaching device for opening Valve (Valve Opener)

A device must be attached to the cylinder head to open the engine valves to the various test positions. The usual method is to attach a threaded mount so the end of the threaded part contacts the end of the valve stem. As the threaded rotates, it pushes open the valve. A 0 to 1” x 0.001 (20 mm x 0.01) dial indicator may be mounted to the same fixture with its tip contacting the valve spring retainer to measure the amount of the valve opening. The standard valve springs should be replaced with soft springs for testing. This is to make it easier for the valve opening during testing.

Figure 3.6: Valve opener

3.2.2 Swirl

i. Swirl Meter

Swirl flow in actual of operating engine is very difficult to measure of observe because of the flow is very quick fast and high temperature. Usually used to observe and determine the characteristic of the flow of the engine is by using flow bench. A swirl meter was used to observe the swirl steady-flow.

Figure 3.7: Set of Swirl Meter

Swirl meter mounts between the bore adapter and the flow bench and record the gross axial, circular motion of intake. To make the accurate and repeatable swirl measurement, clearance between bore adapter and blade should be consider. Clearance between bore adapter and blade is a very secure to ensure the blade rotate smoothly. If the clearance is not the same i.e. different by more than 0.01 to 0.02”, adjust the blade or change the other blade.

Blade length	Adapter bore diameter	Clearance
82.5 mm	84.1 mm	1.6 mm

Table 3.3 : Dimension of blade

Figure 3.8: Set up the blade

Install the block cylinder on the bore adapter parallel with the intake and exhaust valve. To get the swirl reading, the valve was located as asymmetric valve. The formula was used is 5% lift between left valve and right valve. It is because to make a swirl flow in engine. The Figure below shown the asymmetric valve in the experiment.

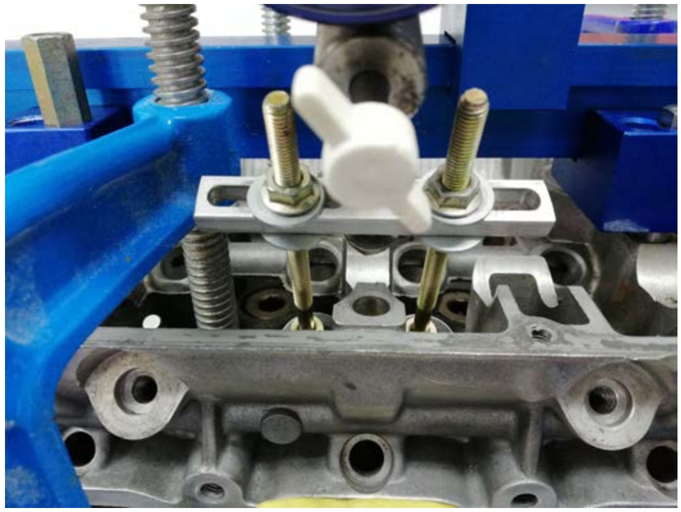

Figure 3.9: Asymmetric Valve

The valve was adjusted to the next L/D ratio and readjust the L/D was repeated until the lift reach maximum L/D ratio. After the left asymmetric valve reach at the maximum lift, the experiment will change the right asymmetric valve to make sure the air flow between left and right asymmetric valve.

Figure 3.10: Experiment was assist with assistant of laboratory

Data was record when the motor temperature reach at 100^0C, and the motor was turned off and let it to cool and temperature drop at 93^0C to 95^0C before continue the test. It is to make sure the flow bench in good condition when running the test. Experiment was conducted with assistant of laboratory.

Test Pressure (H20)	Peak Velocity (ft./sec)	Flow/Unit Area* (cfm/sq. in)
1”	66.2	27.6
3”	114.7	47.8
5”	148.0	61.7
7”	175.1	72.9
10”	209.3	87.1
12”	229.3	95.6
15”	256.4	106.9
20”	296.0	123.4
25”	331.0	138.0
28”	350.3	146.0
30”	362.6	151.1
35”	391.6	163.3
40”	418.7	174.6
45”	444.1	185.1
48”	458.6	191.2
50”	468.1	195.2
60”	512.8	213.8
65”	533.7	222.5

Figure 3.11: Maximum Potential Orifice Flow Rate Vs. Test Pressure.

Suggestion flow test pressure are use 25”, it means the Maximum Potential Orifice Flow Rate use is 138.0. This result to calculate the discharge coefficient.

3.2.3 Tumble

i. Set up experiment

For the tumble flow, the set-up experiment is different with swirl. First, install the swirl meter between the adaptor flow bench and bore adaptor as shown in figure below. Bore adaptor with optional provision for piston at bottom to accurately simulate engine flow geometry. Swivel located at the top of bore adaptor to measure the tumble flow in any orientation. The head was bolted on the bore adaptor to avoid leaking flow.

Figure 3.11: Head engine on the flow bench during test

Figure 3.12: Swirl meter

Figure above shown the swirl meter was located between the bore adaptor and flow bench adaptor. The swirl meter used for measure the speed of flow during the operating of flow bench.

ii. Flow Testing

After all the apparatus were set up completely, so we can begin with the testing. Flow testing consists of sucking air through a component at a constant test pressure. In the earlier measurement by using verlier caliper, we have collected the measurement of the valve diameter and bore diameter . This is because by using the vernier caliper we can know the suggested flow range for the test pressure. This is also to ensure that the flowbench will not run out of capacity. The flow range and test pressure for this experiment are same with the experiment pressure drop and swirl flow.

For this 1.6L Mitsubishi Mivec cylinder head, the valve diameter is 34 mm, so the suggested flow range is 3 and the test flow is 25”. When all the data needed for the experiment completely, we begin to the start operate the machine. For the tumble flow experiment, we used two method to record the data. The first is half lift and the second is full lift. Based on the valve diameter obtained, there are seven L/D ratios (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5). For the half lift is 2.0 L/D and the full lift is 3.5 L/D. This experiment to measure the maximum flow through the swirl meter at degree of head orientation between half lift and full lift.

Figure 3.13: Push the dial gauge

The first experiment, 0.2 L/D valve lift was set up at the zero degree of the head orientation. The cylinder head should be rotate using the swivel from 0 to 360 degree of the head orientation. It causes to determine the maximum flow of the cylinder at each 20 degree of head orientation.

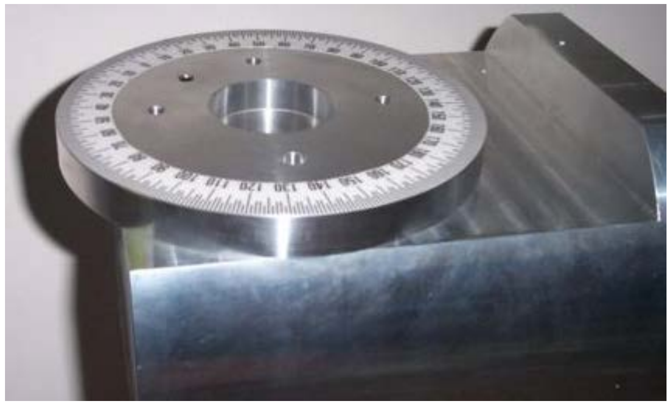

Figure 3.14: Swivel

The reading of swirl ratio was recorded when the test pressure is 25” and the temperature of the flow bench will increase. To record the next crank angle, make sure the temperature cool down at 90℃ – 94℃. Then, repeat the step to the next head orientation.

Figure 3.15: Cylinder head at 120-degree head orientation

The second experiment, 0.35 L/D valve lift was set up at zero-degree head orientation. The procedure of experiment is same with the 0.20 L/D ratio.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Overview

The previous chapter was described the detail of experimental and the methodology of experiment used for data analysis. This chapter will continue and describes the analysis the data obtained.

The experiments have been conducted for a several valve lifts over valve diameter ratio (L/D) that is 0.05,0.1, 0.15, 0.2, 0.25, 0.3, 0.35. These measurements were carried out at one pressure drops, 25" of H_2O. The flow characteristic through the intake port was carried out on the 16-Valve DOHC MIVEC cylinder head using the flow bench machine. Cd was calculated and discussed.

Next, experiment to record the swirl flow reading by using swirl meter to find the swirl speed (rpm) versus Valve lift ratio (L/D). Data for each experiment was discussed and represented. After that, experiment tumble flow was conducted to obtained the maximum tumble speed at the head orientation angle. Then, the data and result of tumble flow was discussed and represented.

4.2 Discharge Coefficient (Cd)

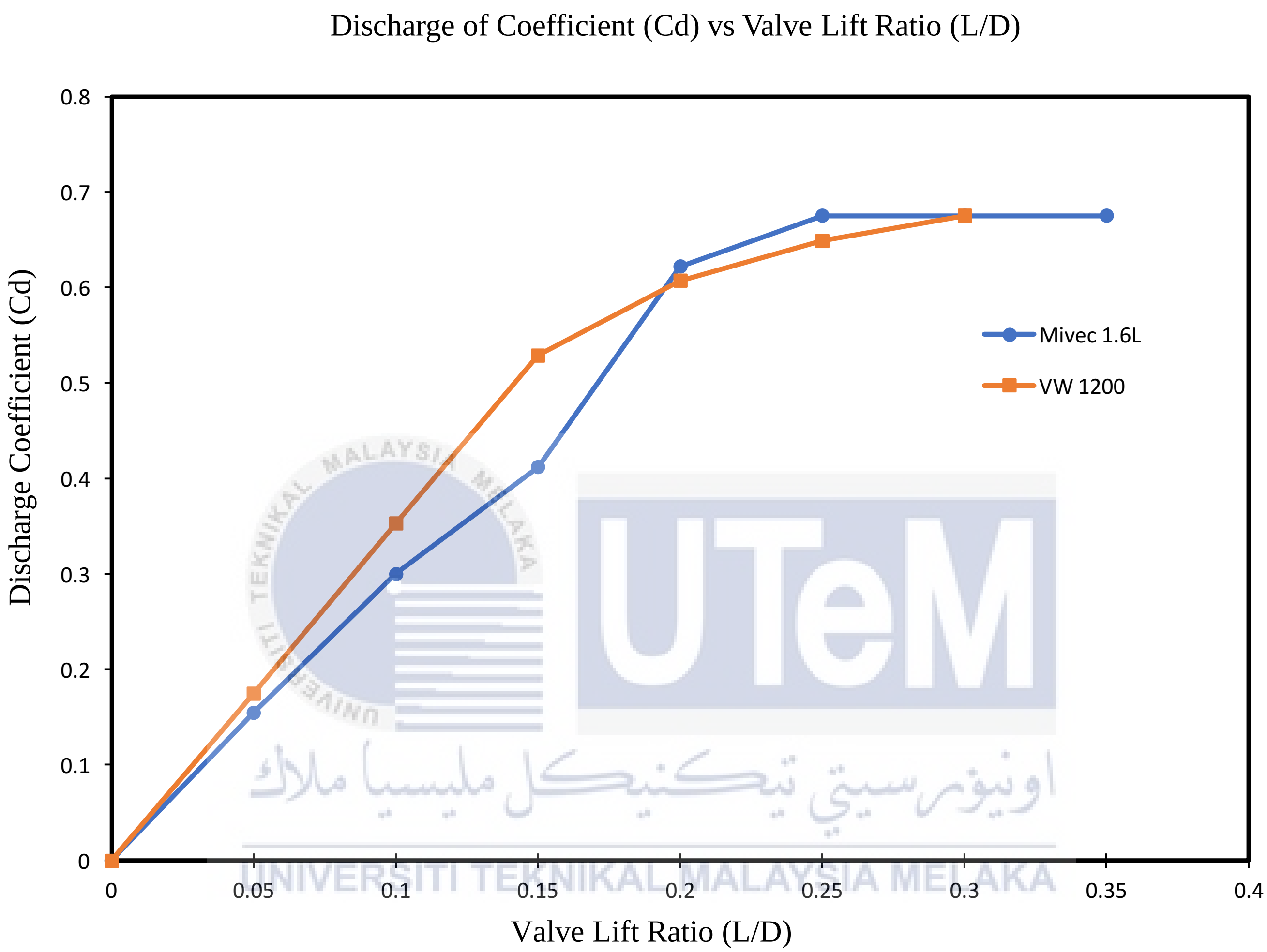

Figure 4.1: Discharge Coefficient versus Valve Lift Ratio (L/D)

Based on the result above, the graph between Discharge Coefficient (Cd) and Valve lift ratio (L/D) was recorded. The graph shown the different of the Discharge Coefficient (Cd) between Mivec 1.6L and VW 1200. The graph increase gradually and when the 0.30 L/D. The graph shown the higher of valve lift ratio, the higher of Discharge Coefficient. It causes the more valve lift opened, the more air flow in machine.

The boundary layer will affect the backpressure on the fluid flow in the engine. The higher the free-stream speed, the thinner the boundary layer. The free-stream speed is velocity of the fluid flow through the layer. In other words, the larger the Reynold number, the thinner the boundary layer. Reynold number for this experiment is a valve lift ratio. In this experiment valve lift ratio is increase 0.05 respectively. So, the increase valve lift ratio, the Reynold number also increase. The higher the valve lift ratio, the higher the backpressure on the fluid flow. The higher the Reynold number, more air can flow through the intake port. The Corrected flow (cfm) in the engine and Coefficient Discharge (Cd) increase due to boundary layer development.

The boundary layer approximation between high Reynold number and low Reynold number, and between the slip condition and no-slip condition. When the wall surface and fluid flow between the relative velocity is a zero, this phenomenon is call as no slip condition. In other words, when the decrease of the fluid flow is known the no slip condition. Euler equation can be used to enforce the no-slip condition at wall surface to correct some the major deficiencies of the boundary layer. When the adhesion was stronger than cohesion, the particles of surface wall are close each other, the fluid flow is known the slip condition. Hence, the higher the fluid flow is known the slip condition.

Flow separation will occur after through the intake port and intake valve. Amount of the flow separation depend on the valve lift. At the low valve lift ratio, the flow separation is small, sometimes no flow separation and no backpressure occur. When the higher valve lift ratio, the backpressure also increase. This is because, the flow separation start to separate from the intake valve. Hence, this experiment shown the Discharge Coefficient increase gradually due to valve lift ratio. For the both of the engine Mivec 1.6L and VW 1200 shown the Discharge coefficient increase gradually due to the valve lift ratio.

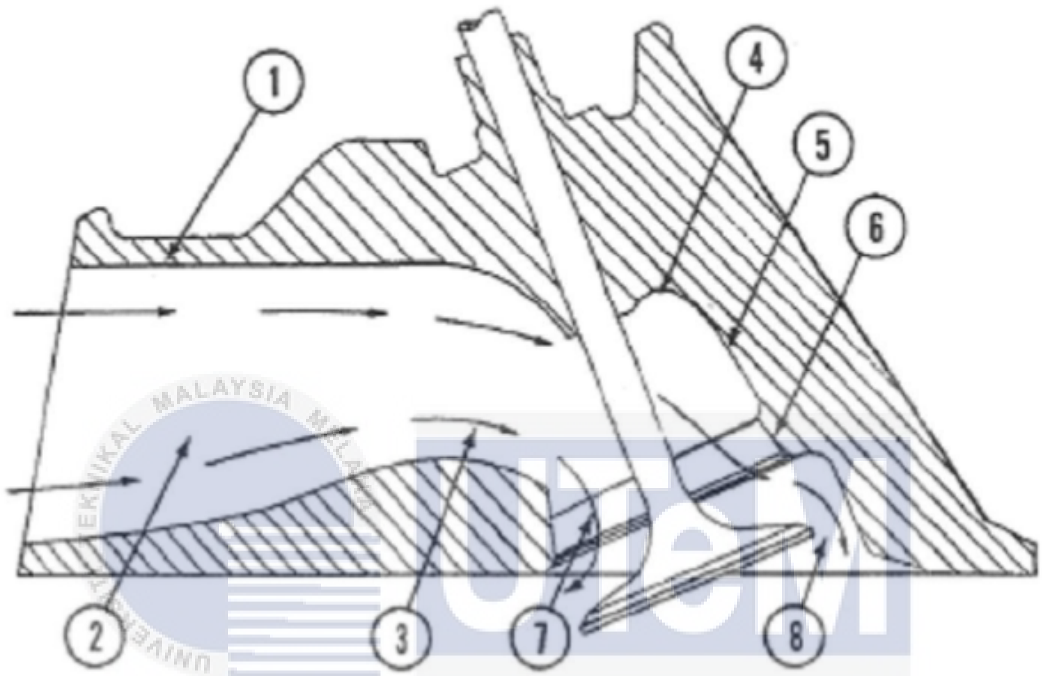

Figure 4.2: Loses in the Intake port

The air flow performance through intake and are subjected to losses due to the restriction when the air enters of leave the combustion chamber. It is impossible to eliminate all the losses. However, one way to overcome some losses is by smoothing the process of air flow entering or leaving by polishing the intake and exhaust ports. Referring to Figure 2.5, the losses from each part have been described clearly. To increase the air flow hose losses should be eliminated.

No.	Source of Flow Loss	% Of Flow Loss
1	Wall Friction	4
2	Contraction at Push Rod	2
3	Bend at Valve Guide	11
4	Expansion Behind Valve Guide	4
5	Expansion 25 Degrees	12
6	Expansion 30 Degrees	19
7	Bend to Exit Valve	17
8	Expansion Exiting Valve	31
	Total	**100**

Table 4.3: Source of flow loss

4.3 Swirl

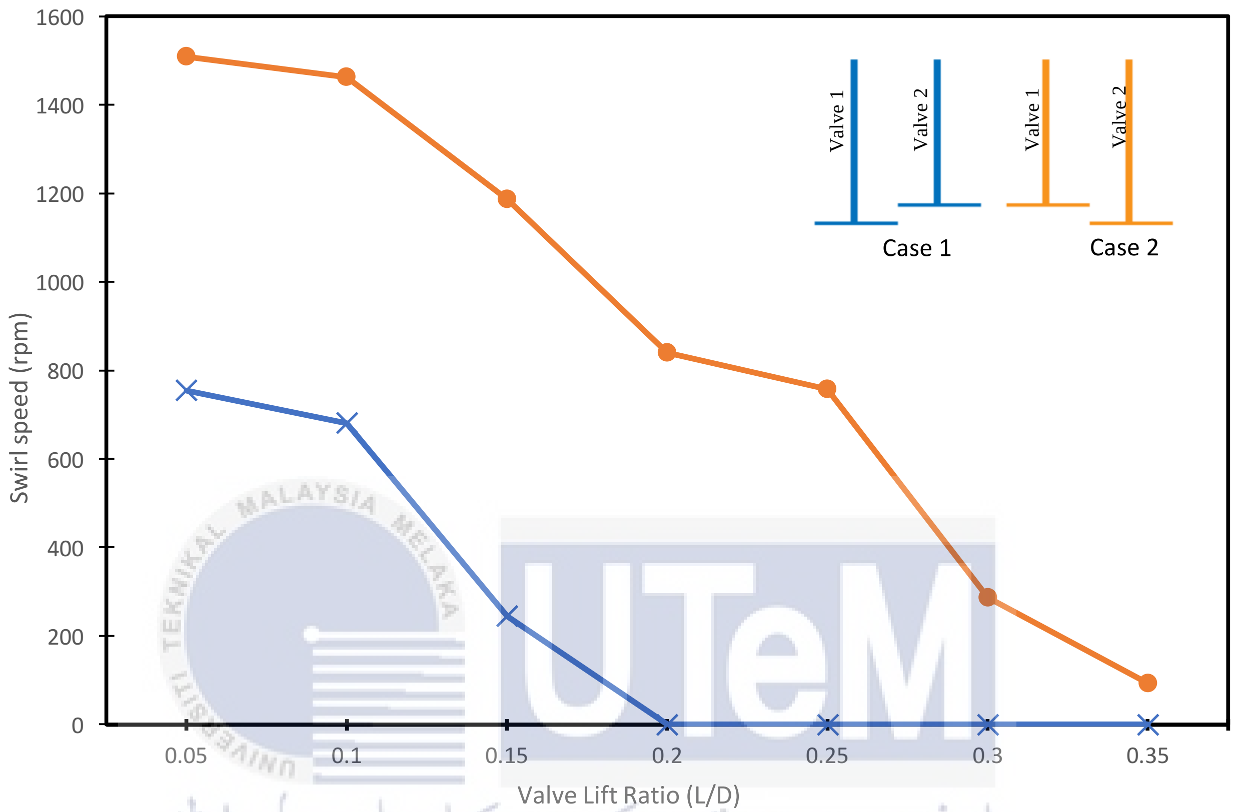

Figure 4.3: Valve lift ratio (L/D) versus Swirl speed (rpm)

Preminary test has been conducted with the intake valves being lifted symmetrically. No swirl observed during the measurement. To verify the zero swirl observation, the measurement was repeated with asymmetric valve lift. The finding shows the engine generally breaths with no swirl. As the swirl speed to plummet to zero before even reach the high valve lift values.

The experiment is conducted by positioning the valve 1 and valve 2 in symmetry. During the experiment, the swirl meter reading is zero. This means that swirl meter blade is not rotate even though there is an air flow from the engine. Therefore, the air flow might directly pass through the blade swirl meter and cause no swirl flow happen in the engine.

In a standard test for the two-intake valve and two-exhaust, the intake valves should be opened symmetric valve, but for this condition the reading of swirl is zero. So, the test was carried out with the asymmetric valve. Asymmetric valve means the position of two valves are separately lift. This experiment is separated by two cases where during the first case, valve 1 will be lifted 0.17 cm higher than valve 2. Meanwhile, in case 2, the valve 2 will be lifted 0.17 cm higher than valve 1.

Swirl experiment was conduct with case 1 and case 2. Case 1 was represented right asymmetric valve while case 2 was represent with left asymmetric valve. Case 1 shown the Swirl speed was increase twice between case 2. Swirl speed for case 2 constants zero when valve lift reach 0.2, 0.25, 0.3 and 0.35.

Based on the graph above, when the valve lift ratio (L/D) increases, the Swirl speed (rpm) will decrease. One of the factors influence from resulted graph is type of intake port in engine. There are two types of intake port which are Upright Straight Intake port and Horizontal Intake port. The upright straight intake port is normally used for diesel engine because it needs exceed amount of air flow for combustion in the chamber. This intake port also commonly produced higher tumble flow. Next, horizontal intake port mostly used for petrol engine where it will produce higher swirl flow depends on the vertical and horizontal angles of the port.

Based on the observation and measurement on Mivec 1.6L engine, the most suitable port for this engine is horizontal intake port. However, the vertical angle for this intake port is observed to be higher than the horizontal intake port. This causes Swirl speed of the swirl meter to decrease. At higher-end valve lift ratio 0.05 (L/D), the Swirl speed is higher because the open valve chamber is too small and pressure will increase. The graph towards the higher-end of the range of valve lift.

Figure 4.4: Swirl Test setup

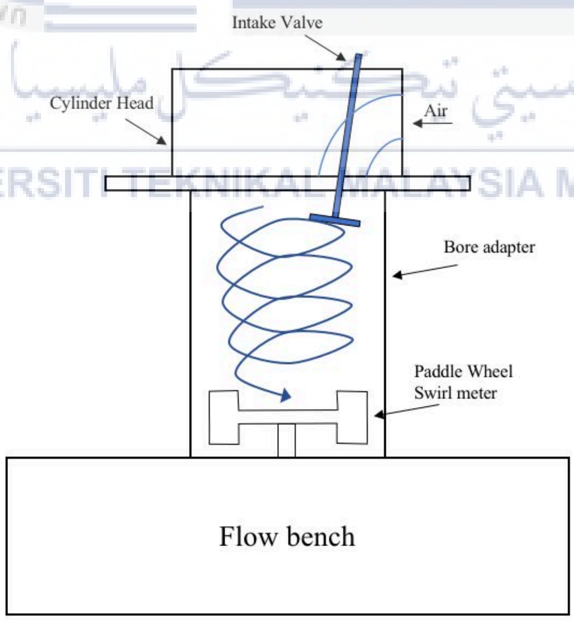

Figure 4.5: Schematic diagram of Swirl Test

4.4 Tumble

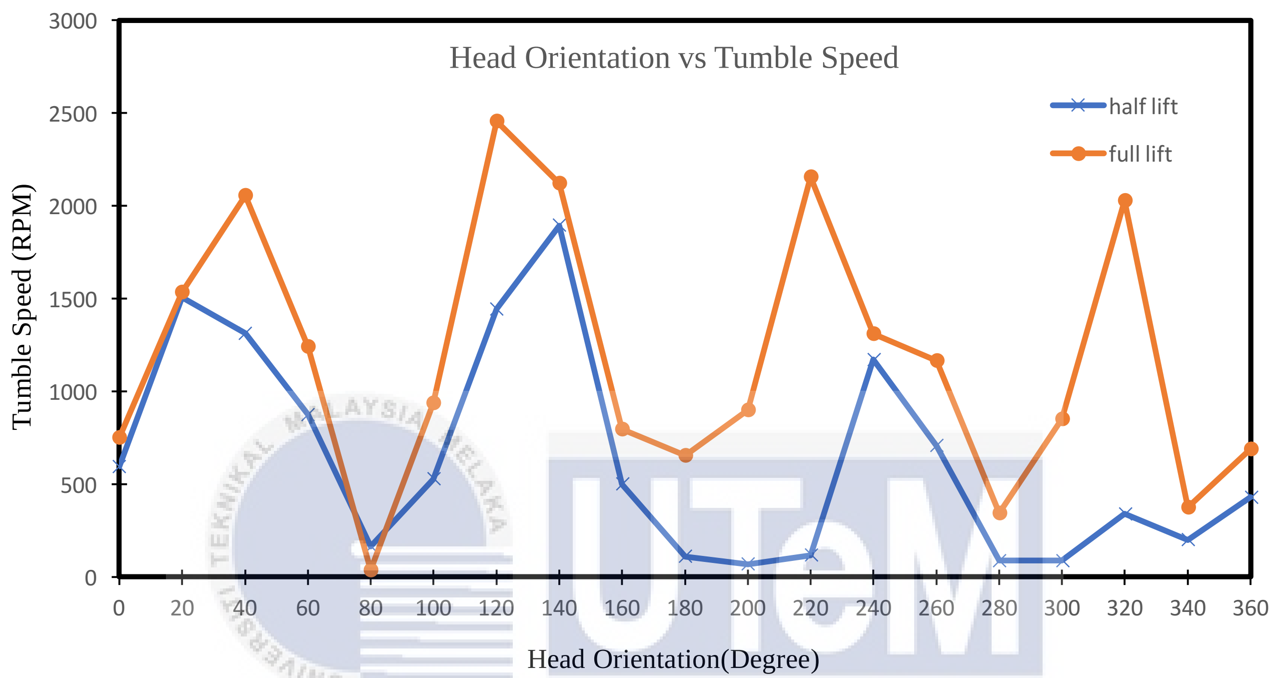

Figure 4.6: Tumble speed (rpm) versus Head Orientation (degree)

Experiment was conduct with the Mivec 1.6L engine on the flow bench as figure below. Experiment was tested on the second cylinder on the engine.

Based on the graph above, there are two experiment on the tumble flow. The blue color represents to half lift of valve while the red color represents for the full lift of valve. The test pressure used for half lift and full lift is 25”. The valve lift is based on Valve Lift Ratio (L/D) which are 0.05, 0.1, 0.15, 0.20,0.25, 0.30 and 0.35. For the half lift of valve is 0.20 (L/D) while the full lift is 0.35 (L/D). This experiment was conduct with 360-degree rotation of engine. It causes to determine the maximum of the flow (RPM) at the different angle in the engine block.

The graph shown the zig zag trend between half lift and full lift. And it shown the peak and trough not constant. For the half lift valve, the maximum tumble speed at the 100 degree to 150 degree. And for the minimum tumble speed at the 180 degree to 220 degree.

During the experiment, there are four peak that shown the increasing of tumble speed which are 40-degree, 130-degree, 220-degree and 320-degree. It shows that the increasing of tumble speed when the head orientation was tilted between intake port and flow bench. It makes the flow that is going through the valve rotates faster than the engine that is parallel to flow bench. The speed that is going through is depend on the valve that is pressed.

The intake port for Mivec 1.6L engine is horizontal intake port, but the vertical angle for intake port is higher than the horizontal angle. Therefore, the tumble flow is higher than swirl flow. The picture below shows the position of the angle that has higher tumble speed. The tumble flow rotates on the Tumble axis as show in figure below. The blade of swirl meter was rotate depend on the flow through in the cylinder.

Experiment was conduct with the Mivec 1.6L engine on the flow bench as figure below. Experiment was tested on the second cylinder on the engine as figure below.

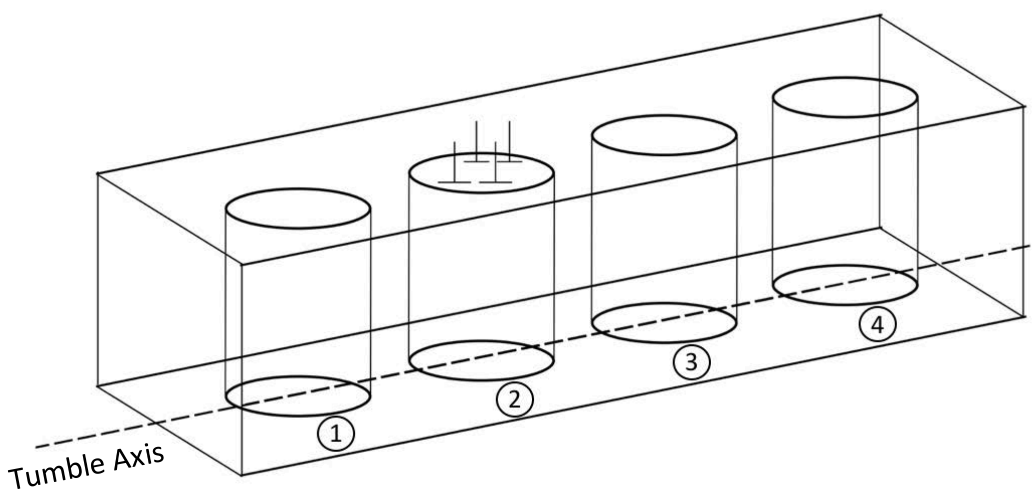

Figure 4.7: Number of cylinder on Mivec 1.6L

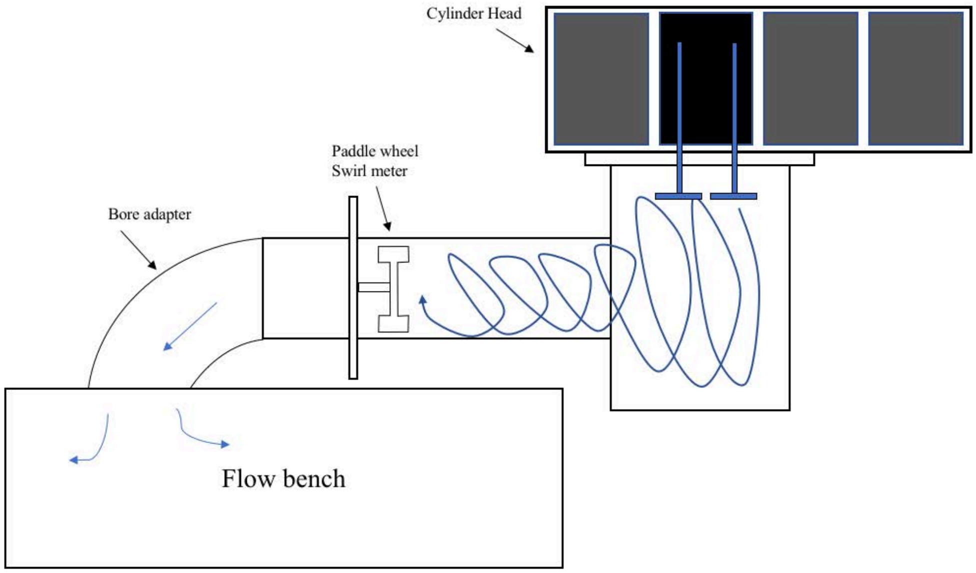

Figure 4.8: Schematic Diagram of Tumble Test

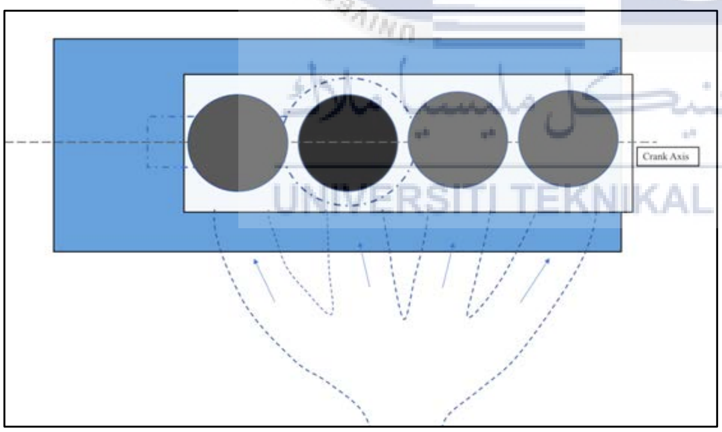

Figure 4.9: Schematic of head orientation at 0-degree

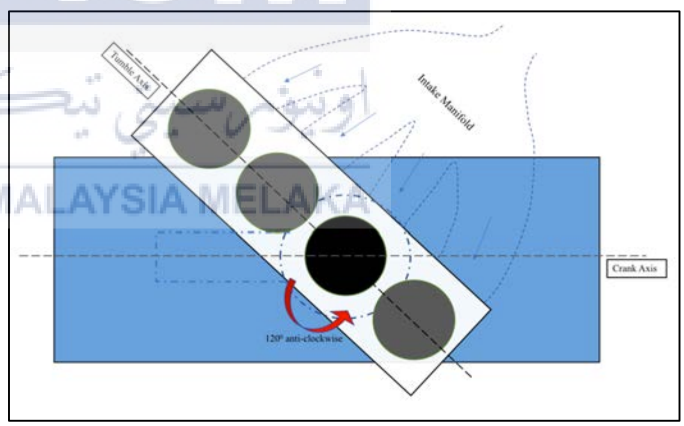

Figure 4.10: Schematic of head orientation at 120-degree

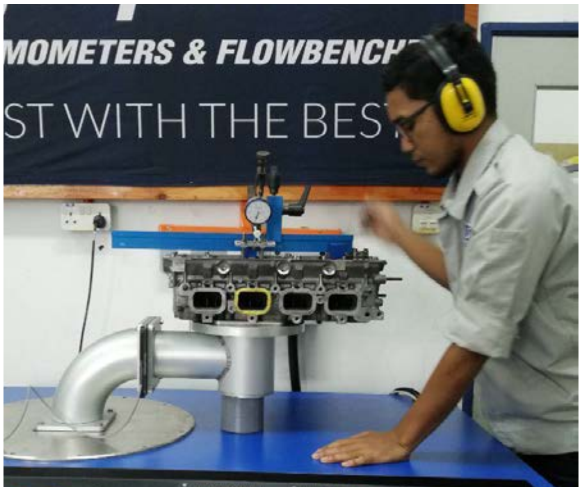

Figure 4.11: Head orientation at 0-degree

The figure 4.11 shows that the head orientation is on 0-degree position. On this position, the tumble speed is around 500-1000 rpm. Also on this position, the air flow that enter into the flow bench horizontal with flow bench adaptor.

Figure 4.12: Head orientation at 40-degree

The figure 4.12 shows that the head orientation is on 40-degree position. On this position, the tumble speed is around 1500-2300 rpm. The tumble speed increases at this angle compared to 0-degree.

Figure 4.13: Head orientation at 130-degree

The figure 4.13 shows that the head orientation is on 130-degree. According to the graph above, this position produces the maximum tumble speed that is around 1800-2500 rpm. The air flow that goes into the bore adaptor is faster than another head orientation.

Figure 4.12: Head orientation at 220-degree

The figure 4.12 shows the head orientation is on 220-degree. According to the graph above, the tumble speed is around 1000-2300 rpm.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

From the experiment, airflow was recorded (cfm) and the Discharge of Coefficient was calculated. The graph of the Cd and Valve Lift Ratio (L/D) was plotted. The graph shown the Cd increase gradually with the increase of valve lift ratio due to developing boundary layer and flow separation.

The swirl test done and the result shown the Swirl speed decrease with the Valve lift ratio (L/D). The test had done with the two situations, first is symmetric valve and second is asymmetric valve. The symmetric valve shown the zero reading in the swirl speed. No reading shown when the use symmetric valve. Experiment had done with the asymmetric valve with 2 case. The result shown the swirl speed decrease. It can be concluded the fluid motion respect no swirl present in the Mivec 1.6L engine.

The tumble test done with Tumble speed and Head orientation. The graph shown the zig zag trend and has a four peak through 360-degree on head orientation. The experiment was conducted with 2 condition which are half lift and full lift. The head engine was rotated from 0-degree to 360-degree. The graph shown the maximum tumble speed at 120-degree head orientation with both of valve lift.

5.2 Recommendation

In order to get a better and variety experimental results in next testing, it is recommended the next testing can be use the Computational Fluid Dynamic (CFD) method to determine the flow behavior of the intake port in engine. The CFD method can show the behavior of flow in engine to ensure the engine flow has swirl or tumble.

Besides, the recommendation for future work of this experiment is a study about flow pattern through the exhaust valve at low and high lift. It is because, some engine has a behavior for the exhaust port for the swirl and tumble flow.

Next, the recommendation for future work of this experiment is study about intake port of the engine. Some engine has a upright straight intake port, and some engine has a horizontal intake port. It will influence the behavior of the engine which are swirl and tumble flow.

Lastly, the recommendation for future work of this experiment is study about in-cylinder flow at all intake port and determine the flow at maximum speed of the swirl and tumble. For this experiment, the second intake port has been used. So, for the next experiment the recommendation used for all intake port.

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APPENDIX

Data for pressure drop

Valve Lift (L/D)	Air Flow (cfm)	Coefficient of Discharge (C_d)
0.05	21.4	0.155
0.10	41.4	0.300
0.15	56.9	0.412
0.20	85.8	0.622
0.25	93.2	0.675
0.30	93.2	0.675
0.35	93.2	0.675

Data for swirl

i. **Case 1**

Valve Lift ratio (L/D)		**Valve Lift (mm)**	**Average reading (RPM)**	**Air Flow (cfm)**
Left	**Right**			
0.00	0.05	1.7	755	9.6
0.05	0.10	3.4	681	34.1
0.10	0.15	5.1	245	64.5
0.15	0.20	6.8	0	93.1
0.20	0.25	8.5	0	95.2

ii. **Case 2**

Valve Lift ratio (L/D)		**Valve Lift (mm)**	**Average reading (RPM)**	**Air Flow (cfm)**
Left	**Right**			
0.05	0.00	1.7	1509	12.0
0.10	0.05	3.4	1463	37.4
0.15	0.10	5.1	1186	70.4
0.20	0.15	6.8	840	95.2
0.25	0.20	8.5	757	95.2
0.30	0.25	10.2	287	95.2
0.35	0.30	11.9	93	95.2

Data for Tumble flow

	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360
Average at half lift	569	1508	1313	875	164	528	1445	1895	500	110	70	118	1172	708	89	88	340	200	430
Average at full lift	753	1534	2057	1242	36	937	2455	2120	798	654	900	2155	1309	1165	345	852	2029	376	688
Flow	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1	94.1