THE CHARACTERISTICS OF THE IN-CYLINDER FLUID FLOW OF THE 660cc PETROL ENGINE

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A report submitted

in fulfillment of the requirements for the degree of

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DECLARATION

I declare that this project report entitled "The Characteristics of the In-Cylinder Fluid Flow of The 660cc Petrol Engine" is the result of my own work except as cited in the references

Signature :……………………………….

Author :……………………………….

Date :……………………………….

APPROVAL

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

Signature :.………..…………………...…………..

Supervisor's Name :………………………………………...

Date :………………………………………...

DEDICATION

"I hereby dedicate this final year report for my beloved father and mother"

ABSTRACT

Two major challenges for modern engine in the industry of automotive is continuous increase of fuel price and strict emission regulations. Numerous research and development on air flow during the intake stroke and air flow in the engine cylinder are done. This is because in-cylinder fluid flow has significant effect on the in-cylinder mixture preparation, combustion performance and engine response. This is all towards cleaner emissions and high fuel efficiency. Introduction of new engine technologies such as spark controlled compression ignition (SPCCI) that is use in Mazda Skyactiv-X engine also contribute to increasing of attention on in-cylinder charge motion. In-cylinder fluid flow in an engine are air flow going into the engine cylinder with a swirl or tumble motion of air. The fluid flow enhances fuel vaporization and fuel-air mixing process for combustion. Therefore, the aim of this project is to study in-cylinder fluid flow of 660cc, petrol engine under steady state condition. Parameters of in-cylinder fluid flow that going to be study are air flow rate into the cylinder that is then translated into coefficient of discharge, Cd, swirl speed and tumble speed during intake stroke using a Superflow® SF-1020-SB flow bench machine. The experiments were done on cylinder 2 of the engine at 25” H_2O test pressure. Cd and swirl speed were measured at various intake valve lift per diameter ratio, L/D. Tumble speed was measured at intermediate and maximum L/D at various cylinder head orientation, θ. Result from all the test done was recorded and discussed in the report. Cd increase gradually with L/D and the maximum Cd was 0.33. Swirl speed also increase with L/D but the trend is more random. Maximum swirl speed is 1770rpm at 0.35L/D. Maximum tumble speed obtained was 2250rpm at 0.35L/D. And the orientation that produce high tumble speed at both intermediate and maximum L/D is at 0˚.

ABSTRAK

Dua cabaran utama untuk enjin moden dalam industri automotif adalah kenaikan berterusan harga bahan api dan peraturan emisi yang ketat. Banyak penyelidikan dan pembangunan pada aliran udara semasa strok masukan dan aliran udara dalam silinder enjin dijalankan. Ini adalah kerana aliran cecair dalam silinder mempunyai kesan ketara ke atas penyediaan campuran dalam silinder, prestasi pembakaran dan tindak balas enjin. Ini semua ke arah emisi yang lebih bersih dan kecekapan bahan api yang tinggi. Pengenalan teknologi enjin baru seperti Spark Controlled Compression Ignition (SPCCI) *yang digunakan dalam enjin* Mazda Skyactiv-X *juga menyumbang kepada peningkatan perhatian pada gerakan cas silinder. Aliran cecair dalam silinder di dalam enjin adalah aliran udara masuk ke dalam silinder enjin dengan gerakan pusaran atau jatuh udara. Aliran cecair meningkatkan pengewapan bahan api dan proses pencampuran bahan api untuk pembakaran. Oleh itu, matlamat projek ini adalah untuk mengkaji aliran bendalir dalam silinder 660cc, enjin petrol di bawah keadaan keadaan mantap. Parameter aliran cecair dalam silinder yang akan dikaji ialah kadar aliran udara ke dalam silinder yang kemudiannya diterjemahkan ke dalam pekali pelepasan, Cd, kelajuan putaran dan kelajuan jatuh semasa stroke pengambilan menggunakan mesin bangku aliran* Superflow® SF-1020-SB . *Eksperimen dilakukan pada silinder 2 enjin pada tekanan ujian 25 "H2O. Kelajuan Cd dan pusaran diukur pada nisbah pengambilan injap pengambilan pelbagai, L / D. Kelajuan putaran diukur pada L / D pertengahan dan maksimum pada pelbagai orientasi kepala silinder, θ. Hasil dari semua ujian yang dilakukan telah direkodkan dan dibincangkan dalam laporan tersebut. Cd meningkat secara beransur-ansur dengan L / D dan maksimum Cd ialah 0.33. Kelajuan berputar juga meningkat dengan L / D tetapi trendnya lebih rawak. Kelajuan putaran maksimum ialah 1770rpm pada 0.35L / D. Kelajuan maksimum jatuh ialah 2250rpm pada 0.35L / D. Dan orientasi yang menghasilkan kelajuan jatuh tinggi pada kedua-dua pertengahan dan maksimum L / D adalah 0˚.*

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LIST OF SYMBOLS

SPCCI	-	Spark Controlled Compression Ignition
Cd	-	Coefficient of discharge
SI	-	Spark ignition
cc	-	Cubic centimeter
L	-	Liter
rpm	-	Revolution per minute
2V	-	Two valve
4V	-	Four valve
SOHC	-	Single Overhead Cam
Kg	-	Kilo gram
hp	-	Horse power
mm	-	Mili meters
Rs	-	Swirl ratio
Rt	-	Tumble ratio
ω_s	-	Swirl angular speed
ω_t	-	Tumble angular speed
cfm	-	Cubic feet per minute
L/D	-	Valve lift per diameter ratio
Δp	-	Pressure drop
θ	-	Cylinder head orientation
"	-	Inch

CHAPTER 1

INTRODUCTION

1.1 Introduction

Two major challenges for modern engine in the industry of automotive is continuous increase of fuel price and strict emission regulations (M. El-Adawy et al., 2017). Numerous research and development on air flow throughout the intake stroke and air flow in the engine cylinder are done. It has significant effect on the in-cylinder mixture preparation, combustion performance and engine response. This is all towards cleaner emissions and high fuel efficiency (M. El-Adawy et al., 2017, Mazda, 2017). Introduction of new engine technologies such as Spark Controlled Compression Ignition (SPCCI) that is used in Mazda Skyactiv-X engine (Mazda, 2017) have cause increasing of attention on in-cylinder charge motion. To overcome the challenges and produce an innovation, the dynamics of in-cylinder flow structures need to be understand thoroughly (A. Mohammad Ebrahim et al., 2013)

The reasons above act as a motivation of this study and the title of "The Characteristics of the In-Cylinder Fluid Flow of 660cc, Petrol Engines" is proposed. Characteristics of in-cylinder fluid flow are air flow in an engine cylinder that is swirl and tumble motion. Both of the two motions are rotational motion but on a different axis. Swirl is an air rotational flow in the cylinder on Z axis while tumble is a rotational motion on X and Y axis as shown in figure 1.1. Both swirl and tumble motions enhance the fuel vaporization and fuel-air mixing and results in better performance (C. Ramesh Kumar and G. Nagarajan, 2012, Saud A. Binjuwair B.Sc., M.Sc, 2013). Three parameters of in-cylinder fluid flow of a small displacement spark ignition (SI) engine that is going to be study are coefficient of discharge, Cd (-), swirl speed (rpm) and tumble speed (rpm).

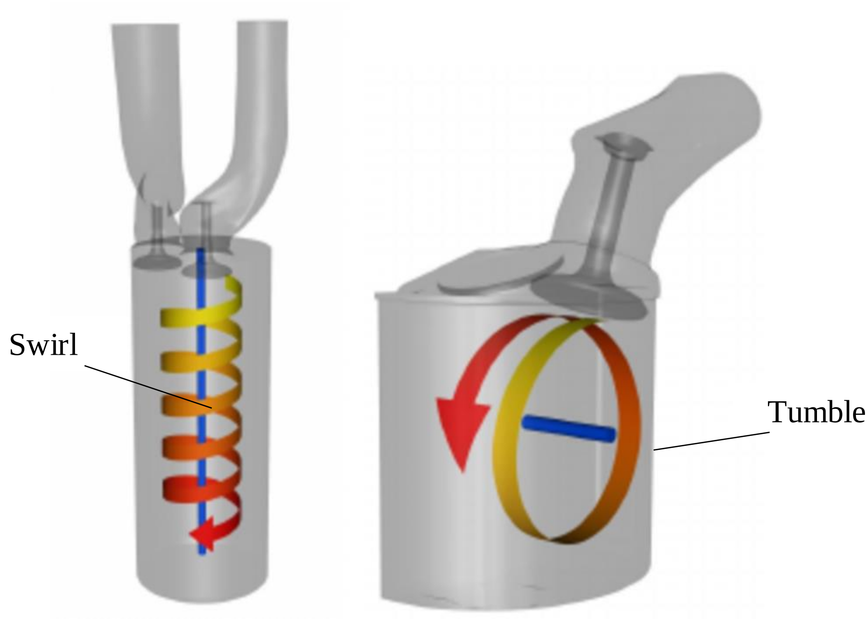

Figure 1.1. Swirl and tumble motion

Air is needed for the combustion process. Because of that, air needs to flow into the cylinder. Coefficient of discharge (Cd) can be used to quantify an engine breathing potential or the air flow (N. A. Mohamad Shafie et al., 2017). Cd can be described as the air flow rate efficiency (Abdul Rahim Ismail and Rosli Abu Bakar, 2008) of the intake port of the 660cc, 3-cylinder, petrol engine going to be tested. Since the value of Cd shows the air flow rate efficiency, it can be concluded that, the higher the value of Cd, the more efficient the air flow of the intake port.

After air flow into the engine cylinder, fuel is injected to be ignited with the air. Swirl and tumble are required to mix the air and fuel to produce a mixture of air and fuel. If the mixture is homogenously mixed, the combustion will be more efficient. Swirl and tumble can be computed in term of tumble ratio and swirl ratio (Ujwal D. Patil, 2013, C. Ramesh Kumar and G. Nagarajan, 2012). Swirl measurements is usually used on two valves (2V) and four valves (4V) diesel engines and two valves petrol engines, while normal tumble also referred as tumble is usually applied to a pent roof four valves petrol engines (M. El-Adawy, 2017)

In a single valve small displacement engine, in-cylinder fluid flow characteristics were expected to have a low value of swirl and tumble because there was only one valve for the intake port and exhaust port respectively. Hence, this study is to investigate the air flow, swirl and tumble motion of a small displacement engine and getting the exact value of the variables stated above using a flow bench machine.

This study was strictly to know the air flow performance of a 'Perodua Kancil' engine that is Daihatsu EF-CL SOHC I3. The cylinder head of the engine going to be tested using the flow bench machine or more specifically the Superflow® SF-1020-SB Flow bench machine and the port that was tested is the intake port. The flow in the intake port is measured as the coefficient of discharge(Cd). A wide variety of inlet port geometry patterns will affect the amount of air entered the port. Swirl and tumble motion of air can be examined with the additional equipment that is a swirl meter.

1.2 Problem Statement

For a car performance enthusiast, engine modification is a popular option but with a tight budget cylinder head modification is a brilliant option. In an internal combustion engine, the cylinder head has an important role in the engine performance. It closes in the top of the cylinder, forming the combustion chamber. This joint is sealed by a head gasket. In most engines, the head also provides space for the passages that feed air and fuel to the cylinder, and that allow the exhaust to escape.

Air flow in a cylinder head port can be used as an important factor to know the engine performance. Valve and port design determines the discharge coefficient (Cd) of the port and consequently the volumetric efficiency of the engine. Discharge coefficient describes the behavior of all real flows contract in an area as they pass through any restriction. Since the performance of the engine is dependent on the amount of air entering the combustion chamber, this study is aimed to determine the flow. The effect of boundary layer development on backpressure also needs to be studied because pressure drop may affect the Cd value.

Swirl motion is expected will occur in the cylinder because of the direct port design (Ujwal D. Patil, 2013, John B. Heywood, 1988). But how it was generated and what are the swirl speed of a 660cc engine is unknown. For the tumble motion, a single valve is not considered to have tumble motion of air in previous studies. Tumble motion is usually measured in a pent roof 4 valve engine (M. El-Adawy, 2017). Hence, this study concerns on measuring the swirl and tumble motion in a 660cc, 3 cylinders, 6 valve engine.

1.3 Objectives of the project

The objectives of this project are: -

1) To investigate the cylinder head coefficient of discharge at a range of inlet valve lift.
2) To investigate the swirl motion and tumble motion of air at a range of inlet valve lift.

1.4 Scopes of Project

The scopes of this project are: -

1) Studies the details of intake port cylinder head of a Perodua Kancil 660 cc, Daihatsu EF-CL SOHC I3 engine.
2) Operate the Superflow® SF-1020-SB Flowbench machine to determine the air flow through the intake port, determine the coefficient of discharge(Cd), swirl speed and tumble speed.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter explains the specs of each component and apparatus that was used in this project, based research and reference done in this project. The function and the application for the component will be explained in this chapter. The information was obtained from journals, books and browsing through the internet. Automotive industries nowadays have enlarged in impressive ways. The internal combustion engine first developed in the year 1876 until now, the engines have continued to develop as the knowledge of engine processes has increased, where new technologies have been invented and available as the demand for new cars and new engine arose. Analysis of the cylinder head of Daihatsu EF-CL SOHC13 engine will be done using the Superflow® SF-1020-SB Flow bench machine with a swirl meter. The high flow of air-fuel mixture that can enter the cylinder head will determine the performance of the engine. The performance can be defined by the terms coefficient of discharge, Cd, swirl and tumble.

2.2 Coefficient of discharge (Cd)

During the intake stroke, air is drawn into the cylinder through the intake manifold, intake port and intake valve. The air flow needs to be quantified to determine the performance of the cylinder head. One of the parameters for cylinder head performance is the coefficient of discharge (Cd). Port and valve design determines the discharge coefficient (Cd) of the port and consequently the volumetric efficiency of the engine. Discharge coefficient which is less than 1 describes the behavior of all real flows contract in an area as they pass through any restriction in the cylinder head (M. F. Samuri et al., 2015, Y. Cengel and J Cimbala, 2013). For example, Cd of venture meters are very high, it ranges from 0.95 to 0.99. And for flow with high Reynold number through an orifice meter, the Cd is 0.61 (Y. Cengel and J. Cimbala, 2013). This shows that the higher the Cd of an orifice the better the flow is.

The engines port flow coefficient of discharge for a particular flow can be defined as the ratio of actual discharge to ideal discharge. Mathematically, Cd can be translated as measured mass flow rate over the ideal mass flow rate or measured air flow over calibrated air flow as in equation 2.1 (C. Ramesh Kumar and G. Nagarajan, 2012). In term of the flow bench machine, Cd is Test Flow over Potential Orifice Flow as shown in equation 2.2 (SuperFlow Technologies Group, 2004).

In an engine surrounding, an ideal gas is considered an ideal discharge and the process to be free from friction and surface tension and other disturbance. Coefficients of discharge are used to monitor and determine the flow efficiency through various engine components and are quite useful in improving the performance of components tested (Abdul Rahim Ismail and Rosli Abu Bakar, 2008). From the previous study of Abdul Rahim Ismail et al

(2008), results shown that, increasing the increase of valve lift increase the coefficient of discharge.

In this study, the value of Cd of the cylinder head is expected to be dependent on the boundary layer in the intake port. Boundary layer is the layer of reduced velocity region in fluids flow. Boundary layer is next to the intake port roof, wall and floor (Harold Bettes, 2010).

$$\mathrm{Cd} = \frac{\text{Measured Air Flow}}{\text{Calibrated Air Flow}} \tag{2.1}$$

$$C_d = \frac{\text{Test Flow}}{\text{Potential Orifice Flow}} \tag{2.2}$$

2.3 In-cylinder Fluid Flow

Extensive knowledge of the in-cylinder fluid flow of an engine is important to optimize the air-fuel mixture preparation and the combustion process. The in-cylinder flow that occurs during the intake stroke can be categorized into two structure that is organized or unorganized structure. The unorganized structures are simply filling the cylinder with undefined flow moving. But the organized structures are the one that going to be studied. It has rotational flow structures that can be defined and it is generated by the inlet port design, inlet valves assembly and cylinder head and piston geometry. In addition, valve lift is considered to have an important role in the generation and development of in-cylinder flow motion (A-F M Mahrous et al., 2006). Two organized fluid flow is swirl and tumbles motion.