DEVELOPMENT OF CONSTANT VOLUME CHAMBER AND HIGH INJECTION PRESSURE SYSTEM FOR BIO-DIESEL COMBUSTION

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ABSTRACT

Compression period in a diesel engine is generally seen as initial characteristics before injection into combustion chamber. The piston moves freely in a rapid compression machine (RCM) has been designed to simulated combustion phenomena to observe the physical and chemical kinetics studies at high pressures and temperatures. The purpose of this study was to clarify the effect of the cylinder wall temperature on the heat release of air, particularly during compression. This method is done with a lighter piston launcher by nitrogen bomb and will stop at the stopper. Tests performed on a light weight compression piston rapid compression machine (RCM) with the aim to simulate the actual compression associated with the phenomenon of combustion. During this phenomenon, the influence of the ambient temperature of the cylinder wall has appeared useful to start biodiesel fuel blend and achieve the best pre-mixing. The test will three times to investigate the effects of different temperatures on the cylinder walls during compression stroke. The results show that high temperature in the cylinder wall will affect the current drop in temperature after the compression stroke. After analyse, new features rapid compression machine will produce to develop and analyses for ignition delay and image of sprays.

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LIST OF SYMBOLS AND ABBREVIATIONS

RCM	-	Rapid Compression Machine
ECU	-	Electronic Control Unit
NO_X	-	Nitrogen Oxide
PM	-	Particulate Matter
B5	-	5% Biodiesel
B50	-	50% Biodiesel
B100	-	100% Biodiesel

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CHAPTER 1

INTRODUCTION

In recent year, the new alternative fuel must be created for accommodate the user requirements. Biodiesel is one development of alternative fuel on the future. The increase in oil prices in the world market, coupled with a reduced supply of fossil fuels are not renewable, has caused concern for the need for renewable energy sources to replace fossil fuels. Many methods will use for research to develop the properties and performances about the biodiesel. In modern technology, the rapid compression machine is an instrument designed to simulate a single small engine of an internal combustion engine. For purpose of elementary study on diesel combustion, it is therefore advantageous to employ a single shot burning device compare to the ordinary engine. An alternative method is to be use which attains high pressure and temperature by compressing air using moving free piston.

In the present study, the new design rapid compression machine is to develop to enable to investigation on basic aspects of the diesel combustion including compression period, ignition and mixture formation. Basically, this machine can operate by bombing gas nitrogen consists of a long cylinder and a free moving piston light. Piston is bombing to compress air in the cylinder and finally attaining in constant volume chamber. The different temperature of wall cylinder was investigated on air heat release to look pattern graph of pressure against time.

1.1 Background of Study

Recently, the price of petrol and diesel has increased. Some solution is economic stability such as using biodiesel fuel. A system common rail high-pressure fuel accumulates in normal train and injects fuel into the engine cylinders at the time of controlled by the electronic control unit (ECU) engine. It also allows the injection of high pressure independent of engine speed. As a result, common rail system can reduce hazardous ingredients such as nitrogen oxides (NOx) and particulate matter (PM) in output and generating more engine power.

Combine a system common rail high pressure and rapid compression machine will be analysis about main part such as image spray, pressure, ignition delay and temperature for biodiesel combustion. High speed camera also will be used to display image spray for more details. The viscosity of biodiesel is higher than diesel and petrol. It needs high pressure for injection system. For this study, focus of variant temperature on linear to know effects during compression period.

1.2 Problem Statement

Ignition delay is an important part for combustion in diesel engine. Due to the short time of combustion, the mixture formation in this available short time always consists of fuel-rich and lean region which encourage the formation of nitrogen oxide (NOx) and particulate matter (PM). Trade-off between NOx and PM show opposite behaviour, the formation of nitrogen oxides is reduced at low temperature but increase the production of particulate matter and vice versa. The high kinematic viscosity in biodiesel properties must been reduced with high pressure injection.

In the case study to solve the problem, the variant temperature of cylinder wall using for analysis. A high injection pressure will be used to reduce emission. This will enable to inspection display on an image process spray biodiesel use a visualization optical technique.

1.3 Objective

The objective of this research is to investigate:

i. The effects of the variant temperature of wall cylinder during compression period.

ii. To construct a new constant volume chamber together with the high precision of single-shot common rail system

iii. To investigate the detail of heat release during combustion process

iv. To make recommendation the benefits of bio-diesel combustion based on the development of engines technologies, especially in controlling the combustion process for fuel consumption aspects

1.4 Scope of Study

i. The variant wall cylinder temperature varies 40°C, 50°C, 60°C, 70°C and 80°C.

ii. The temperature of combustion chamber is 40°C.

iii. The position of piston is 150 mm at left linear.

CHAPTER 2

LITERATURE REVIEW

Overview

In this chapter, all the literature studies will be discussed and shown. Start on the history, definition, descriptions and impact of rapid compression machine. Previously, that a lot of research have been conducted in the area of rapid compression machine. Improvements carried out each time the experiment was complete.

2.1 Internal Combustion Engine

The internal combustion engine is heat engine combustion occurs inside the engine rather than in a separate furnace. It also can to be interpreted that convert chemical energy in a fuel to mechanical energy. This thermal energy raises the temperature and pressure of the gases within the engine. High pressure gas then expands against mechanical linkages of the engine to a rotating crankshaft to produce an output of the engines. Heat expands to produce a gas high pressure and high temperature a produced by piston or turns a gas turbine. Others applications include stationary engines to drive generators or pumps, and portable engines for things such as a chain saw and other machine static. Most an internal combustion engines are reciprocating engines have pistons that reciprocate back and forth in cylinders internally within the engine. The others of internal combustion engine also exist in much fewer numbers, one important one being the rotary engine.

By 1892, Rudolf Diesel (1858-1913) had perfected his compression ignition engine into basically the same diesel engine known today. This was after years of development work, which included the use solid fuel in his early experiment engine. Early compression ignition engine were noisy, large, slow, and single-cylinder engine. They were, however, generally more efficient than work spark ignition engines. It wasn't until the 1920s that multi-cylinder compression ignition engines were made small enough to be used with automobiles and trucks [1].

2.2 Formation Mixture

The air and fuel mixture formation (preparation) represents an important role of the engine working cycle which impacts the mixture behaviour with controlled ignition and the resulting combustion process. In principle, there are two concepts of the mixture preparation such as internal and external. Elongation ignition delay caused by low swirl motion. Both high-pressure injection and low swirl motion lengthen spray tip penetration and promote mixture formation at spray tip region near the chamber wall. Mixture formation during ignition delay period and large amount of combustible mixture is formed by high-pressure injection [2]. The spray of penetration weakened caused by high ambient density. Mixture formation in the burning process and ignition delay period will be influences of the high ambient density due to increasing boost pressure. Method of optical photograph like schlieren can capture spray evaporation, spray interference and mixture formation clearly with real images. The difference density will effects on image sprays and ignition delay [3].

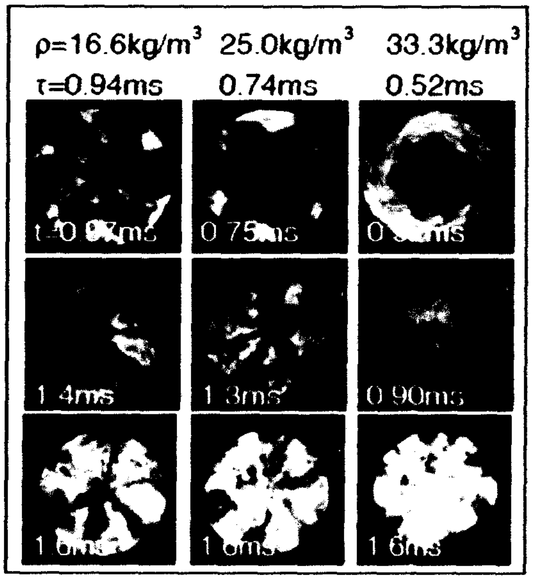

Figure 2.1: Flame development and mixture formation [3].

2.3 Biodiesel

Biodiesel refers methyl esters derived from vegetable oils by the process of transesterification. Biodiesel may be used in existing diesel engines without necessitating engine modifications. Biodiesel combustion process does not result in a shortening of engine life. It also can be used as an alternative fuel in compression ignition engines. NOx emissions were reduced at low load with negligible effect on soot at high load soot emissions. It is clearly that the biodiesel fuels would appear to present a beneficial means of manipulating the traditional NOx/smoke trade-off [4]. In conclusion, the pure biodiesel or B100 contains high kinematic viscosity more than B5 and B50.

Table 2.1 : Cetane number of each of the fuels and their blends and kinematic viscosity of biodiesel and blends at 40°C

Cetane Number			
Fuel	Rape	Soy	Waste Oil
5%	47.6	47.4	47.4
50%	50.6	51.4	51.2
100%	53.9	59	63.2
Diesel	54		
Kinematic Viscosity (mm^2/s)			
5%	2.482	2.461	3.444
50%	3.189	3.308	4.459
100%	4.546	4.63	5.89
Diesel	2.453		

2.4 Homogeneous Charge Compression Ignition

Homogeneous Charge Compression Ignition (HCCI) engines have normally low NOx and particulate emissions and high fuel efficiencies. HCCI the oxidation chemistry determines the auto-ignition timing, the heat release rate, the reaction intermediates, and the ultimate products of combustion. The reduced kinetics model can be used to predict the HCCI pre-ignition behaviour including temperature, pressure, ignition delay and heat release [5]. The balance between combustion pressure and hydraulic load will define the compression ratio of the opposite combustion cylinder. Compression ratio low will be caused decrease on average temperature and in cylinder pressure. This is called delay in the start of main combustion. The reduction of compression pressure and temperature lowers the peak of the heat release rate and lengthens the main combustion period. Slow combustion will result in a knock on compression. Heat release increased while O_2 concentration was lowered. This happens is that fuel evaporation and mixing with air was promoted furthermore as ignition timing delayed. Other reason is that the chemical reaction rate was strongly influenced by O_2 excess ratio rather than by O_2 concentration [6].

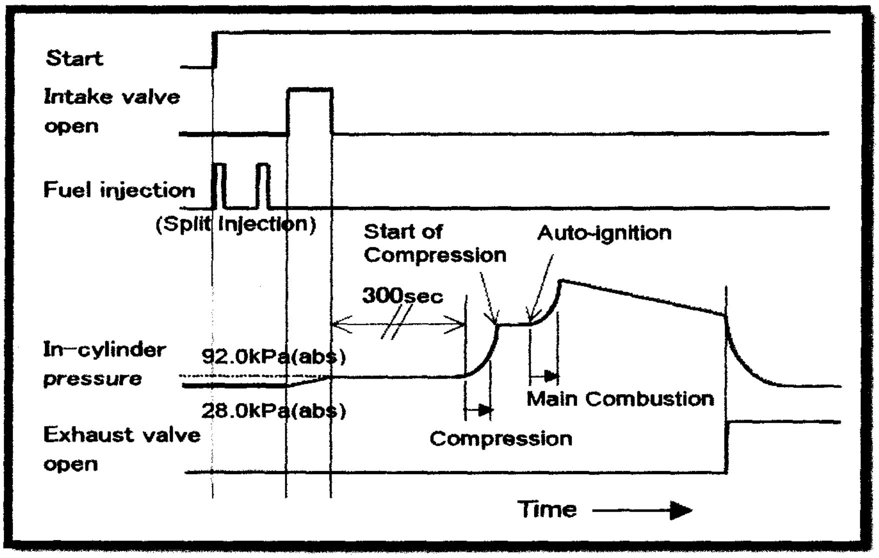

Figure 2.2: Produced of RCM Test [6]

2.5 Diesel Engine

Diesel engine needs high compression ratios to generate high temperatures required for auto-ignition. Figure 2.3 shows main parts of diesel fuel ignition. Air is drawn into the cylinder in the intake stroke and then compressed during the Compression Stroke. At near maximum compression, finely atomized diesel fuel is sprayed into the hot air, initiating auto-ignition of the mixture. During the subsequent power stroke, the expanding hot mixture does work on the piston, and then the burnt gases are purged during the exhaust stroke. The outward linear motion of the piston is ordinarily harnessed by a crankshaft to produce circular motion. Valves control the intake of air-fuel mixture & allow exhaust gasses to exit at the appropriate times [7]. In this research, focus on study diesel engines that use common rail fuel injection system.

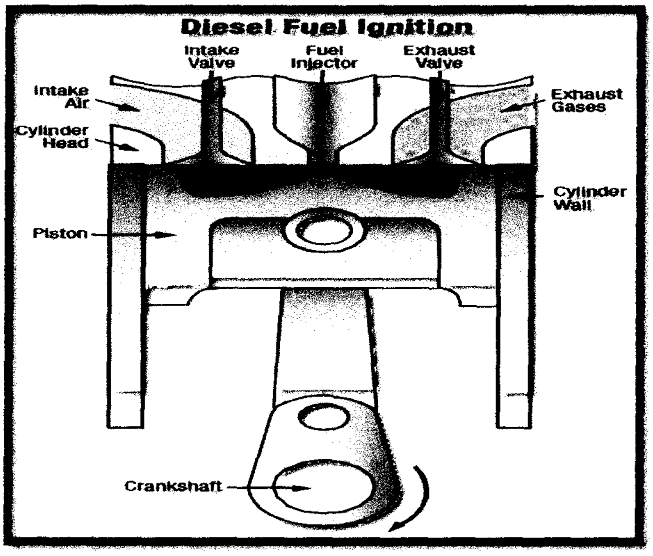

Figure 2.3: Basic diesel fuel ignition system [7]

2.6 Fuel Injectors

Fuel injection is one important component for injection of fuel into the intake air chamber especially diesel engine. Fuel injectors are nozzles that inject a fuel spray into the intake air. Many types of injection such as mechanically and electronically fuel injectors. High injection pressure over 100MPa could reduce particulate matters (PM) by it has high momentum resulting in better atomization, evaporation and mixing [8]. Injector pressure will control all each fuel amount inject in time duration of injections. Figure 2.4 shows diagram of electronic unit injector.

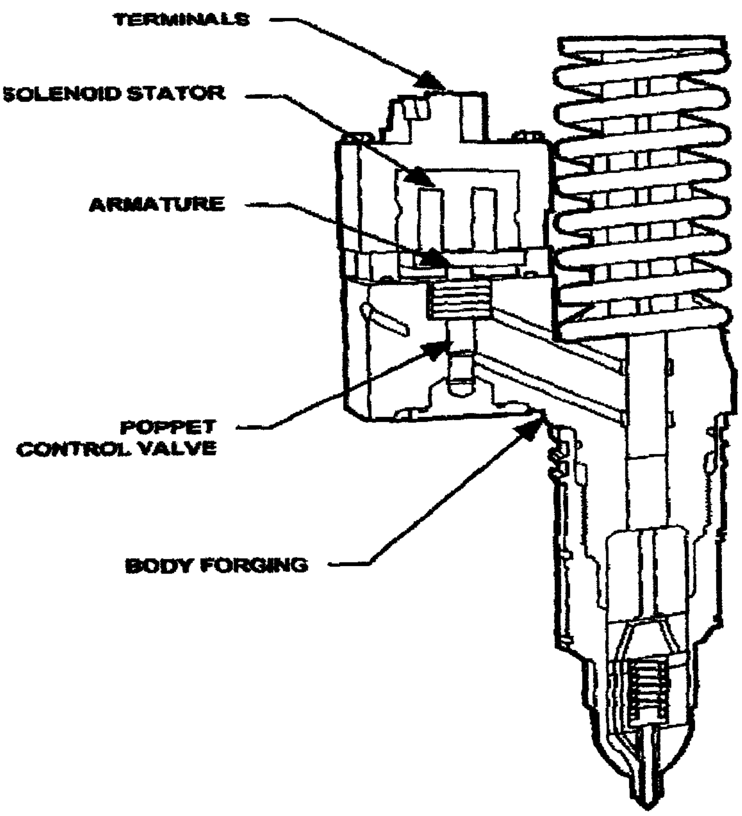

Figure 2.4: Section View of Electronic Unit Injector [9]

2.7 Rapid Compression Machine (RCM)

A rapid compression machine (RCM) has been designed for the purpose of chemical kinetics studies at elevated pressures and temperatures. This machine can run only for one cycle consisting of intake, compression, expansion and exhaust stroke, and it facilitates to investigate parametrically the effects of temperature, pressure, density, and composition of atmosphere on combustion. The machine is pneumatically driven and hydraulically actuated and stopped. In RCM chamber, the gases are compressed to high pressure and high temperature in a few milliseconds and reaction as a constant volume and mass chamber. The piston is driven pneumatically to travel at very high velocities for avoiding significant heat loss and reactions from happening before reaching its end position. After compression, the initial pressure, temperature and compression ratio can be varied to control the pressure and temperature.

Advantage of RCM over shock tubes lies in its capability to provide longer time duration for experiment. Experimental duration in shock tube is limited to less than 5 m/s due to interference from reflected waves. In RCM, experimental duration of an order of magnitude larger than shock tube can be obtained, as there is no interference problem and experimental duration is limited only by heat loss to the cold wall. [10]

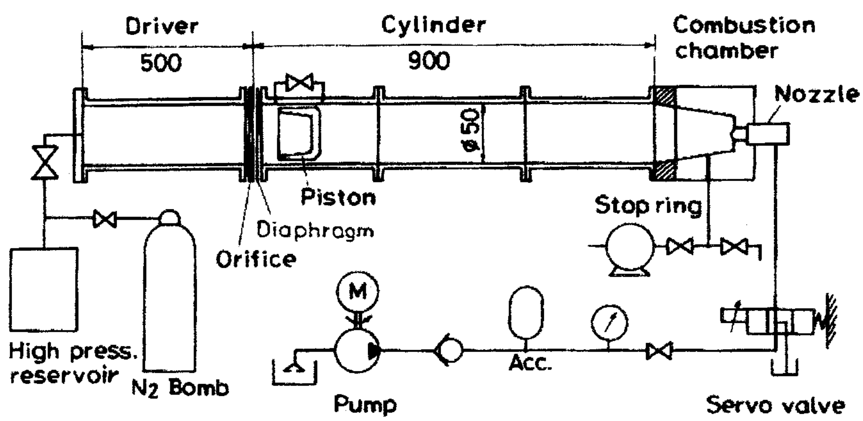

Figure 2.5: Experiment set-up rapid compression machine and injection system [11]

2.8 Cylinder Linear

Cylinder Liner is a main part in rapid compression machine. This is the part where the full combustion process is take place. The cylinder liner contains driver, piston, diaphragm, stopper, orifice and swirl. Diaphragm, driver, and piston is primary part of linear Driver is the part that will allow nitrogen gas,N_2 and push the piston to compress the air inside the liner and into the combustion chamber. The piston inside the driver is driven pneumatically using concept bombing by nitrogen gas. For avoid wastage, the N_2 gas is not supplied directly to the piston directly. This is because only a small amount of gas is needed for a single acting process. So, the driver will store a small amount of N_2 gas to be used for the single acting process. The compression process is a very fast process, about 20 ms. In ensure the speed, there must be no leakage in supplying N_2 gas to the driver and piston. All parts in cylinder and chamber must be tightened join and install gasket to avoid leaking gas during compression period [12].

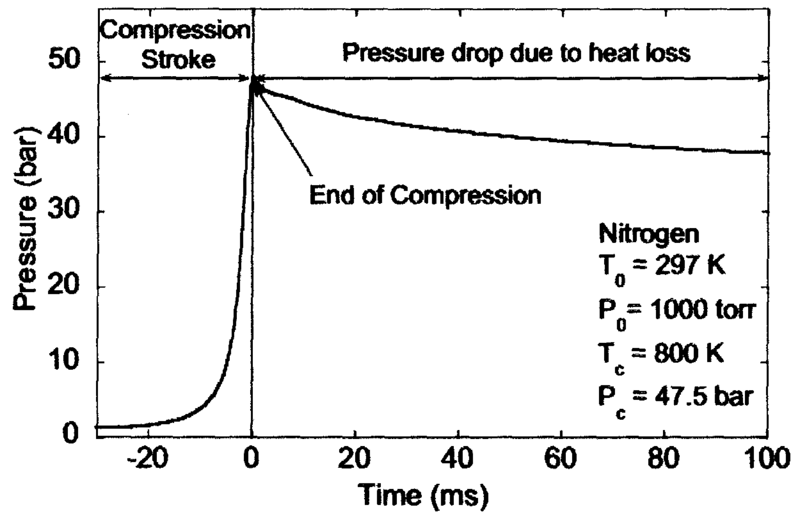

Figure 2.6 : Typical pressure trace for compression of inert gas in an RCM.

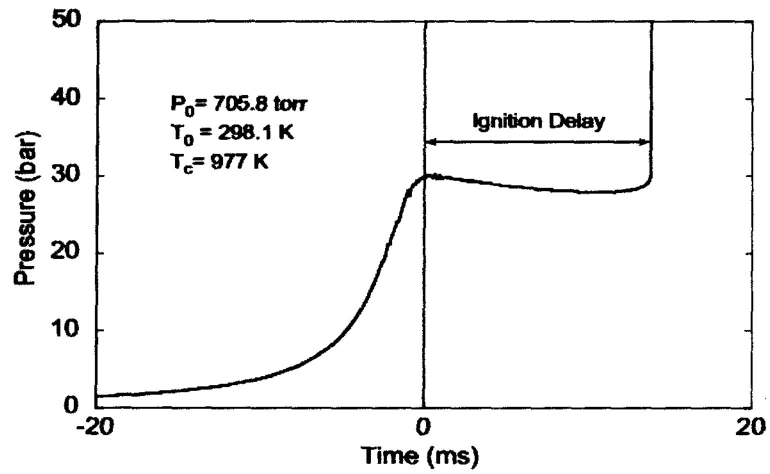

Figure 2.7: Typical Pressure trace during ignition of a reactive mixture in an RCM.

2.9 Ignition Delay

The ignition delay in a diesel engine is generally seen as consisting of two different consecutive although overlapping phase such as the physical and the chemical ignition delay. As is commonly accepted, the physical ignition delay corresponds to the mixture formation, and the chemical delay to the time necessary to get an exponential increase in the chemical reaction rate. The ignition delay will be shortening when value of density is high [13].

The ignition delay is the period during which chemical reactions remain very slow. There are two processes in ignition delay like physical and chemical delay. After the end of this period the combustion spreads very rapidly during the premixed combustion. As the chemical delay reaction rate rises exponentially with temperature and radical concentration, a considerable amount of fuel burns almost instantaneously, possibly resulting in diesel knock. The zones in which this combustion takes place produce a lot of NOx, due to the high temperatures that are reached and the availability of oxygen [14].

2.10 Spray Characteristics

The injection process is analysed from this point of view, mainly using as basis the structure of the fuel spray in the combustion chamber, making this study of high importance for optimizing the injection process, and therefore reducing the pollutant emissions and improving the engines performance. There are many studies on the effects of spray formation that affects the ignition process in diesel engine. Ishiyama et al has reported on the concepts of evaporation of spray droplets and atomization of spray for a better fuel-air mixture and gradually leading to a better combustion process [15].

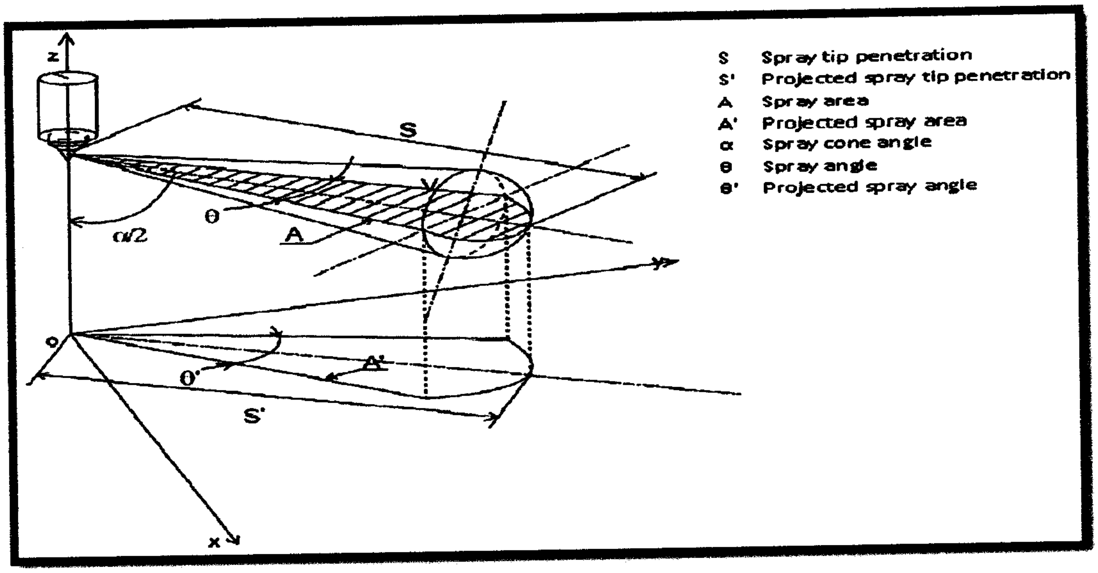

Figure 2.8: Investigation of (a) spray tip penetration, (b) spray cone angle, (c) spray area [15].

2.11 Spray Formation

Spray formation represents a very important aspect in CI engines, mainly diesel engine systems, as its shape and composition strongly affects the ignition and flame propagation processes. Spray formation directly impacts combustion quality through air utilization. Thus it optimizes injection process and therefore reduces pollutant emissions and improving engine performances. Figure 2.6 shows the characteristics of a spray formation

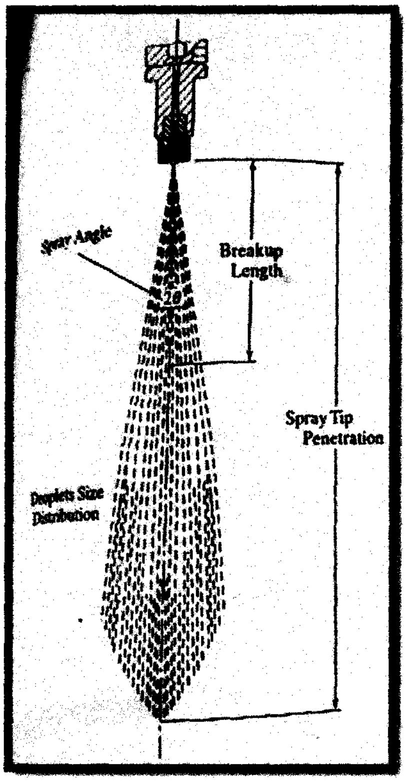

Figure 2.9: Characteristics of a Spray Formation [16]

One of the most important parameter in spray formation is the penetration of the liquid length through the combustion chamber [16]. For example, , a larger spray cone angle may place the fuel on top of the piston, and outside the combustion chamber in open chamber DI diesel engines. This would then lead to incomplete combustion forming excessive smoke due to depriving the fuel of access to air available in the chamber.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology chapter will discuss the methods that were used to prepare specimens and tests carried out on specimens based on the study. All procedures for this study will be discussed in detail in this chapter. This chapter will also provide detailed information about the equipment that will be used to perform analysis on the specimen. Information about the materials used will be discussed here to better understand the nature of the material.

3.2 Flow Chart

Figure 3.1 shows the flow chart diagram for the methodology for this research. This flow chart shows the flow of this project for the entire experiment.

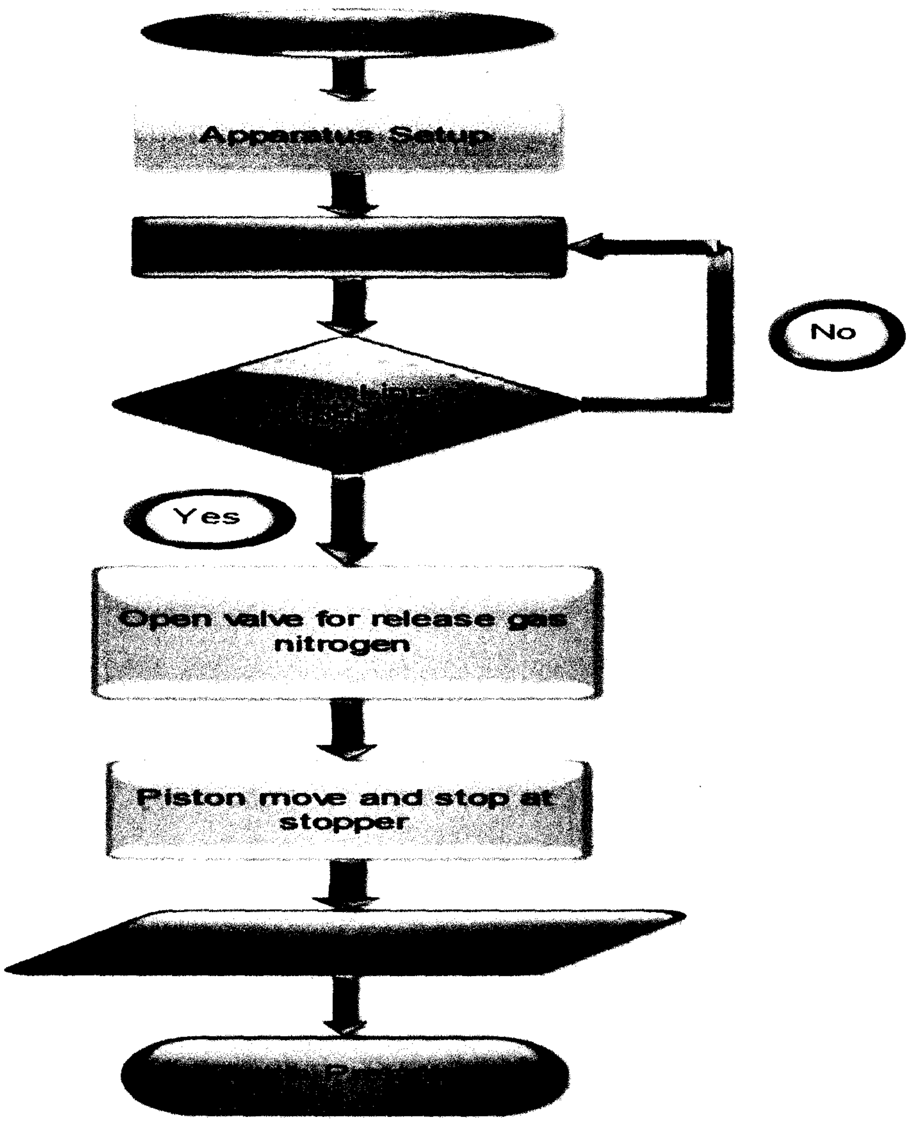

Figure 3.1: Methodology flow chart

3.3 Materials and Equipment's

Before to start the experiment, we must to know about what need to bring and have in experiment. The firstly, prepare the required materials and equipment need which are piston, heat controller, linear, chamber, change amplifier, nitrogen gas and diaphragms. After that, ensure all equipment was provided.

3.4 Heat Controller

Heat controller is most important during experimental because the parameter depend on temperature of linear. There two heater will use for heating at linear and chamber. At linear, the temperature will sets 40°C, 50°C, 60°C, 70°C and 80°C. While a chamber the temperature will set constant of 40°C. Heater of chamber use two rods for support heating process while heater of linear use two couple stainless steel for support heating process. A probe will used as sensor to detect temperature running on linear and chamber for certainty.

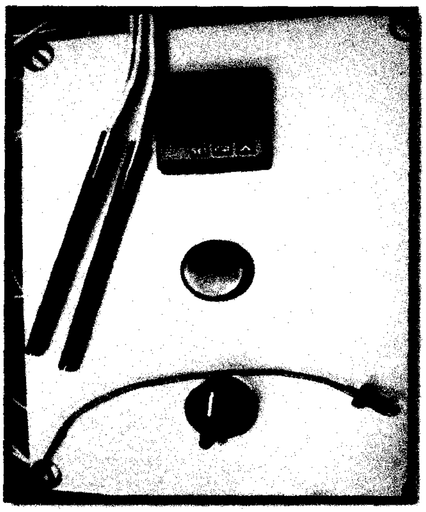

Figure 3.2: Complete Heat Controller

3.5 Linear

The cylinder is one shape need to strength because there is inside high pressure during high compression. The size of linear especially for length of 960 mm, thickness as 20 mm and diameter inside as 50 mm. The material of linear is stainless steel for good material during heating and compression process. A piston will been installed into linear for air compression after the temperature reaches the desired level. The weight of piston is 110 grams. The character of piston is light for easily air compression to get high pressure. A moving piston will be stop at stopper before evaluated for the time and pressure.

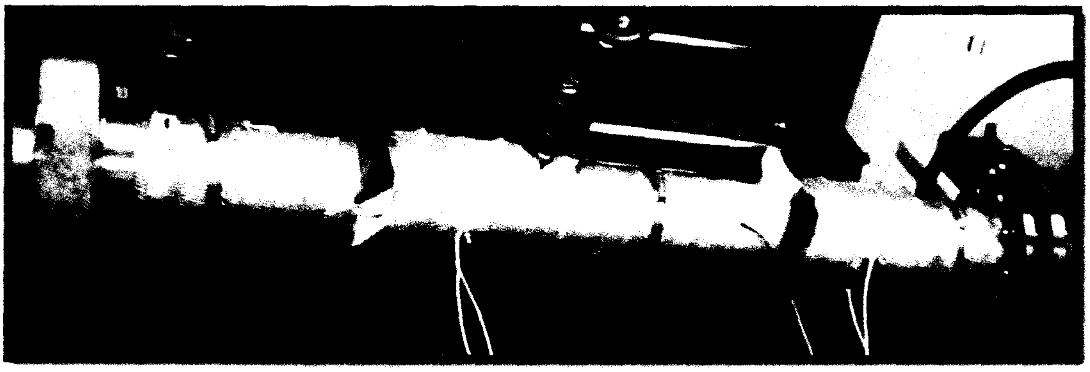

Figure 3.3: Linear

3.6 Combustion Chamber

The material of chamber is stainless steel. There many are connection linked to the chamber such as sensor, injector, rod heater, probe, cover, swirl and stopper. A length chamber is 60 mm before installed a holder injector and cover. After that, the chamber length is limit to 20 mm. In rapid compression machine chamber, the gases are compressed to high pressure and high temperature in a few milliseconds and reaction as a constant volume and mass chamber. The piston is driven pneumatically to travel at very high velocities for avoiding significant heat loss and reactions from happening before reaching its end position.

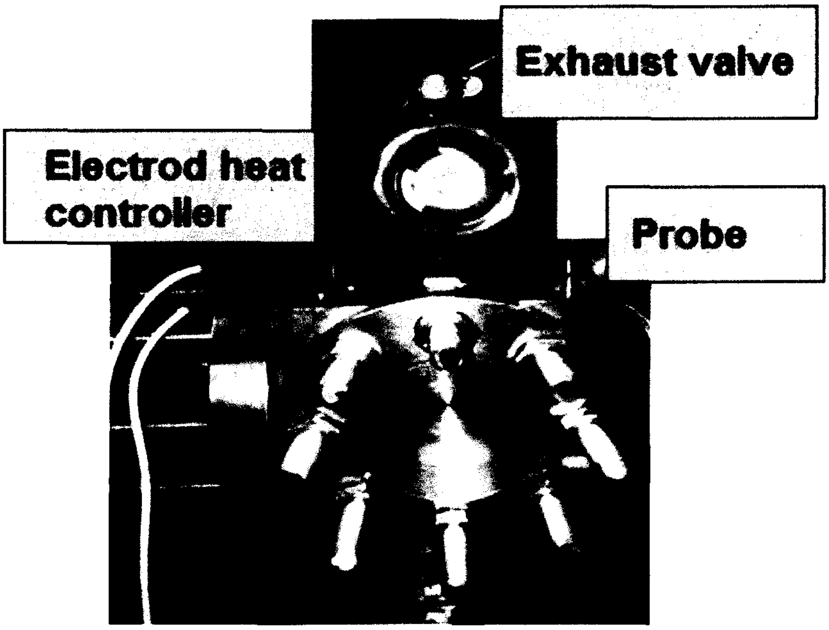

Figure 3.4: Combustion Chamber

3.7 Gas Nitrogen

Storage and high pressure tank gas nitrogen must be fastened for avoid unwanted matter. After complete install linear and chamber, the valves must be closed to avoid leaking during release gas nitrogen. Set pressure 15 bar on high pressure tank. Open a valve to slowly for avoid diaphragms early leak. If the diaphragms early leak, a piston will move and data is not accurate. Open valve until pressure drops 13 bar for full into driver before release. After that, setting 17 bar on high pressure tank. Open full valve push piston.

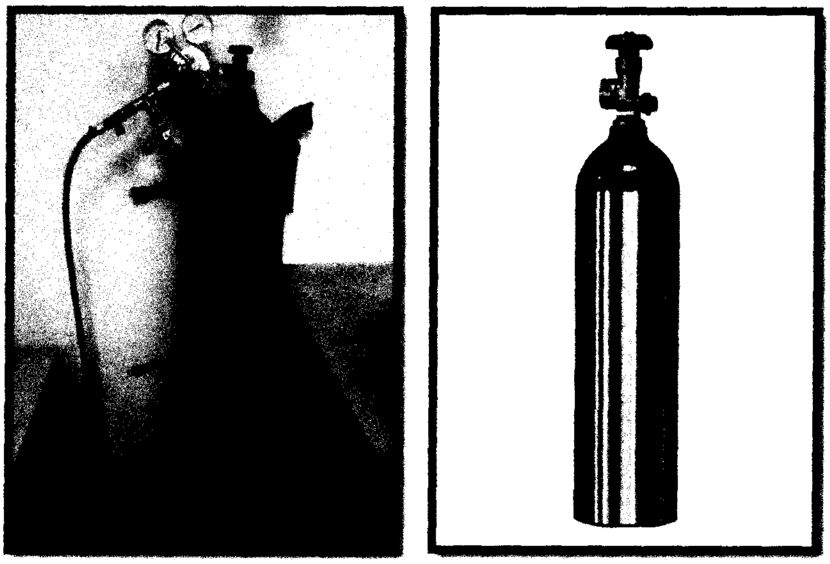

Figure 3.5: Storage and high pressure tank nitrogen gas

3.8 Piston

Free piston is run on the linear during compression period. A light piston is pneumatically shot and gets hammered in a stopper at the compression end. It will be used for compression process. The character light is also support for reduce heat release during compress. The weight is about 110 grams. Table 3.1 below is shown more details about specification piston.

Table 3.1: Specific of Piston

Material	Aluminium
Character	Light
Weight	110 grams

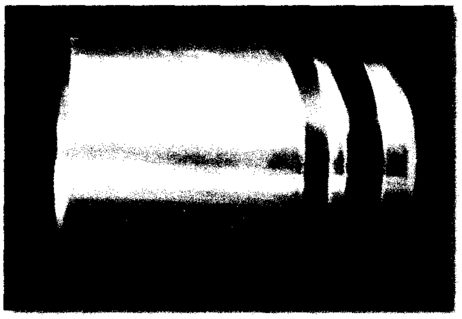

Figure 3.6: Piston

3.9 Measurement Equipment's

The measurement tools such as sensor will been used for detect pressure during compression period. The compression will be produced more than 40 bar.

3.9.1 Pressure Sensor and Change Amplifier

Piezoelectric sensing is of increasing interest for high-temperature applications in aerospace, automotive, power plants and material processing due to its low cost, compact sensor size and simple signal conditioning, in comparison with other high-temperature sensing.

Table 3.2: Specification Change Amplifier

Type of transducer	Kistler 1510A
Type of sensor	K6503
Form Factor	Handheld
Instrument Type	Charge Meter
Modifier	Piezoelectric Sensor

Figure 3.7: Pressure sensor

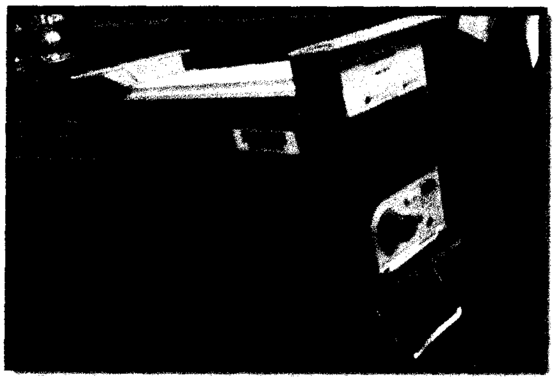

Figure 3.8: Kistler 1510A

3.9.2 PicoScope 3000 Series

PicoScope 3000 Series PC Oscilloscopes are designed to measure voltages in the range -20 V to +20 V. Inputs are protected to ±100 V (±30 V for external trigger). PicoScope 3000 Series PC Oscilloscopes connect direct to the ground of a computer through the interconnecting cable provided to minimise interference. Transducer will be connected to Pico for transfer data. Pico will be connected direct to computer for display all data.

Figure 3.9: PicoScope 3000 Series

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