THE CHARACTERIZATION OF FUEL INJECTOR SYSTEM FOR AUTOMOTIVE TECHNOLOGY

PUTERI AMIRAH BINTI JAMAL ZABIDI

A report submitted

in fulfilment of the requirement for the degree of

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DECLARATION

I declare that this project report entitled 'The Characterization of Fuel Injector System for Automotive Technology' is the result of my own work except as cited in the references.

Signature :.....

Name :.....

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 (with Honours).

Signature :.....

Name :.....

Date :.....

DEDICATION

This report is dedicated to my beloved mother,

Wan Pauziah binti Wan Ibrahim.

ABSTRACT

These researches are to investigate the design component on diesel injector, identify the fuel preparation system and evaluate the injector fuel spray pattern. Nowadays, diesel is no longer used for heavy vehicles such as buses and trucks. In fact, the diesel has been widely used for passenger vehicles as it has better fuel efficiency and can pull heavy loads easily compared to petrol engine. Biodiesel is renewable fuel that can be used instead of diesel fuel and made from palm oil, recycled cooking oil, soy bean, vegetables oil and animal fats. It is an additive to standard diesel fuel that can be used with little or no modification. Biodiesel is environmental friendly as it does not have sulphur content and high biodegradability. The common rail injection system test rig has been designed to test with biodiesel as it has better combustion efficiency. Furthermore, one of the parts in the common rail injection system which are the fuel injector has been studied thoroughly. The experiment on three fuel injector have been conducted in order to know the functionality and to obtain a spray pattern. The fuel injectors used are completed fuel injector, fuel injector without nozzle needle and BMW injector.

ABSTRAK

Penyelidikan ini bertujuan untuk mengkaji komponen reka bentuk pada penyuntik diesel, mengenal pasti sistem penyediaan bahan api dan menilai corak semburan penyuntik bahan api. Kini, diesel tidak lagi digunakan untuk kenderaan berat seperti bas dan lori. Malah, diesel telah banyak digunakan untuk kenderaan penumpang kerana ia mempunyai kecekapan bahan api yang lebih baik dan boleh menarik beban berat dengan mudah berbanding dengan enjin petrol. Biodiesel adalah bahan bakar boleh diperbaharui yang boleh digunakan selain daripada bahan api diesel dan diperbuat dari minyak sawit, minyak masak dikitar semula, kacang soya, minyak sayuran dan lemak haiwan. Ia adalah tambahan kepada bahan api diesel yang boleh digunakan dengan sedikit atau tiada pengubahsuaian. Biodiesel adalah mesra alam kerana ia tidak mengandungi kandungan sulfur dan mempunyai biodegradasi yang tinggi. Rig ujian sistem suntikan 'common rail' telah direka untuk diuji dengan biodiesel kerana ia mempunyai kecekapan pembakaran yang lebih baik. Selain itu, salah satu bahagian dalam sistem suntikan 'common rail' yang merupakan penyuntik bahan api telah dikaji dengan teliti. Eksperimen pada tiga penyuntik bahan api telah dijalankan untuk mengetahui fungsi dan untuk mendapatkan corak semburan. Penyuntik bahan api yang digunakan adalah penyuntik bahan api, penyuntik bahan api tanpa jarum muncung dan penyuntikbahan api BMW.

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LIST OF ABBREVIATION

CO_2	Carbon dioxide
EPA	Environmental Protection Agency
MPOB	Malaysian Palm Oil Board
B15	Biodiesel 15
UTeM	Universiti Teknikal Malaysia Melaka
NO_x	Nitrogen
CI	Compression Ignition
BDC	Bottom Dead Center
TDC	Top Dead Center
SI	Spark Ignition
ECU	Engine Control Unit
CRDI	Common Rail Direct Injection
ECM	Engine Control Module
CO	Carbon Dioxide
HC	Unburned Hydrocarbons
WD-40	Water Displacement 40th
BMW	Bavarian Motor Works

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CHAPTER 1

INTRODUCTION

1.1 Background

Diesel engine is associated with big trucks and buses where its longevity and strong pulling power make it better choice than petrol engines. Heavy duty trucks engines will often run up to a million miles between overhauls. Diesel also produces higher torque at low engine speeds which make it better for a long journey trip and travelling. Next, diesel engines are better fuel efficiency compared to petrol engine because it can deliver fantastic gas mileage often approaching that of hybrid cars. In addition, unlike petrol engines, diesel engines can run on renewable fuels such as biodiesel with no major modifications but the major disadvantages of diesel engines are it has a reputation of being smoky and smelly. It affects the earth by reducing the ozone layer and it cause global warming which will be the cause of harmful diseases such as skin cancer. The temperature is also rising each year by 1 degree Celsius.

Biodiesel has many environmentally beneficial properties because the fuel produces no net output of carbon in the form of carbon dioxide (CO_2). Biodiesel also is rapidly biodegradable and completely non toxic and it is good for earth and life. According to the Environmental Protection Agency, EPA, biodiesel reduces greenhouse gas emissions by at least 57% and up to 86% when compared to petroleum diesel-making it one of the most practical and cost-effective ways to immediately address climate changes. However, the

use of biodiesel in Malaysia is not as widespread as people thought that biodiesel is inefficient and these things happen because of lack of info about biodiesel.

Malaysian Palm Oil Board, MPOB has invited the Technical University of Malaysia Melaka UTeM to participate in the development of the B15-15% of bio fuel for public acceptance of biodiesel in Malaysia. UTeM have responded to these challenges and has initiated a number of research and experimentation on B15. I have also been involved in the development by designing common rail injections system for the purpose of the test.

1.2 Problem Statement

Biodiesel has been widely used in foreign countries such as the United States as a clean-burning diesel replacement that is reducing the dependence on foreign petroleum and improving the environment. Biodiesel can be used in existing diesel engines without modification and is covered by all major engine manufacturers' warranties, most often in blends of up to 5% or 20% biodiesel and it is produced at plants in nearly every state in the country. If it is increasingly used in foreign countries and better for environment compared to petroleum diesel why it is not widely used in Malaysia. In addition, Malaysia was not properly understood about biodiesel due to lack of information and disclosure.

1.3 Objective

The objectives of this project are as follows:

1. To investigate the design component on diesel injector.
2. To identify the fuel preparation system of diesel injector.
3. To evaluate the injector fuel spray pattern.

1.4 Scope Of Project

The scopes of this project are:

1. Only results of investigation in design component on diesel injector presented in this report.
2. The result of identifying the fuel preparation system of diesel injector is analysed in this report.
3. Experiment only focuses on performance; spray pattern of the fuel injector and does not use software.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

3.1 Literature review

Journals, articles, or any materials regarding the project will be reviewed.

3.2 Experiment

The diesel injector functionality will be check, dismantle the component in the injector and cleaned by injecting WD-40 and air compressor.

3.3 Analysis and proposed solution

Analysis will be presented based on the spray pattern produced by the diesel injector. Solution will be proposed based on the analysis if there was a problem with the diesel fuel injector.

3.4 Report writing

A report on this study will be written at the end of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Diesel Engine

A diesel engine is a type of internal combustion engine in which the fuel or air charge is ignited by the heat of compression. It differs from a spark-ignited engine in which the fuel or air charge is ignited by a spark from a spark plug. The diesel engine is a compression-ignition engine (CI) in which the fuel and air are mixed inside the engine. It was named after German engineer Rudolph Diesel, who has invented and developed first Four- Stroke engine. In diesel engine, only air is highly compressed inside the combustion chamber and generates high temperature which is sufficient for the diesel fuel to ignite when it is injected into the cylinder. Basically, there are two types of diesel engines which are Four Stroke and Two Stroke types. Most of the modern diesel engine is four-stroke cycle. The four strokes involve moving a piston either from the top of its travel which is top dead center (TDC) to its lowest point of travel: bottom dead center (BDC) or vice versa. The four stoke that comprise the four-stroke cycles are intake, compression power and exhaust.

Figure 2.1.1: Four-stroke diesel engine cycle

Diesel and petrol engines are the most commonly used internal combustion engines. Even though their operations seem similar, they have some interesting differences such as a diesel engine is compression ignition (CI) while petrol engine is spark ignition (SI). In diesel engine, fuel is injected at a high pressure, compressed air in the cylinder causing it to burn and force the piston down which is no spark is required. In petrol engine, the air and fuel mixture is ignited using a spark plug and is drawn in by the falling piston. Diesel engines can pull heavy loads easily and used in heavy vehicles like bus and lorry because of higher compression ratio and high in power.

In term of fuel, diesel engine has better full efficiency, low volatility of burn fuel and less fuel consumption because it used crude oil which is much cheaper than petrol. Different from diesel engine, petrol engine is lighter in construction and are used in light vehicles like car, motorcycles and scooters which is less power. Even the petrol engine is lighter than diesel engine but the fuel consumption in petrol engine is higher than the diesel because it uses petrol which is refined oil and is fairly costly. Although the costs of maintenance of both types of engine are similar, repairing a diesel engine is higher than repairing a petrol engine. Diesel engines generate more noise and vibration across the surface compared to petrol.

2.2 Principal Diesel Combustion

Diesel engine is a type of internal combustion engine in which the fuel is burned internally and the combustion products are used as the working fluid. The temperature ratio of diesel engine is higher as the temperature inside the combustion chamber may be high as 700^{o} C to 900^{o} C. A full cycle of a diesel engine requires turning two complete rotations. Firstly, for the intake stroke the piston is connected to the crankshaft by means of

a wrist pin and connecting rod. Due to induction stroke, the crankshaft rotates and the piston is descending from top dead center (TDC) to bottom dead center (BDC); the inlet valve is fully open and the air is drawn in while the exhaust valve is closed.

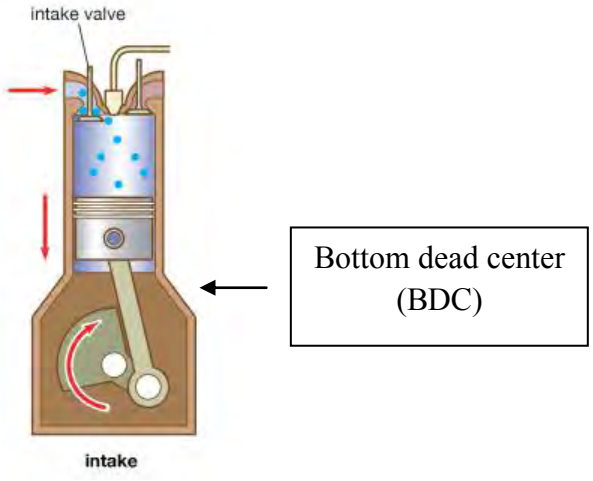

Figure 2.2.1: Intake stroke of diesel engine

Next, as the piston rises on its compression stroke from bottom dead center (BDC) to top dead center (TDC) after the completion of the intake stroke, the intake valve is closing sealing the engine cylinder while the exhaust valve still closed. The quantity of air in the cylinder does not change but the intake air is compressed, thus gives it less space and heats it up.

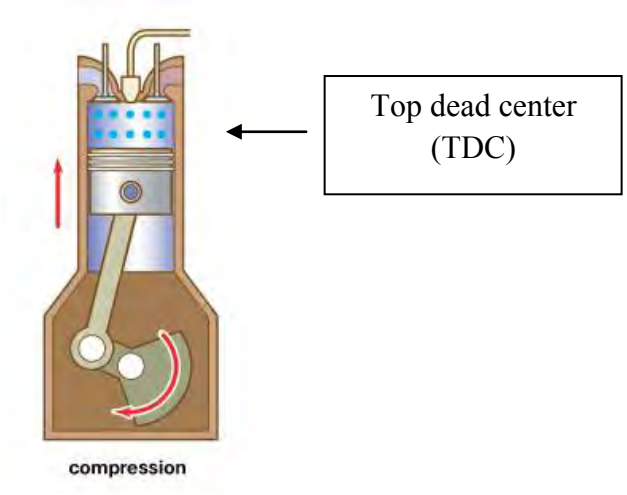

Figure 2.2.2: Compression stroke of diesel engine

Shortly before the completion of the compression stroke, atomized fuel is introduced directly into the engine cylinder by fuel injector. The compressed air cause the fuel ignited by hot air charge. Both the inlet and exhaust valve are closed. The power stroke drives the piston downwards from top dead center (TDC) to bottom dead center (BDC) as a result of combustion fuel acts on the piston.

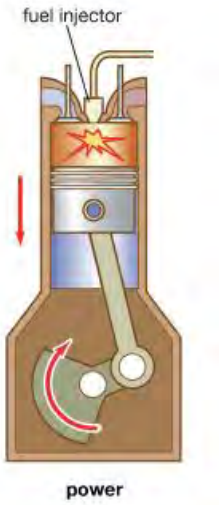

Figure 2.2.3: Power stroke of diesel engine

During the exhaust stroke, most of the heat energy that can be converted to kinetic energy has been converted. The end gas in the cylinder escapes through the open exhaust valve as the piston rises again to top dead center (TDC) from bottom dead center (BDC).

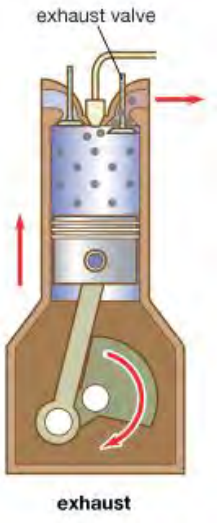

Figure 2.2.4: Exhaust stroke of diesel engine

Diesel as fuel has slower combustion compared to petrol because of power produced higher torque at low speeds which is primary requirements of a heavy engine. It also employ higher compression ratios, peak pressures and temperature reached are higher as compared to petrol engines which is need the engine to be heavy and robust. The density of diesel is greater than petrol, thus gives 15% more energy per unit volume on combustion.

Diesel engines are bigger and fit for heavier vehicle like bus and lorry where the compression ratio and vibration level is higher. The diesel engine compresses at ratio of 14:1 up to 25:1, whereas in petrol engine the compression ratio is between 8:1 and 12:1. This shows that lighter vehicle such as passenger car is not suitable for diesel engine because the design itself is much smaller compared to heavy vehicle. Furthermore, as for power diesel produce higher torque which needed to move heavy loads and it is a primary requirement for heavy vehicles. Diesel produces slow energy on burning of fuel and the

efficiency of the engine increases with load which is why diesel engine is suitable and largely used for heavy vehicles (Engineer, 2017). When a petrol engine has combustion ignition, we often call it “knock” and it can ruin the engine but diesel engines are built to take advantage of it. (Roberson, 2013).

2.3 Fuel Preparation System

The common rail was developed by Vickers, Ltd. in 1993 which become very popular. Then in the late 1960s, the common rail prototype was developed by Robert Huber of Switzerland and Dr. Marco Ganser at the Swiss Federal Institute of Technology in Zurich furthers the development of the common rail technology. The purpose of traditional diesel engine fuel injection systems being designed is to secure the acceptable fuel spray characteristics during the combustion process at all load conditions. The efficiency will reduce and the emissions of harmful species will increase if the injection is incorrect. The first American engine with common rail injection system was built by the Atlas Imperial Diesel Company of Oakland, California in 1919 (Deluca).

The traditional injection system has an auxiliary cam on the engine camshaft drives a single-cylinder injection pump. Early in the stroke of the plunger, the inlet port is closed and the fuel trapped above the plunger is forced through a check valve into the injection line. The injection nozzle has several holes through which the fuel sprays into the cylinder. A spring-loaded injection needle keeps the injection valve closed until the pressure in the injector volume, acting on parts of the needle surface, overcomes the spring force and opens the valve. Thus, the phase of the pump camshaft relative to the engine crankshaft controls the starts of the injection, while the force given by the initial displacement of the spring gives the opening pressure. Injection is stopped when the inlet port of the pump is