THE CHARACTERIZATION OF FUEL INJECTOR SYSTEM FOR AUTOMOTIVE TECHNOLOGY

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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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First and foremost, I would like to express my greatest gratitude and fully sincere to my best supervisor Prof. Dr Ghazali bin Omar from Faculty of Mechanical Engineering of Universiti Teknikal Malaysia Melaka (UTeM) for his guidance, knowledge and essential support towards the completion of this project.

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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.

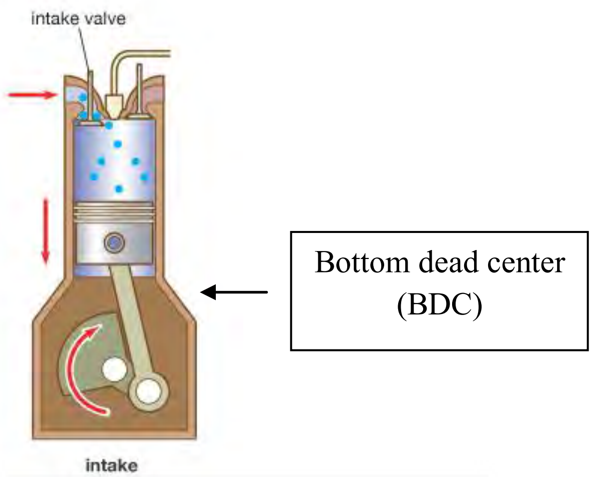

Figure 2.2.1: Intake stroke of diesel engine

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.

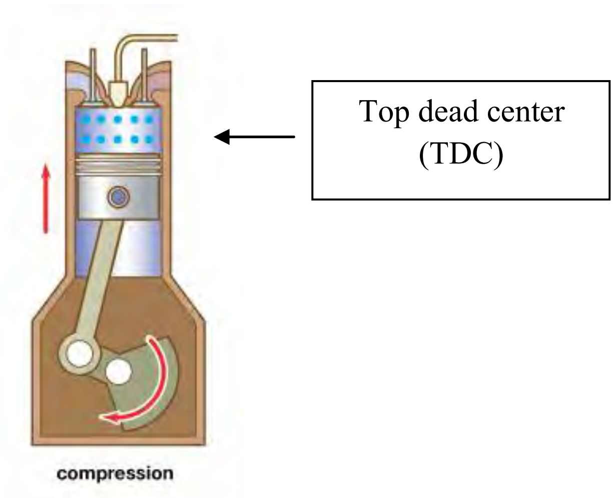

Figure 2.2.2: Compression stroke of diesel engine

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.

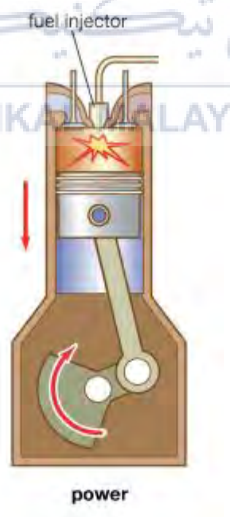

Figure 2.2.3: Power stroke of diesel engine

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).

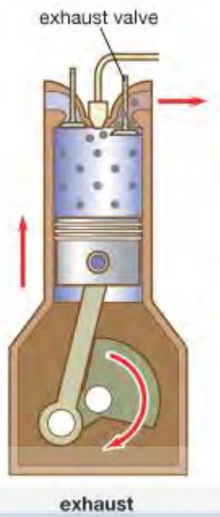

Figure 2.2.4: Exhaust stroke of diesel engine

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 uncovered by a helical groove in the pump plunger, and the high pressure above the plunger and in the injector volume is released. The injection pump cam design and the position of the helical groove determine the amount of fuel injected into the cylinder. Thus, for a given cam design, the rotating plunger and its helical groove control the load. (Bunes & Einang, 2000).

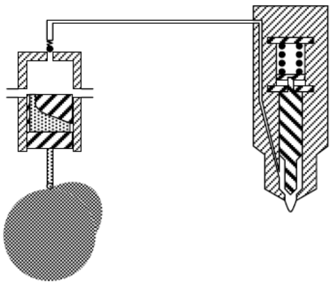

Figure 2.3.1: Traditional cam-driven fuel injection system

Source: (Bunes & Einang, 2000).

Contrary to the traditional injection system, pressure generation and injection are decoupled in the common rail system. Modern common rail system, whilst working on the same principle, is governed by an engine control unit (ECU) which opens each injector electronically rather than mechanically (CRDI (Common Rail Direct Injection), 2013). The injection pressure can even be generated independently of engine revs and the injected fuel quantity can be freely selected within limits (Bunes & Einang, 2000). The fuel is direct injecting to the engine cylinder with high injection pressures: 100 bars or 1500 psi for normal engine if high performance engine the pressure is 2000 bar or 30 000 psi. The term "common rail" refers to the fact that all of the fuel injectors are supplied by a common fuel rail which is nothing more than a pressure accumulator where the fuel is stored at high pressure (CRDI (Common Rail Direct Injection), 2013). Common rail fuelling provides engine control module (ECM) much better control over injection which is better management of combustion in the engine cylinder. The result is an improved ability to meet fuel economy expectations and diesel emission standard where the Europe transport emission of carbon dioxide (CO_2) is 3.5% of total global CO_2 emissions.

The common rail injection system consists of fuel subsystem; supplies fuel to the high-pressure rail pump and the common rail itself with the function to store fuel at injection pressures. Next, high-pressure pump create sufficient high flow volume so that when subject to flow restriction, they achieved the required rail pressures. The injectors in the common rail system are controlled and operated by the engine control module (ECM) after taking into consideration multiple sensor and signal inputs. The system pressure is monitored by the rail pressure sensor. The filter in common rail is vital as it ensure system cleanliness and lifespan. Moreover, the return manifold controls the return of fuel back to the fuel tank while the overflow valve enables excess fuel to overflow back into the tank. The most common applications of common rail engines are marine and locomotive applications and is suitable for all types of road cars with diesel engines, ranging from city cars such as the Fiat Nuova Panda to executive cars such as the Audi A6 (CRDI (Common Rail Direct Injection), 2013).

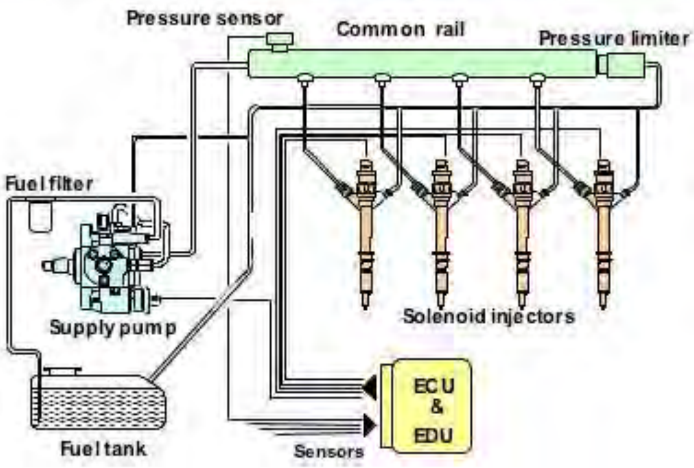

Figure 2.3.2: Common rail injector system

Source: (Common Rail Pump, 2014)

2.4 Diesel Fuel

Crude oil is a naturally occurring and a mixture of hydrocarbons that formed from plants and animals that lived millions years ago. Crude oil is defined as having different chains of hydrocarbons that occur in different length; the longer the chain of hydrocarbons, the higher its boiling point whereas the shorter hydrocarbons chains have lower boiling point. It is a fossil fuel that exists in liquid form such an in underground pools or reservoir and can be refined to produce usable products such as butane, petrol, kerosene, diesel and asphalt. Also, the most common method to obtained crude oil is by drilling from the ground or the sea for example in Malaysia; oil filter plant at Lutong, Sarawak and Kerteh, Terengganu. In other hand, crude oil is limited resource because it is a non-renewable resource which means it cannot be replaced naturally.

Figure 2.4.1: Crude oil

Source: (Oyedele, 2015)

Diesel fuel is one of the usable product created from crude oil and is used in the diesel engine which is mostly used in heavy trucks such as truck, buses and boats, also some cars and small trucks that have diesel engine. Crude oil refining starts with the boiling of the viscous liquid to vaporizing temperatures of up to 400ºC, (What Is Diesel Fuel Made Out Of?, 2017). During the refining process, the viscous dark thick crude oil turned into the much lighter diesel fuel. This process turns liquid into vapor on account of crude oil is made up of hydrocarbons with different length of chain, the vaporized crude oils begins to return to the liquid state then enters at the different levels of fractional distillation power, as it starts to cool down. Diesel fuel is a mixture of hydrocarbons with boiling points in the range of 150 to 380ºC which are obtained from petroleum (W.Addy Majewski, 2016). At this range of temperature, the diesel fuels will form and later siphoned off into a diesel holding tank for final treatment.

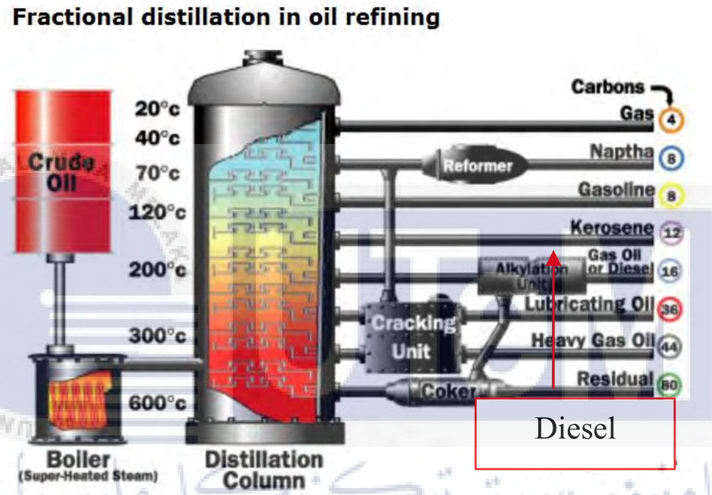

Figure 2.4.2: Fractional distillation in oil refining

Source: (McClain, 2012)

According to Adaileh et.al (2012), the performance of diesel engine fuelled by a biodiesel shows reductions in carbon dioxide (CO), and unburned hydrocarbons (HC), but the nitrogen (NO_x) was increased. The experimental results show that the fuel consumption rate, brake thermal efficiency, and exhaust gas temperature increased while the emission indices of CO_2, CO decreased with an increase of engine speed. Moreover, the engine power increased when increasing the biodiesel percentage In particular, biodiesel produced with the addition of the peroxidation process had the lowest equivalence ratio and emission indices of CO_2, CO. Therefore, the peroxidation process can be used effectively to improve the fuel properties and reduce emissions when biodiesel is used.

2.5 Bio-fuel

Fossil fuels are limited and non-renewable source, also the potential of fossil fuels to decrease is high as the demand for it is increasing with the advancement of the world. Although, these fuels are contributing largely to the world energy supply, their production and use have raised environmental concerns and political debates (Alemayehu Gashaw, 2015). Biodiesel is introduced as it saves on resources and most important is to reduce the emission from diesel fuel. It has been shown that 98% of carbon emissions are resulted from fossil fuel combustion (Aransiola, 2012). The emissions produced from diesel cause environmental pollution such as greenhouse gases and ozone depletion which will slowly increase the temperature and can cause dangerous diseases like skin cancer. Apart from these emissions, petroleum diesel is also major source of these air contaminants including NO_x, SO_x, CO, particulate matter and volatile organic compounds (Kannahi, 2013). The use of bio-fuels in place of conventional fuels would slow the progression of global warming by reducing sulfur and carbon oxides and hydrocarbon emissions (Alemayehu Gashaw, 2015).

Bio-fuel or biodiesel is a renewable fuel that can be used instead of diesel fuel and it was made from vegetables oils, animal fats, recycled cooking oil and soy bean. Moreover, bio-fuel is an additive to standard diesel fuel instead of petroleum or crude oil and usually blended with standard diesel fuel. It can be used in existing diesel engines with little or no modification and can reduce exhaust pollution and engine maintenance cost. As early as the 1930s, there was interest in splitting the fatty acids from the glycerin in vegetable oil in order to create a thinner product similar to petroleum diesel. In 1937, G. Chavanne was granted a Belgian patent for an ethyl ester of palm oil (which today we would call biodiesel). In 1938, a passenger bus fueled with palm oil ethyl ester plied the route between Brussels and Louvain (Jon Van Gerpen, 2012). At present, biodiesel is mainly produced from conventionally grown edible oils such as soybean, rapeseed, sunflower, and palm (Demirbas, Bafail, Ahmad, & Sheikh, 2016). The major feedstock for biodiesel is fat or oil from animal and plant respectively. Tables below show various oil used for biodiesel production.

Table 1: Production of biodiesel in Different countries

S/N	Country	Sources of Biodiesel
1.	USA	Soya Bean (Mustard is under study)
2.	Brazil	Soya Bean
3.	Europe	Rape seed oil(>80) and Sunflower oil
4.	Spain	Linseed and Olive oil
5.	France	Sunflower oil
6.	Italy	Sunflower oil
7.	Ireland	Animal fat, Beef tallow
8.	Indonesia	Palm oil
9.	Malaysia	Palm oil
10.	Australia	Animal fat, Beef tallow and rapeseed
11.	China	Guang pi
12.	Germany	Rapeseed oil
13.	Canada	Vegetables oil/Animal fat
14.	India	Jatropha

15.	Ghana	Palm oil, Palm nut, Coconut oil

Source: (Owolabi, Adejumo, & Aderibigbe, 2012)

The source of biodiesel in Malaysia is palm oil which is can be found in the states with lots of palm trees as in Sabah. It is produces domestically which helps to reduce the dependency of oil import of the country (Shahabuddin, et al., 2012). Palm oil has good potential as a feedstock for biodiesel production as it is a strong competitor with other biodiesel feedstock crops in terms of fuel yield per acre (4751 liter per hectare compared with 523 liter per hectare for soybean oil, and 954 liter per hectare for rapeseed oil) (Applanaidu, Arshad, Shamsudin, & Yusop, 2009). Using palm diesel and its emulsions in an indirect injection diesel engine, emulsification was found effective in reducing emissions level for CO, CO_2, HC, NO_x, SO_x and smoke particulates (Kalam & Masjuki, 2005).

Table 2: Chronology of biodiesel development in Malaysia

Year	Milestone
1982	Laboratory research on palm methyl esters (PME) biodiesel began
1983	Palm Diesel Steering Committee formed by the Minister of Primary Industries
1984	Construction of a PME biodiesel pilot plant (3000 tonnes a year capacity) began
1984-1985	Preliminary field trials in taxis conducted
1985	PME biodiesel pilot plant launched
1986-1989	Field trials phase I began—31 commercial vehicles and stationary engines
1990	Field trials phase II began—bench test by Mercedes Benz in Germany
1990-1994	Field trials phase III began—commercial buses

1995	Transfer of PME production technology to industry to produce oleochemicals, carotenes (pro-Vitamin A) and Vitamin
2001	Use of a CPO and fuel oil blend for power generation initiated Research on low-pour-point palm biodiesel initiated
2002	Field trials using processed liquid palm oil and petroleum diesel blends (B2, B5, B10) in MPOB vehicles began (i.e. a straight vegetable oil [SVO] biofuel blend)
2004	Trials of refined, bleached and deodorised (RBD) palm oil and petroleum diesel blends (B5) using MPOB vehicles (i.e. an SVO biofuel blend) began
2005	Transfer of technology from the MPOB to Lipochem (M) Sdn Bhd and Carotino Sdn Bhd to build PME biodiesel plants Design of commercial low-pour-point PME biodiesel plant National Biofuel Policy drafted
2006	National Biofuel Policy launched First commercial-scale biodiesel plant began operations Envo Diesel launched 92 biodiesel licences approved
2007	Increase in CPO price caused many biodiesel projects to be either suspended or cancelled
2008	Malaysian Biofuel Industry Act 2007 came into force Usage of Envo Diesel was scrapped and replaced with B5
2009	Government vehicles from selected agencies began use of B5 blend
2010	Government announcement that the B5 mandate for commercial use will be

	deferred to June 2011

Source: (Chin, 2011)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in the project in order to get the details of development of common rail injector system test rig to evaluate the diesel fuel injector spray pattern. The flow chart of the project is shown in Figure 3.2.1. This project start by studying the common rail injector used in diesel engine followed by the inspecting the injector by dismantling to check every component. Then, assemble the injector to testing the operation of the injector and testing the spray pattern of the injector using WD-40.

3.2 Flowchart

The flow chart below is the overall process that involved throughout this project. This project starts by studying the basic knowledge such as the concept of diesel engine and fuel preparation system.

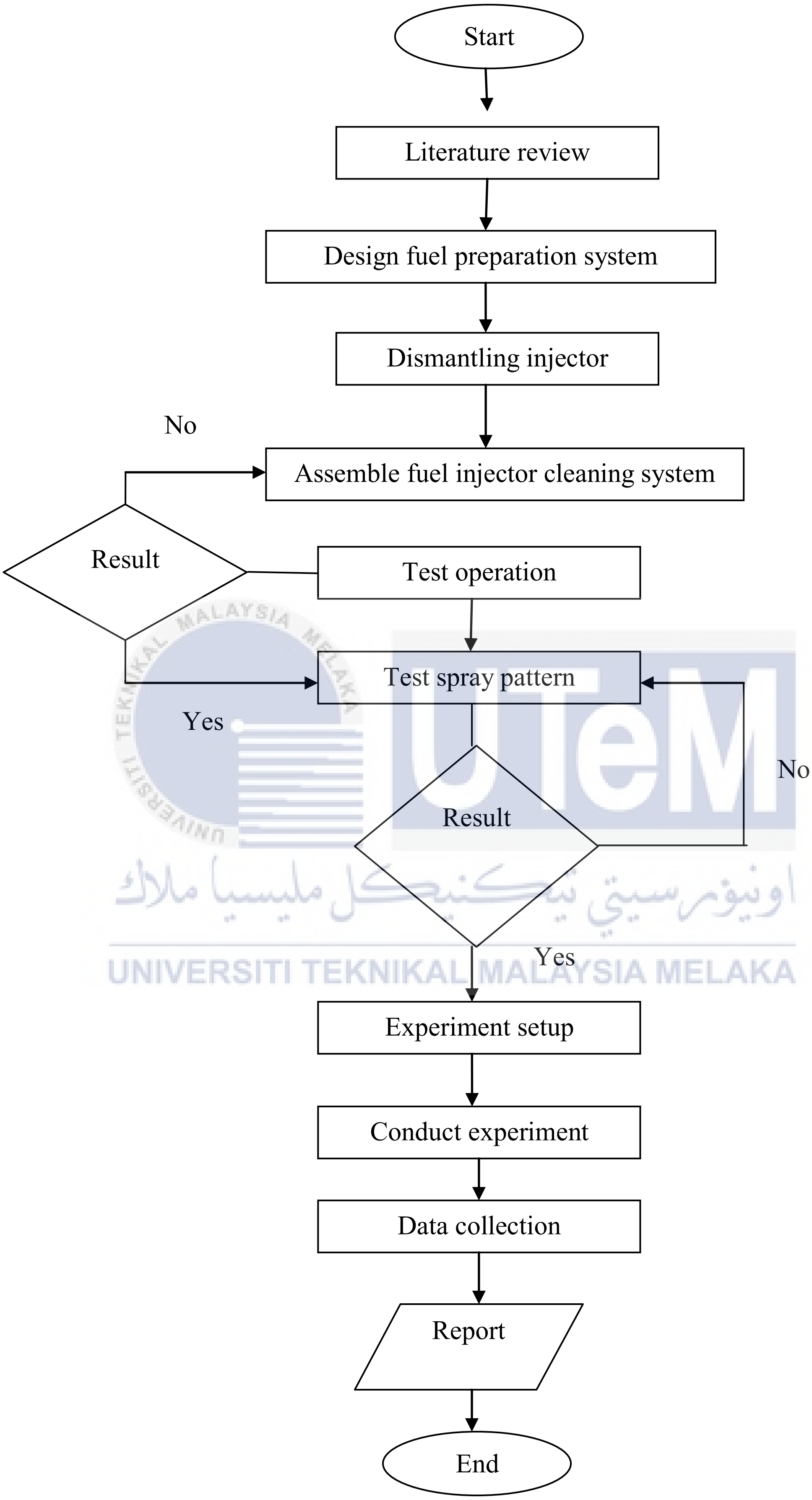

Figure 3.2.1: Flow chart of the project

3.3 Design of Fuel Preparation System

The flow chart shown below is process of designing the fuel preparation system which is the common rail injection system. Firstly, the process start by gathering information from the journal and article about the common rail injector; the components involved such as fuel rail and high pressure pump. Next, is determining the design requirements and conceptual design by sketching the common rail injection system. If the conceptual design has all the requirements, then the process will continue with the material selection for the system. The material selection for common rail injector system consists of the wooden frame for the support.

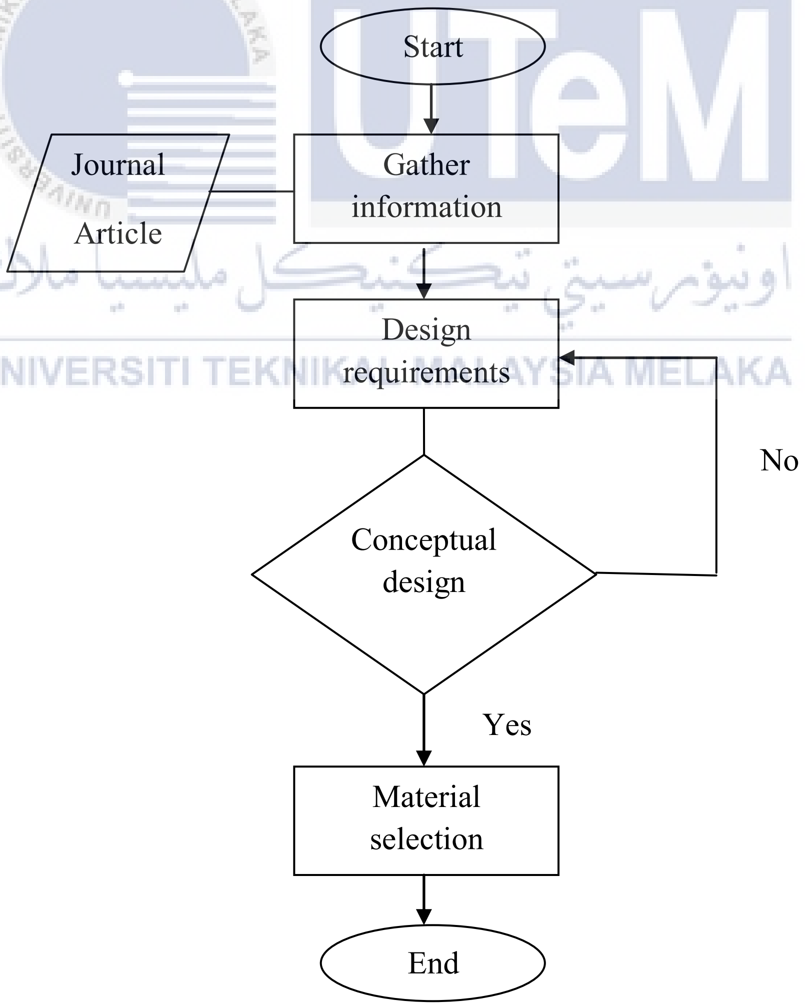

Figure 3.3.1: Flow chart of design fuel preparation system

3.4 Inspecting The Injector

For the inspection process, the injector used is the injector of the Mitsubishi diesel engine and BMW injector. Figure 3.4.1 shows the common rails of diesel injectors in the engine block. Figure 3.4.2, Figure 3.4.3, and Figure 3.4.4 shows the injector that will be used for inspection. The inspection of the injector will be done by dismantling the injector to check every component in the injector and to check the functionality of the injector. The dismantling process will be done at the automotive workshop which has all the equipment need such as toolbox and vice table.

Figure 3.4.1: Diesel injector common rail

The process started with removing the injectors from the engine block by remove the four bolts that are attached to the engine's fuel rail in order to be able to move it. Once the fuel rail is uncoupled from the injectors, then the injectors is pulled out carefully. The fuel rails are also removed as they will be used for cleaning process. However, the high pressure pump will not be used in the cleaning process because it was not working. The high pressure pump will be replaced with WD-40 as pressure.

Figure 3.4.2: Diesel Injector

Figure 3.4.3: Diesel injector without nozzle needle

Figure 3.4.4: BMW Injector

3.5 Construct Fuel Injector Cleaning System

In order to understand the diesel fuel injector and to test the functionality of the diesel injector, the cleaning process of the injector will be done by using WD 40. The fuel injector are vital in every vehicle, so it must be keep clean in order to keep the engine in good state and has long lasting performance. The purpose of this cleaning process is to remove dirt and dust contained in the injector that causing it to clog and not functioning. At a professional garage, they may use an ultrasonic machine to clean the injectors out. In this project, the cleaning process will only use injector, WD-40, 12 volt direct current power supply, tyre valve, wire connector, switch and rail as shown in Figure 3.5.1(a) and Figure 3.5.1(b).

Figure 3.5.1(a): The items to be used for cleaning process

Figure 3.5.1(b): The items to be used cleaning process

3.6 Test Operation

The operation of the fuel preparation system will be test after the assembling process is done. The objective of testing the operation is to know the functionality of the diesel fuel injector. It also carried out to identify if there are problems in the injector and each component before it is tested using biodiesel. If problem arise in the course of the testing is conducted, then it must be overcome. The testing will be conducted in the laboratory with supervisor and technician supervision.

3.7 Spray Pattern Testing

After the testing operation of the fuel preparation is done and there is no problem with the system, then the spray pattern testing will be conducted. The purpose to test the spray pattern is to identify the condition of the injector and the spray pattern produced when fuel is injected. However, the injector cleaning process does not use fuel but it only uses WD-40 to be injected into the injector to get the spray pattern. Injector spray pattern will take place at three different injector which are the diesel injector as shown in Figure 3.3.1, diesel injector without nozzle needle in Figure 3.3.2, and BMW injector in Figure 3.3.3,. The spray pattern testing will be conducted in automotive laboratory under supervisor and technician supervision.

CHAPTER 4

RESULTS AND DISCUSSION

4. 1 Introduction

This chapter describes the result obtained from the experiment that has been done in order to understand the characterization of fuel injector system for automotive technology. The result from the investigation of design component on diesel fuel injector, the fuel preparation system and the evaluation of the injector fuel spray pattern is presented.

Generally, the result for this project is only obtained from the diesel injector. First, the inspection process by dismantling each component in the injector. Next, the process of cleaning the injector and conducting the injector spray pattern testing to determine the functionality of the fuel injector.

The inspection is done after the WD-40 injected, the injector did not produced any spray pattern by dismantle the fuel injector and checked the functionality of the parts such as the spring, cap nut, nozzle and needle as well as the intermediate plate and spindle. The cleaning process is performed after the injector is assembled and the purpose is to get the spray pattern. The result of spray pattern is obtained by injecting WD-40 and recorded by using high resolution camera.

4. 2 Inspection of Diesel Fuel Injector

Fuel injector inspection is performed by opening the injector to clean the component inside the injector. The process of dismantle the injector is done by carefully remove the injector nozzle cap nut. The carbon deposit in and around the nozzle retaining cap nut can be removed by washed and blown off with air compressor. Then, carefully remove spring, nozzle and needle also the intermediate plate and spindle of the fuel injector.

Figure 4.2.1: Diesel injector

Figure 4.2.1 shows the diesel injector after being removed from the engine block. As can be seen, the injector is dirty and greasy. In addition, the injector is not working because no spray pattern produced when the WD-40 is injected. After several testing done but there is still no spray pattern produced so the dismantling process is performed to clean the components inside the injector and identify the problem that cause it to malfunctioned.

Figure 4.2.2: Spring

The injector spring shown in Figure 4.2.2 is located inside the fuel injector. The spring holds the needle valve in ‘closed’ position until the pressure in the high-pressure lines reaches the specific value. The spring of fuel injector is still in good condition.

Figure 4.2.3: Cap nut

Figure 4.2.3 shows the cap nut of fuel injector that holds the spring, nozzle and needle as well as the intermediate plate and spindle. There is no problem occurred from the fuel injector cap nut.

Figure 4.2.4: Nozzle and Needle

From the Figure 4.2.4, it shows the fuel injector nozzle and needle. Nozzle is one of the main components of fuel injection systems. It regulates the flow of fuel to the ultimate ignition compartment. The main function of nozzle is to convert the diesel into the diesel vapours and spray it on the piston.

Figure 4.2.5: Intermediate plate and spindle

Figure 4.2.5 shows the intermediate plate and spindle inside the fuel injector. This part that causes the injectors is not functioning properly. When the injector is opened, it was found to be dusty and that is the reason that causes the injector clogging. Spray pattern could not be produced because it was dusty and causes the injector clogging. After identifying the cause of the problem, the parts were cleaned using WD-40 and the air compressor. The injector is reassembled after cleaning process of each parts of the fuel injector is completed.

4. 3 Diesel Injector Cleaning Process

After all parts of the fuel injector is cleaned and reassembled, then the experiment or known as diesel injector cleaning process is repeated by injecting the WD-40 to ensure that the injector can function well and in order to obtain the spray pattern. As a result, the injector is functioning again can produce the spray pattern. The spray pattern is recorded using high resolution camera.

Figure 4.3.1: Cleaning process of fuel injector without nozzle needle

Figure 4.3.1 shows the cleaning process of fuel injector without the nozzle needle. From the testing, the injector is not problematic and can function properly.

Figure 4.3.2: Cleaning process of BMW fuel injector

The cleaning process of BMW fuel injector indicated that the injector is problematic and cannot function. Since it is the piezoelectric injectors, so the injector cannot be opened because does not have the injector kit. Experiment using WD-40 performed several times but failed to produce the spray pattern. Even the WD-40 is injected has been rejected by the injector and caused the tire valve removed.

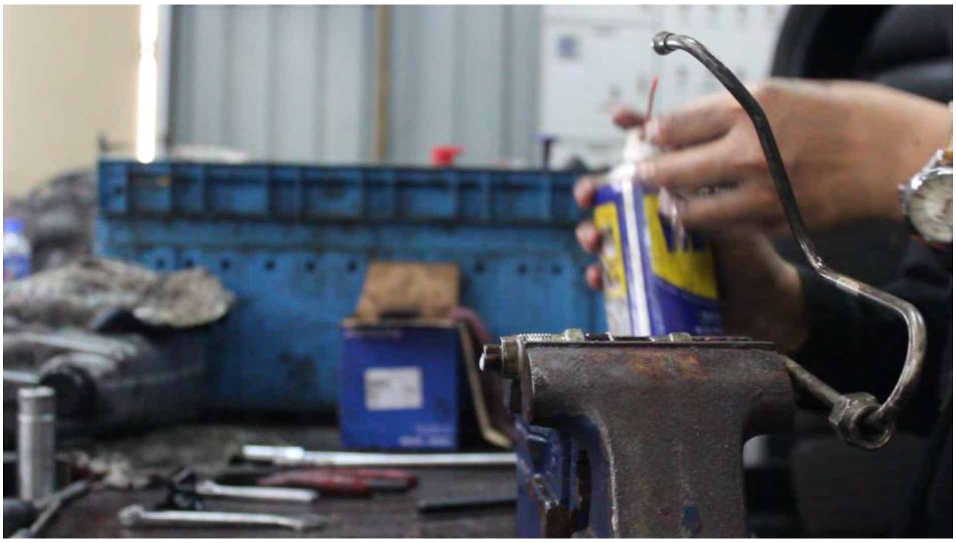

Figure 4.3.3: Cleaning process of complete fuel injector

The cleaning process of diesel injector shown in Figure 4.3.3 managed producing the spray pattern after cleaning each parts of the fuel injector. The experiment only uses the rail and WD-40 it does not use high pressure pump as it is damaged. Although not using the high pressure pump, the injector still able to produce a spray pattern. The pressure of WD-40 injected into the fuel injector range from 655 to 793 kPa at 21°C.

4. 4 Spray Pattern Result

The spray pattern of a fuel injector is very important to the performance of the engine. Incorrect or poor fuel injector spray patterns can cause a wide range of drive ability issues such as emissions, poor starting and poor fuel consumption.

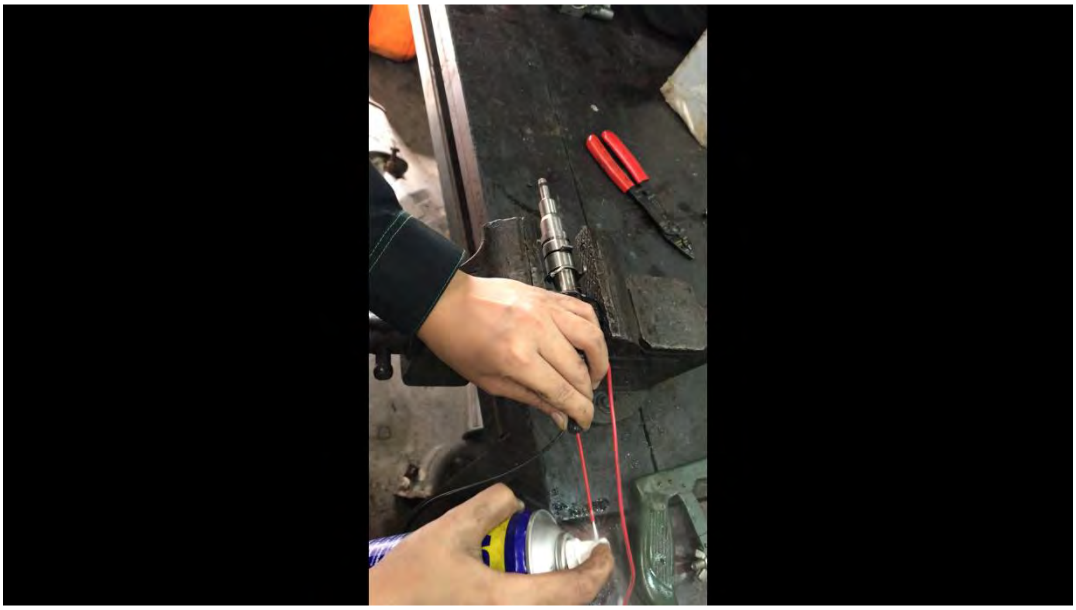

Figure 4.4.1: Spray pattern of BMW injector

The result for spray pattern testing of BMW injector is shown in Figure 4.4.1. It shows that there is no output or spray pattern formed for this injector. It is assumed that the injector has been damaged and clogged due to have not been used for a long time. The injector cannot be opened to further identity the problem faced because does not have an injector kit to dismantle it.

Figure 4.4.2: Spray pattern of fuel injector without nozzle needle

Figure 4.4.2 shows the result of diesel injector without nozzle needle spray pattern. The experiment is done to see the difference between the complete fuel injector and fuel injector without nozzle needle. The resulting result is that both have different spray pattern. Spray pattern of fuel injector without nozzle needle is not as smooth as complete fuel injector.

Figure 4.4.3: Spray pattern of complete fuel injector

Based on Figure 4.4.3, it shows that the spray pattern produced by the injector is bad as referred to Figure 4.4.4, the example of spray pattern produced. Even after cleaning process, the injector still produced a bad spray pattern. It is possible that one part of the fuel injector is worn or damaged, or the nozzle is cracked from overpressure or improper installation of the injector.

Figure 4.4.4: Example of spray pattern produced

Source: (Jack, Clogged fuel injector symptoms, 2014)

4. 5 Design of Common Rail Injection System

Figure 4.5.1 shows the common rail injection system which has been developed for the assemble process. The system consists of high pressure pump, 12 volt direct current power supply, fuel rail, fuel tank, battery, six fuel injector and pipe. The common rail injector is a fuel injector used in diesel engine to provide better fuel efficiency. The fuel injected at high pressure using high pressure pump, then the common rail will supply the fuel to the individual injectors which then inject it into the combustion chamber. However, the common rail injection system test rig that has been designed to evaluate B15% performance cannot be assembled because the tools and materials to set up the system are not ready on time.

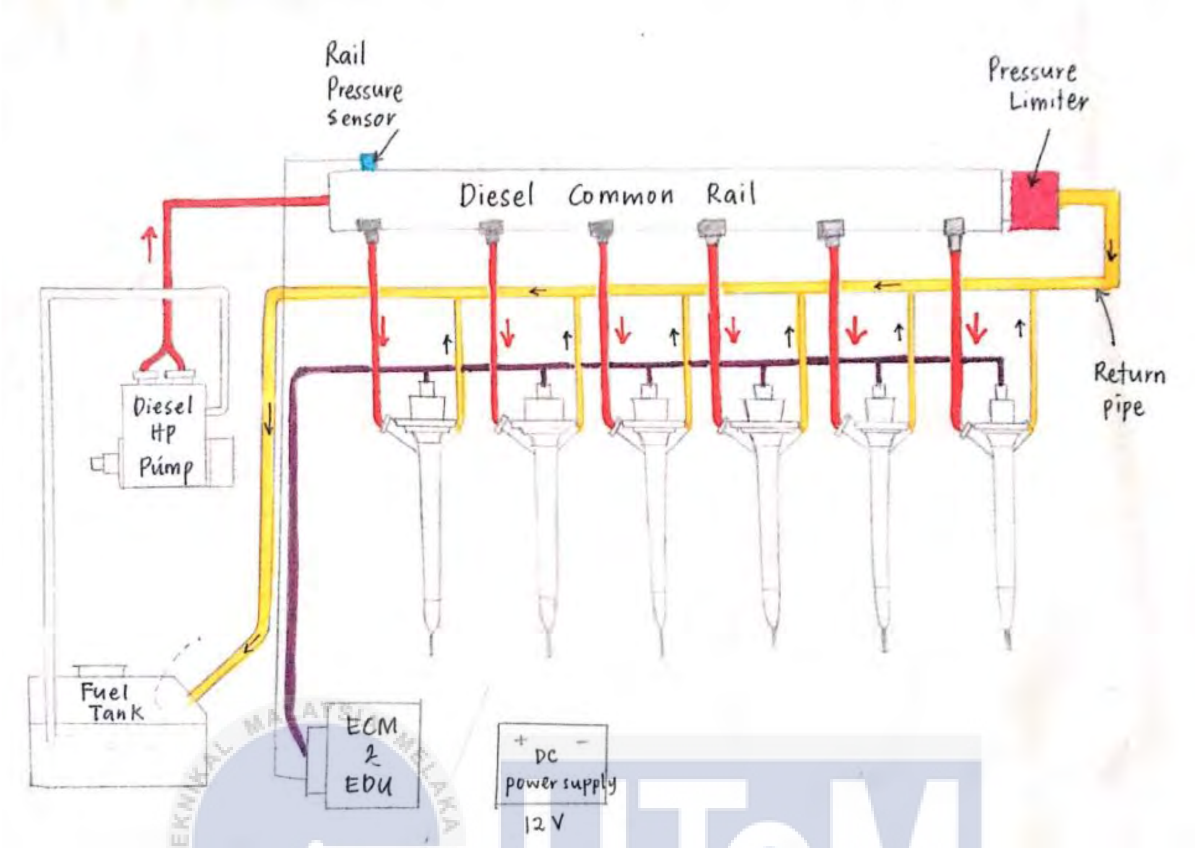

Figure 4.5.1: Common rail injection system

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The investigation on diesel injector is performed by testing the functionality of the injector by conducting a dismantle process in order to check the components in the injector. The cleaning process is proceeding by injecting the WD-40 to obtain the spray pattern. The experiments have been carried out against three types of injectors which are the complete fuel injector, fuel injector without nozzle needle and BMW injector.

Next, the fuel preparation system is identified by designing the components involved in the system. The system comprises of high pressure pump, 12 volt direct current power supply, fuel rail, fuel tank, battery, six fuel injector and pipe. The fuel is injected at high pressure using high pressure pump, then the common rail will supply the fuel to the individual injectors which then inject it into the combustion chamber.

Furthermore, the complete fuel injector has produced the spray pattern after dismantle and cleaning process. However, the spray pattern produced is a bad spray pattern. The fuel injector without nozzle needle functions when tested with injected the WD-40 and producing spray pattern. Spray pattern produced is not as smooth as the complete fuel injector. Lastly, the BMW injector does not produce any spray pattern, it is assumed not working, clogged and damaged.

5.2 Recommendation for Future Works

Common rail injection system is vital in determining the performance of the engine and the car, so it should be maintained solve problems that arise. Biodiesel is still not widely used in Malaysia, so the performance of the engine and car after using the biodiesel is not much. Experiment to find out effectiveness of the biodiesel through flow rate and spray pattern in common rail injection system could not be done due to the equipment for the experiment set up are not ready on time.

In this project, the recommendation for future works is running experiment which has been planned for development on the common rail injection system test rig to evaluate B15% biodiesel performance. In addition, it is also recommended to test the fuel injector using the high pressure pump and carefully identify which parts of the fuel injector is damaged or not working.

Besides, replacing the parts of the fuel injector that has been damaged with new parts so the fuel injector can function better and producing a good spray pattern. Furthermore, it is suggested to dismantling the piezoelectric injector using proper injector kit and studies the piezoelectric injector thoroughly as it has greater efficiency, performance and reduced emissions. It is also recommended to use the piezoelectric injector in future experiment.

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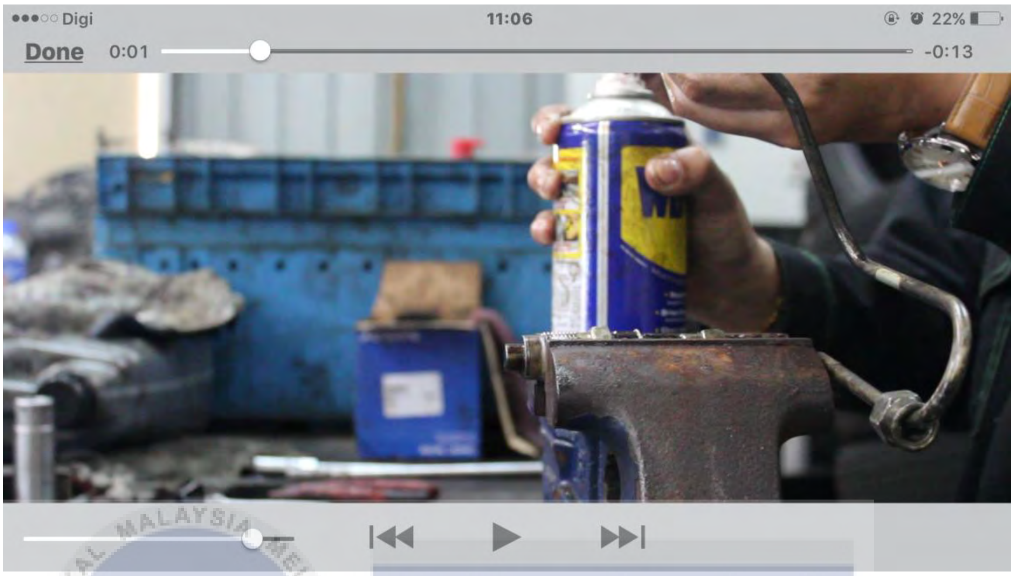
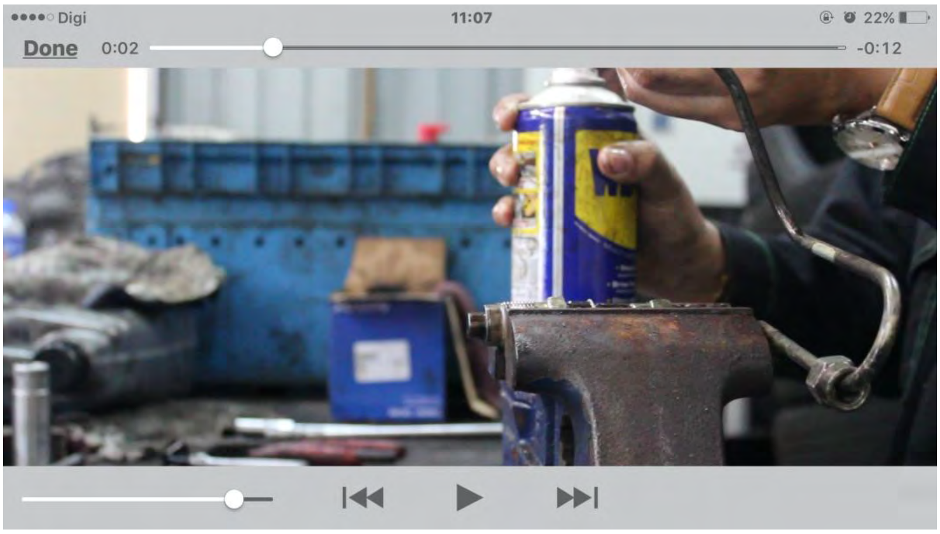
APPENDIX A

SPRAY PATTERN OF COMPLETE FUEL INJECTOR

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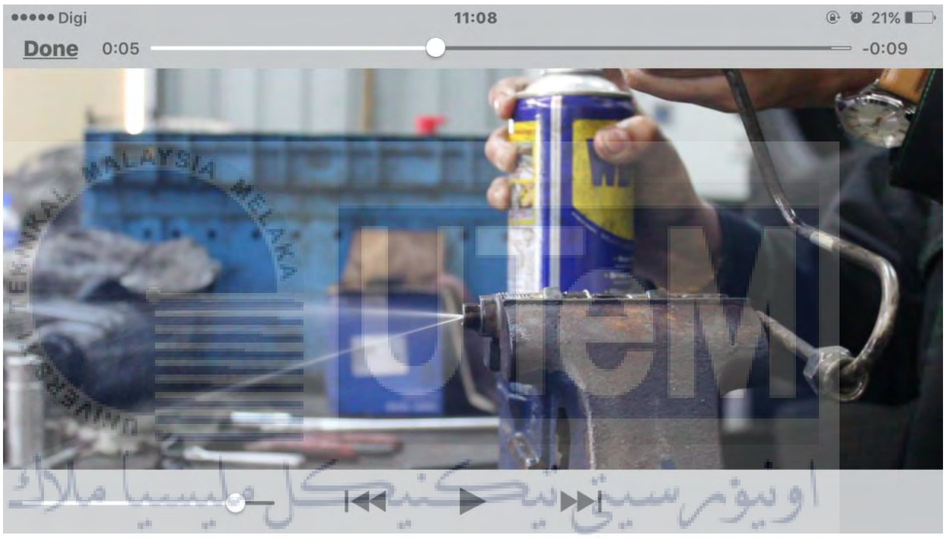
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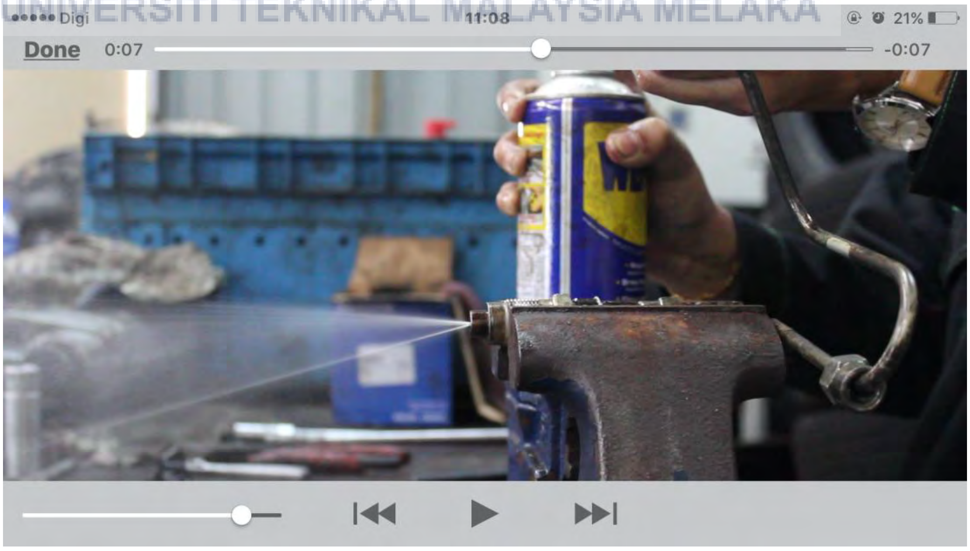
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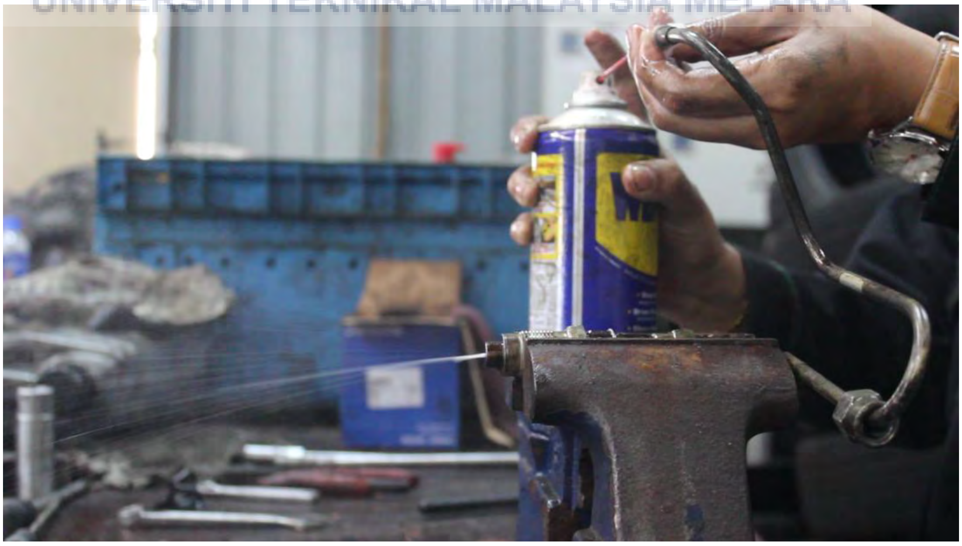

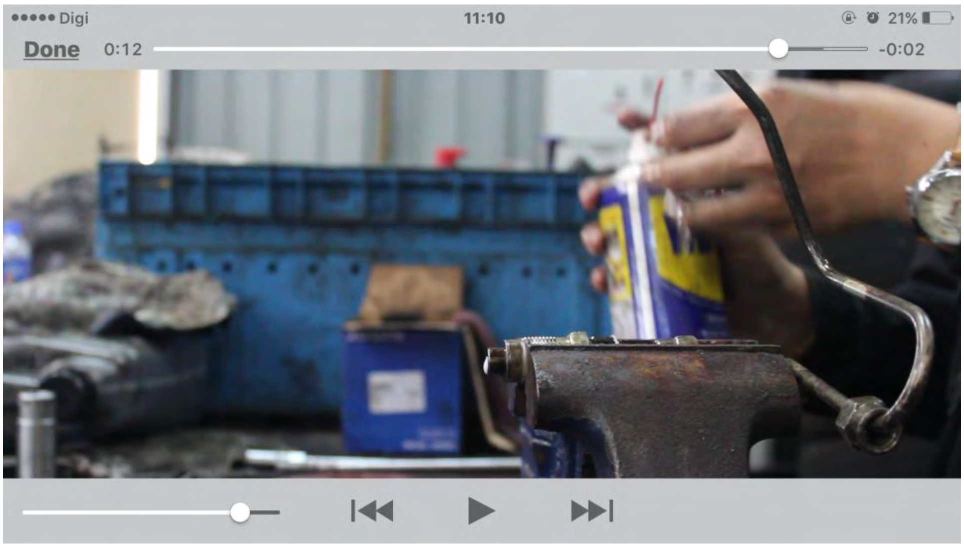
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APPENDIX B

SPRAY PATTERN OF FUEL INJECTOR WITHOUT NOZZLE NEEDLE


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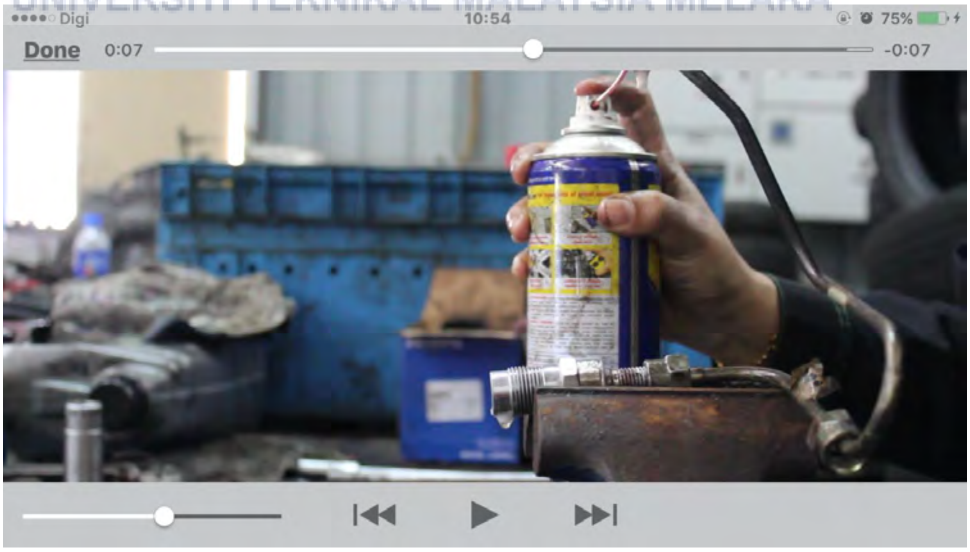
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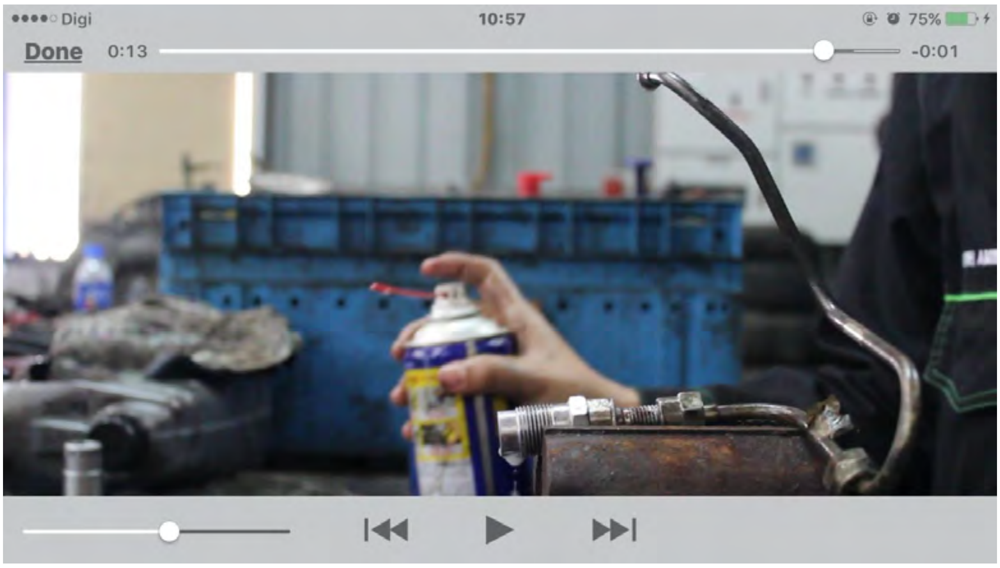
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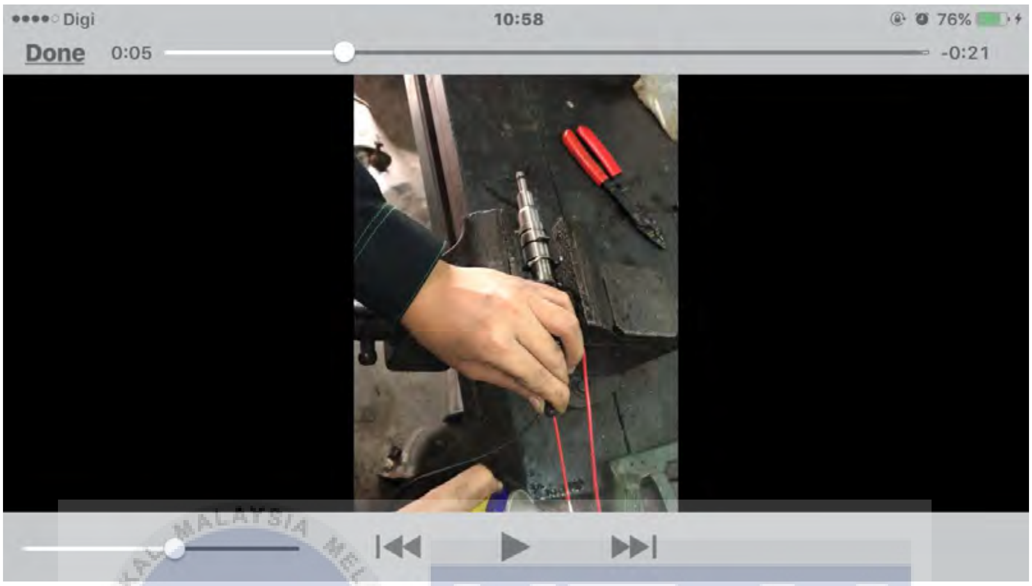
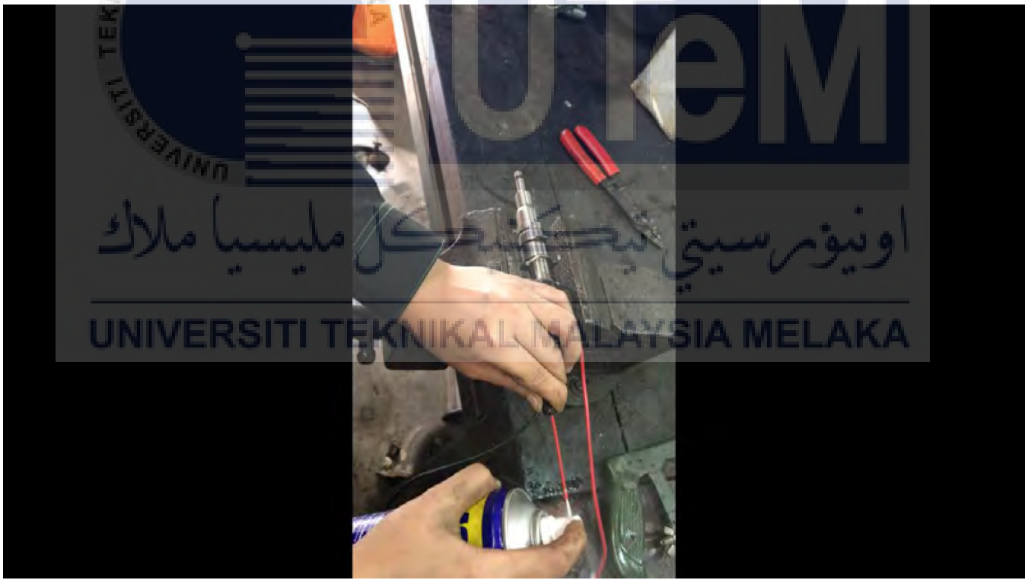
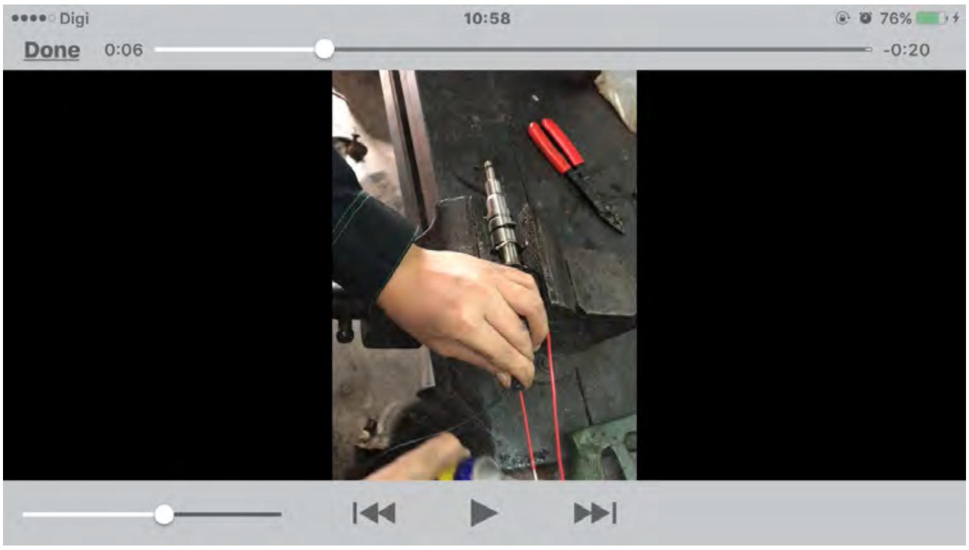
APPENDIX C

SPRAY PATTERN OF BMW INJECTOR



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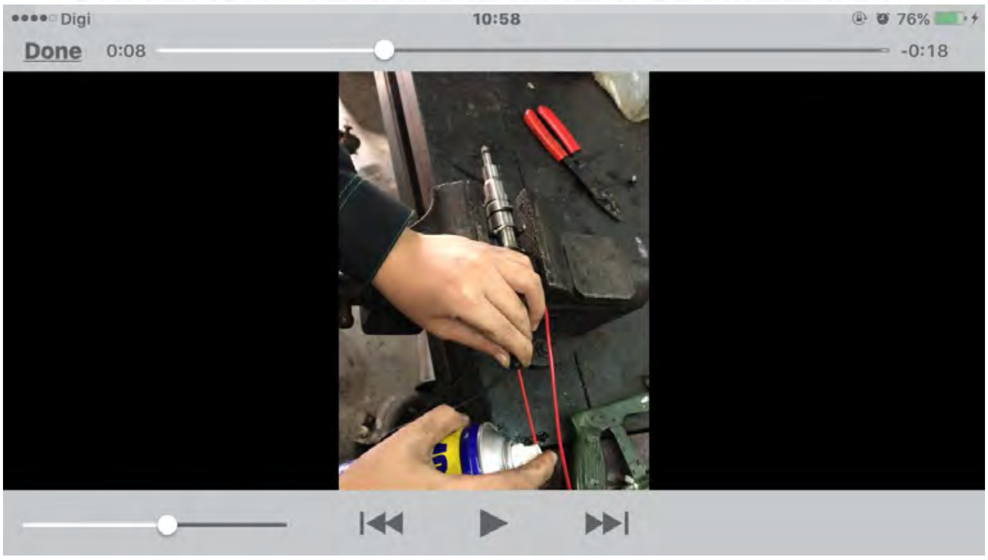
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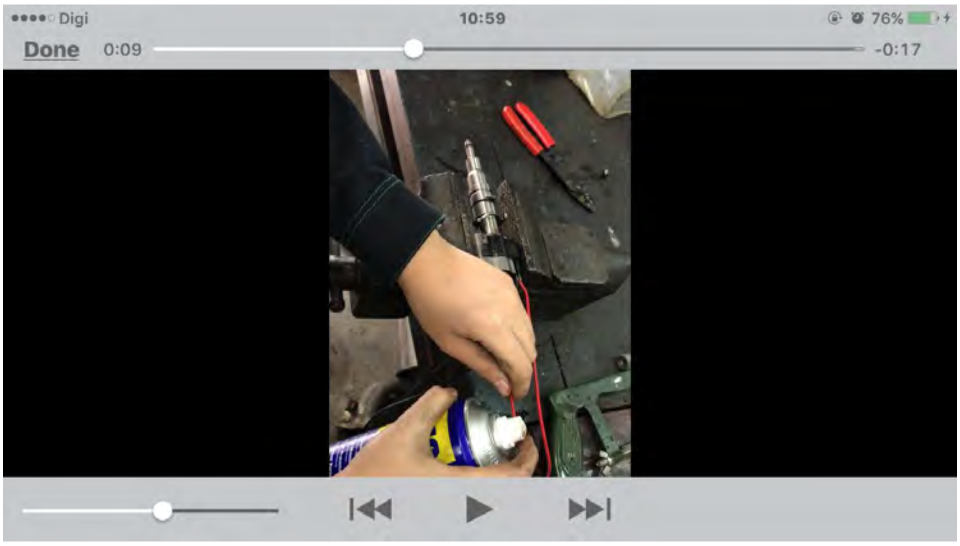
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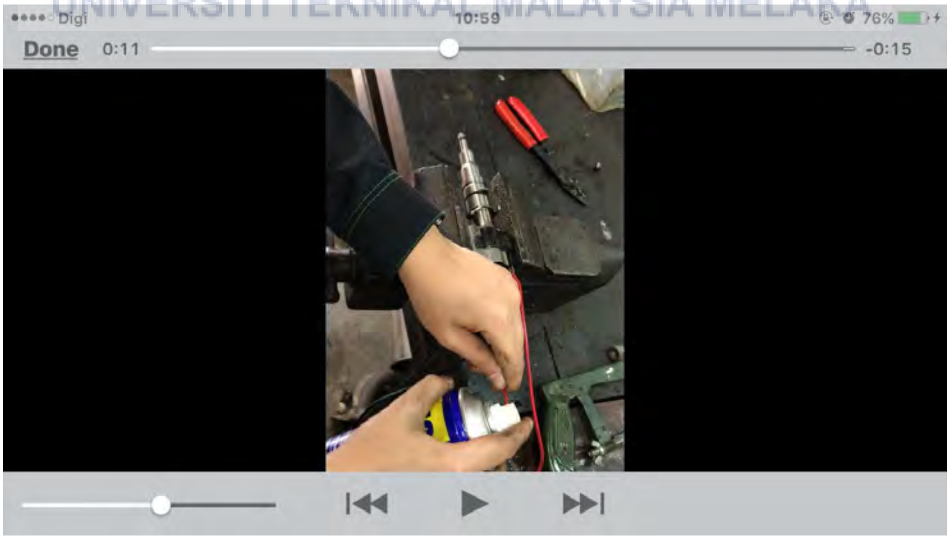
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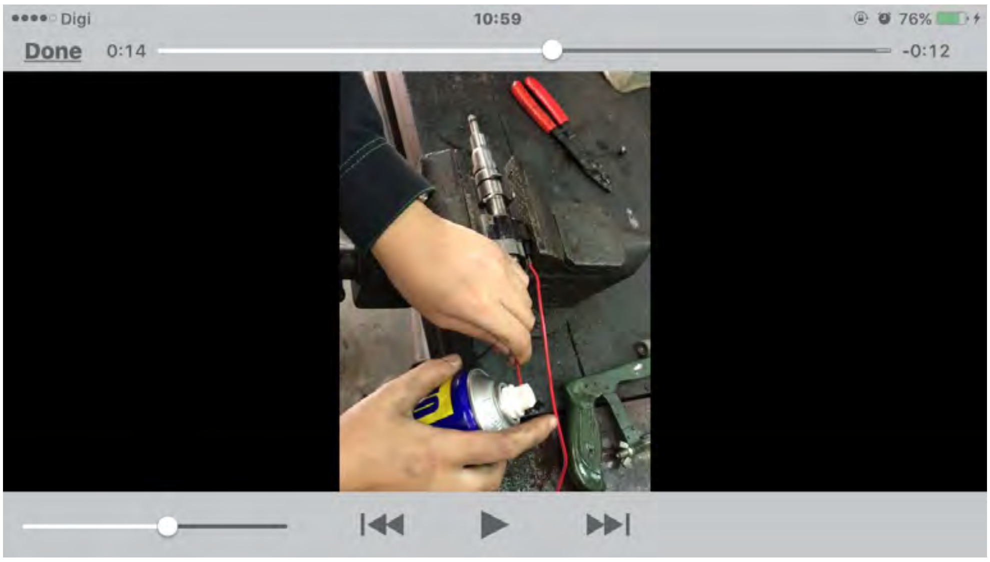
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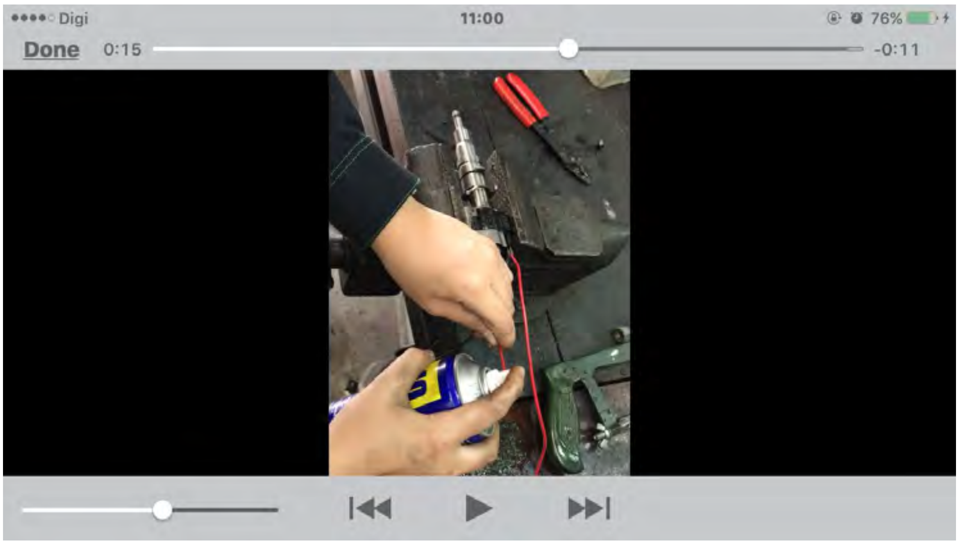
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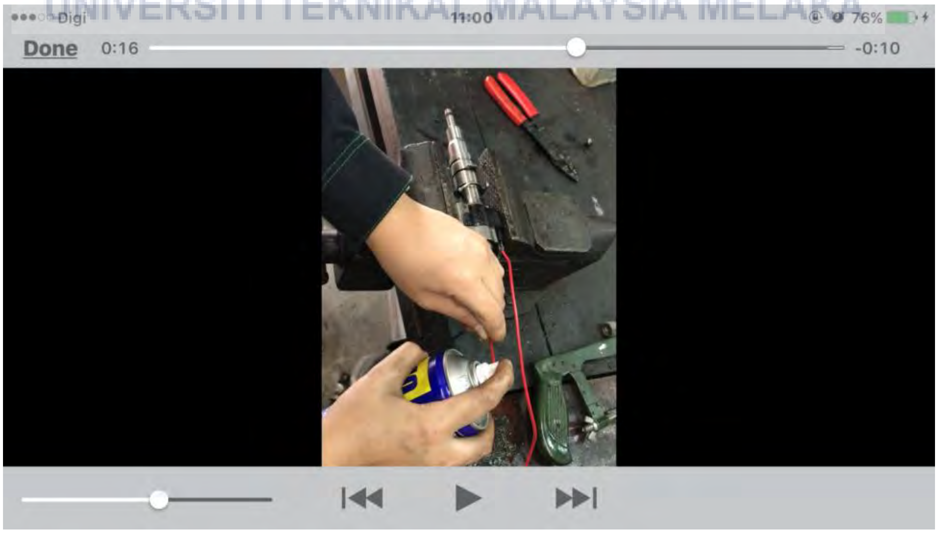
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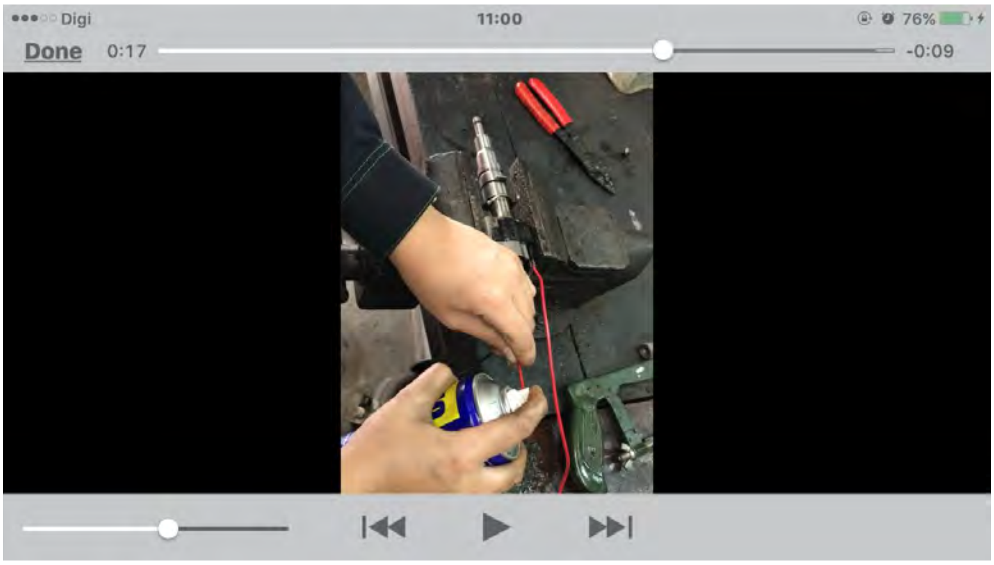
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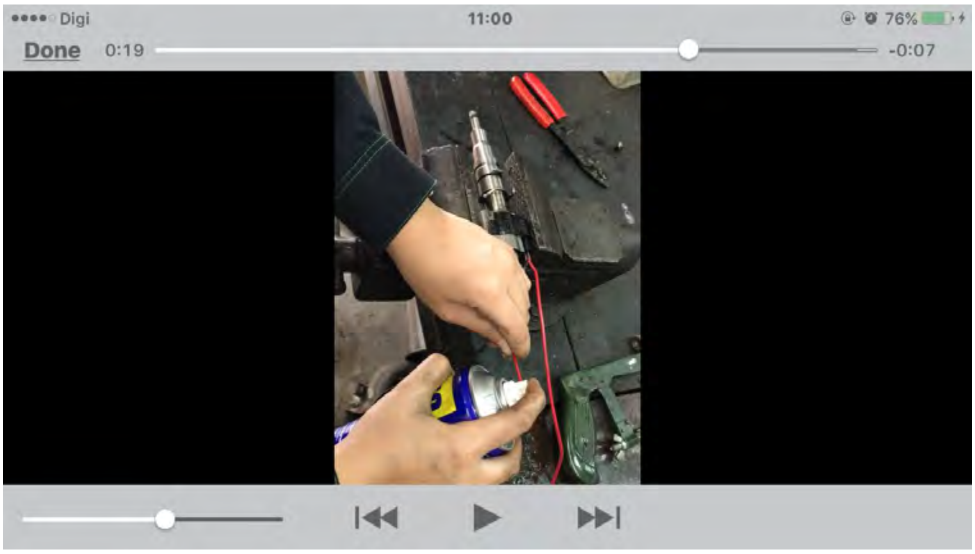
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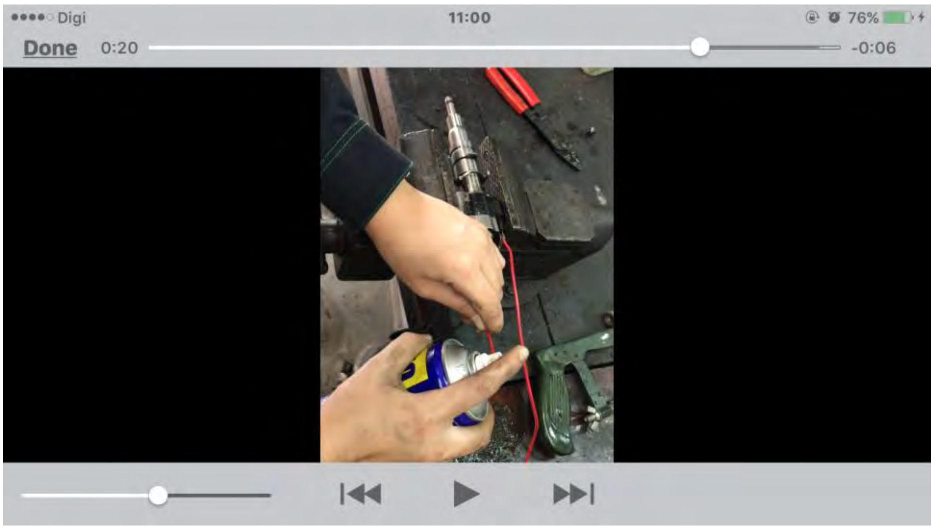
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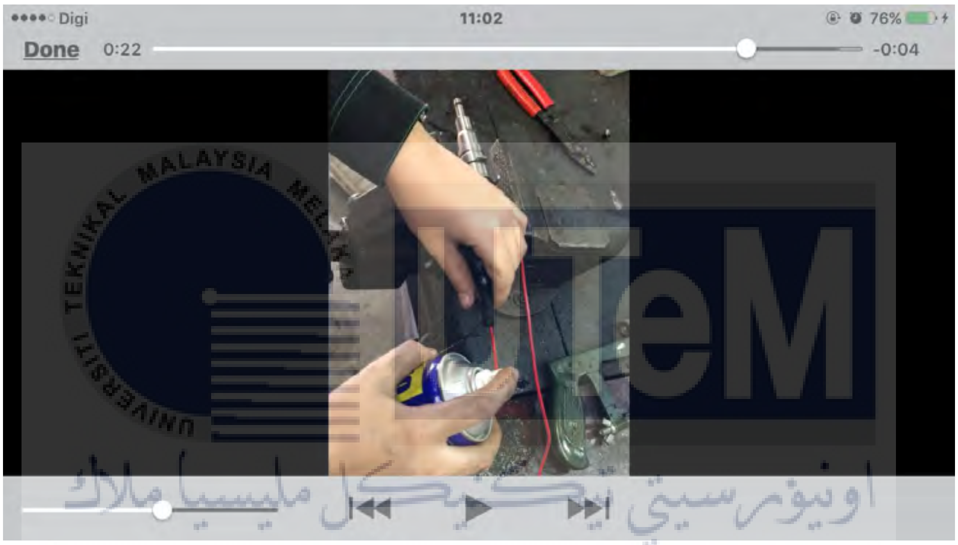
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