Development of Fuel Consumption Map of a Myvi Engine running on a mixture of RON 95 and RON 97 gasoline

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Declaration

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STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated.

Other sources are acknowledged by giving explicit references.

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Abstract

This paper aims to create a 3D fuel consumption map for a Myvi engine (Daihatsu K3-VE) running on a half mixture of RON 95 and RON 97 fuel. A burette is used as the measuring device for determining the amount of fuel consumed within a specified period of time. Before the experiment is started, the density of both fuels are determined using a measuring cylinder and an electronic digital weighing scale. The LHVs of both fuels are also determined before the experiment is carried out by using a bomb calorimeter. An engine fuel consumption map is constructed using two main data – engine speed and engine torque. It is usually done by fixing the torque of the engine and increasing the engine speed. This process is repeated with other values of torque. This means that a wide array of torque-speed combinations are needed to form the map. Because of the large amounts of data that must be collected in conventional engines, engineers are always looking for new methods of drawing more power with less fuel consumption besides manually setting the torque and speed by trial and error. One of the solutions to this problem is to create a generalization or a map whereby the desired output of an engine can be obtained simply after determining the input parameters and plugging them into the map. We are especially concerned with the change in fuel consumption in different situations governed mainly by using engine speed and torque as the input parameters. As compared to carrying out experiments to determine the desired output trend, creating the fuel consumption map can greatly reduce the amount of testing time as well as provide robust results.

Abstrak

Objektif projek ini adalah untuk membuat peta penggunaan bahan api enjin Myvi (Daihatsu K3-VE) yang menggunakan campuran RON 95 dan RON 97 sebagai sumber tenaga enjin. Burette telah digunakan untuk mengukur isi padu campuran dalam masa yang ditentukan. Sebelum eksperimen dimulakan, ketumpatan kedua-dua bahan api telah ditentukan dengan menggunakan silinder pengukuran dan penimbang berat digital. Selain itu, LHV kedua-dua bahan api juga ditentukan dengan mengggunakan bomb calorimeter. Dalam kajian yang dibuat sebelum ini, enjin yang konversional telah digunakan dan banyak data perlu diambil dengan menukarkan parameter secara manual. Ini telah menyebabkan kajian-kajian ini ambil masa yang panjang dan penemuan dari kajian-kajian ini tidak semestinya tepat. Salah satu penyelesaian kepada masalah ini ialah untuk membuat satu peta yang boleh menunjukkan parameter yang diingini apabila input dimasukkan ke dalam peta tersebut. Dalam projek tersebut, khuatir utama ialah penggunaan bahan api alternatif dalam situasi-situasi yang berlainan. Situasi-situasi tersebut akan diubahkan dengan menukarkan input iaitu kelajuan enjin dan tork enjin. Dibandingkan dengan melaksanakan eksperimen-eksperimen yang mengambil masa untuk dilengkapi, pembuatan peta penggunaan bahan api tersebut boleh menolong untuk mengurangkan masa yang diambil, kos tetapi masih boleh memberi output yang tepat.

CHAPTER 1 INTRODUCTION

1.1 PROJECT OVERVIEW

The most commonly used petroleum products used in internal combustion engines are petrol and diesel. Consumption of these products are increasing year by year and they will continue to increase due to increasing number of vehicles across the globe. It is the same case in Malaysia. This has caused the demands for these petroleum products to steadily increase over the years. Fearing these products may become insufficient to meet demands in the near future, it is necessary to think of ways to decrease fuel consumption or improve the performance of internal combustion engines or both [1]. In the paper titled 'Modelling of flame propagation in the gasoline fuelled Wankel rotary engine with hydrogen additives' by E A Fedyanov, E A Zakharov, K V Prikhodkov and Y V Levin, a blend of 70% gasoline and 30% hydrogen was used to accomplish combustion near the T-apex in the stoichiometric mixture. While the paper focuses on the type of additives to be added to conventional petroleum to achieve the aforementioned objectives, this paper aims to figure out the effects of mixing two fuels at a 50-50 ratio volumetrically, on the fuel consumption of the engine used (Perodua K3-VE).

A fuel consumption engine map is a 3D map comprised of engine speeds in revolution per minute (RPM), load torque (T), and the fuel consumption (grams/second). In other words, the fuel map is essentially a summary of the engine's entire operating regime, from an idle state to full load at full throttle and every possible situation in between. [2] In this project, a Myvi engine running on a volumetrically half mixture of RON 95 and RON 97 petrol, is used to develop the fuel consumption engine map. Based on the map, the fuel consumption at certain loads and engine speeds can be determined. The optimum zone of high thermal efficiency for all range of engine speeds and loads can also be obtained.

It is also important to note that every engine has its own mapping. Manufacturers of the engines usually have the 3D fuel consumption maps but it is very hard to get as the manufacturers are not keen to disclose such information to just anyone. Since every engine has its own map, deciding which engine to work with is also an important aspect to consider if the results obtained from this study were to be utilized to its full potential.

In June 2017, Perodua Myvi's manufacturer, established in 1993, Perusahaan Otomobil Kedua Sdn Bhd, PERODUA achieved a new milestone when the company sold 1 million units of Myvi vehicles since its production in 2005 and the number of these vehicles sold continues to increase by the year [3]. Since the car has now become a popular choice among Malaysians, it seemed to be of best interest to this study if it was carried out using a Myvi engine. This study aims to develop a fuel consumption engine map for a Myvi engine running on a volumetrically half mixture of fuels RON 95 and RON 97.

1.2 PROBLEM STATEMENT

Countless researches have been done for various engines (compression ignited and spark ignited) running on conventional petroleum with additives or a mixture of alternative fuel sources with conventional ones. However, there are very few papers on engines running on a mixture of two different conventional petroleum products. Hence, this paper uses a mixture of two conventional petroleum products which are also the main petroleum products in Malaysia – RON 95 and RON 97.

1.3 OBJECTIVE

This project aims to:

1. Measure the effects of using a mixture of RON 95 and RON 97 fuels as the fuel source to the fuel economy of an engine, specifically a Myvi 1.3L engine.
2. Measure the fuel consumptions at different speeds and different torque values and producing a 3D fuel consumption map.
3. Compare between the two products, namely the density and LHV.

1.4 SCOPE OF WORK

One of the limitations of this project is the fact that the cooling system used on (cooling tower) the engine is less than ideal. The engine is mounted onto dynamometer and relies on only a cooling tower which uses water as the cooling agent to cool it down. Albeit a fan used to mimic on road conditions to cool the engine down, the cooling tower has become inefficient. This causes the likelihood of having to shut the engine down after 30 minutes, as the engine might overheat if it runs for more than 30 minutes. Therefore, devising an experiment which uses less than 30 minutes is crucial.

The development of the fuel consumption map in this project is constricted to a Myvi 1.3L engine only. The trend might be the same for other SI engines but the fuel consumption value will be different for engines with different cylinders, firing sequences, injection methods, etc.

1.5 GANTT CHART

Project Activities	Semester 1 (weeks)								Semester 2 (weeks)													
	8	9	10	11	12	13	14	15	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature review and gather information	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Determining the fuel mixture			■	■																		
Assembly and connect all the component						■	■	■														
Inspecting and checking all sensors work fine and have signals being sent from and recevied by them													■									
Making final adjustments and tweaks to ensure smooth operation of the experiments														■								
Determining the density and lower heating values of the fuels															■							
Carrying out experiments (data collection)																■	■	■				
Thesis Writing																			■	■	■	■

The details of the engine's specifications are shown in Table 1.

Engine type	**Four – stroke**
Fuel type	Mixture of RON 95 ad RON 97
Number of cylinder	4
Displacement (cc)	1298
Cylinder bore x stroke (mm)	72 x 79.7
Compression ratio	10
Cooling type	Water cooling tower, fan
Aspiration	Natural Aspirated
Maximum torque	116 Nm at 3200 rpm
Maximum power	64kW at 6000 rpm

Table 1: Myvi engine specifications

CHAPTER 2 LITERATURE REVIEW

Figure A shows that Malaysia's oil product consumption shows a general increasing trend from 2005 to 2016. The unit used on the y-axis is thousands of barrels per day while the x-axis represents the year the data was recorded. It was mentioned in the previous section that the number of vehicles of a particular brand (Perodua) alone has been increasing year by year. As such, this implies a continuing reliance of the citizens of Malaysia on oil products especially petroleum for the years to come.

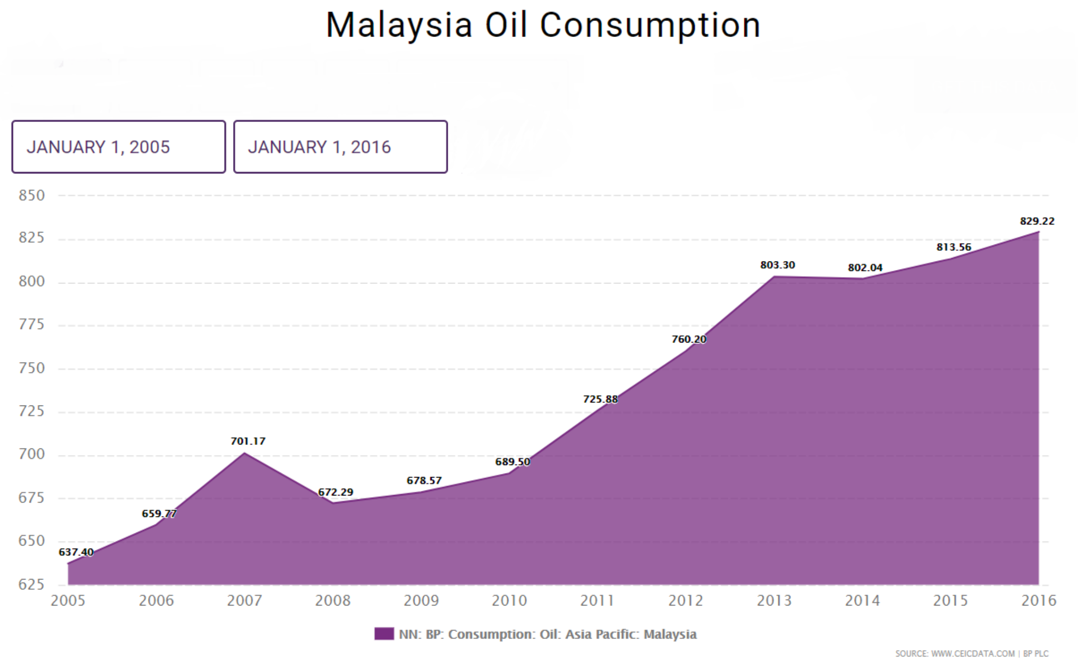

Figure 1: Consumption of oil products in Malaysia from 2005 to 2016 [4]

2.1 Spark Ignited Engines

A spark ignited engine is as the name suggests, an engine which uses an ignition source to initiate the combustion process of air-fuel mixtures in the cylinders [5]. Unlike compression ignited engines, SI engines require a spark plug located inside the cylinder and the spark generated by the plug is controlled by the Electronic Control Unit (ECU) of the engine. The fuel-air mixture pumped into the cylinders will not be ignited without a spark plug as the pressure and temperature in the cylinders are not high enough to cause self-ignition of the fuel. This also allows the ECU to automatically control the ignition timing of the fuel-air mixture in order to prevent damage to parts and loss in power of the engine.

A four-stroke cycle engine is an internal combustion engine that utilizes four distinct piston strokes (intake, compression, power, and exhaust) to complete one operating cycle. The piston make two complete passes in the cylinder to complete one operating cycle. An operating cycle requires two revolutions (720°) of the crankshaft. The activities in each stage are briefly described in Figure B below.

Four stroke Spark Ignition (SI) Engine

Stroke 1: Fuel-air mixture introduced into cylinder through intake valve
Stroke 2: Fuel-air mixture compressed
Stroke 3: Combustion occurs and product gases expand doing work
Stroke 4: Product gases pushed out of the cylinder through the exhaust valve

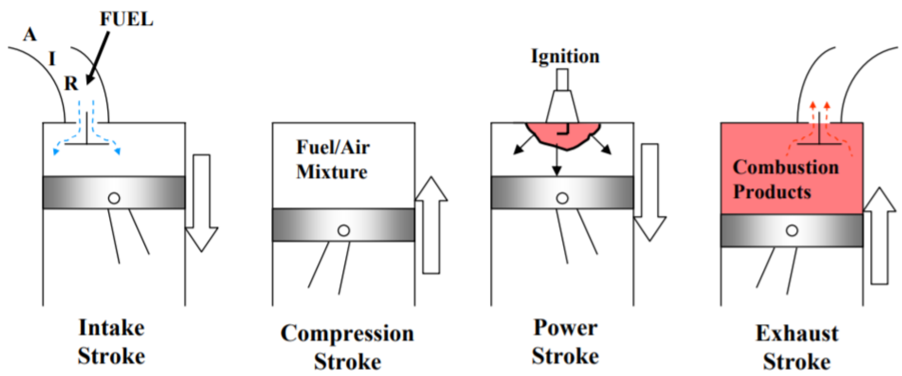

Figure 2: Brief Overview of 4-Stroke Spark Ignited Engine

Intake stroke: The intake event is when the fuel-air mixture is introduced to the combustion chamber (cylinder). The intake event occurs when the piston moves from TDC to BDC. This is when the intake valve opens. The movement of the piston toward BDC creates a low pressure in the cylinder. Ambient atmospheric pressure forces the fuel-air mixture through the open intake valve into the cylinder to fill the low pressure area created by the piston movement. The cylinder continues to fill slightly past BDC as the fuel-air mixture continues to flow by its own inertia while the piston begins to change direction (upwards). The intake valve remains open for a few degrees of crankshaft rotation after BDC. The intake valve closes and the fuel-air mixture is sealed inside the cylinder.

Compression stroke: The compression stroke is when the trapped fuel-air mixture is compressed inside the cylinder. Compressing the fuel-air mixture allows more energy to be released when the charge is ignited as the density of the mixture greatly increases, resulting in higher power per unit volume.

When the piston of an engine compresses the charge, an increase in compressive force supplied by work being done by the piston causes heat to be generated. The compression and heating of the fuel-air vapour in the charge results in an increase in temperature and fuel vaporization. The increase in temperature occurs uniformly throughout the combustion chamber to produce faster combustion (fuel oxidation) after ignition. The increase in fuel vaporization occurs as small droplets of fuel become vaporized more completely from the heat generated by the increasing in-cylinder pressure.

The energy needed to compress the charge is substantially less than the gain in force produced during the combustion process. For example, in a typical small engine, energy required to compress the charge is only one-fourth the amount of energy produced during combustion.

The volume of the combustion chamber when the piston is at TDC is called the clearance volume. The compression ratio of an engine is the ratio of the volume of the whole cylinder to the clearance volume. Petrol engines commonly have a compression ratio ranging from 6:1 - 10:1. The higher the compression ratio, the more efficient the engine is in converting raw fuel into usable mechanical energy. A higher compression ratio usually provides a significant gain in combustion pressure or force on the piston.

Power Stroke: The power stroke is where hot expanding gases force the piston head away from the cylinder head or spark plug. Piston force and subsequent motions are transferred through the connecting rod to apply torque to the crankshaft. The torque applied initiates crankshaft rotation. The amount of torque produced is determined by the pressure on the piston and the size of the piston. Both intake and exhaust valves are closed during this stroke.

Exhaust stroke: The exhaust stroke describes the process where remaining gases in the combustion chamber are expelled after the combustion process and released to the atmosphere. The exhaust stroke is the final stroke and occurs when the exhaust valve is open and the intake valve is closed. Piston movement pushes exhaust gases out to the atmosphere.

As the piston reaches BDC during the power stroke, combustion is complete and the cylinder is filled with exhaust gases and sometimes, unburnt fuel. The exhaust valve opens and inertia of the flywheel and other moving parts push the piston back to TDC, forcing the exhaust gases out through the opened exhaust valve. At the end of the exhaust stroke, the piston is at TDC and one operating cycle has been completed.

2.2 Engine Parameters

Brake specific fuel consumption (BSFC) represents the amount of energy obtainable from a specific amount of fuel. Basically, it is a measurement of how efficient an engine is at converting raw fuel source into usable power. Depending on the region where the vehicle manufactured will be driven in, the gearing of the transmission of the engines are usually tuned to produce an engine speed which gives the lowest BSFC when the vehicle approaches the speed limit of the region. For example, the speed limit of a vehicle on a highway in Malaysia is 110 kmph. This means that the final speed a vehicle being driven on the highway would usually end up being 110 or close to that number. The gear transmission tuned for the lowest BSFC setting at this particular engine speed would give the highest engine efficiency, giving the most worth to end consumers who spend their money on petrol.

There are a number of factors affecting the BSFC of an engine [6]. First, the engine speed. The engine speed parameter matters for mainly two specific reasons – heat absorption and air velocity. At a lower engine speed, the air velocity is not moving fast enough to efficiently atomize the fuel while at higher engine speeds, the fuel is unable to absorb much heat before being ignited, resulting in inefficient burning of the fuel. The engine speed is affected by the load which depends on how much the throttle is opened. The air velocity is low when the throttle is nearly closed and increase as the throttle opens more and more.

Compression ratios is directly related to the amount of power an engine is able to produce, provided other major factors such as number of cylinders, cylinder size and injection systems are the same. The higher the compression ratio, the higher the engine power and the lower the BSFC. However, too high of a compression ratio will cause knocking and pinging of the engine as the fuel in the engine might be ignited uncontrollably due to the high temperatures in the cylinders caused by the high pressures [7].

The temperature of air entering the engine plays a role in the atomization of the fuel as well. Warmer air provides lower BSFC than when an engine is fed with cooler air to form the air-fuel mixture as the fuel atomizes more efficiently. However, this is usually achieved using an Exhaust Gas Recirculation (EGR) system whereby a portion of exhaust gases of high temperature is redirected into the intake manifold to increase the overall temperature of the intake air. The engine used in the experiments does not have the system installed.

2.3 Journal Reviews

One important thing to note is that the standardized test cycles will always be different from real life on-road driving conditions [8]. This is due to a number of factors listed below:

1. The presence of different ambient temperature, pressure, track temperature and air velocity (wind). In Malaysia, the ambient temperature has a narrower range compared to countries with four seasons where temperatures fluctuate greatly between summer and winter season.
2. Standardized tests require the engine to deliver a constant flow of power independent of vehicle class. This is usually the case for final drive patterns on highways and freeways but is almost never the case for on-the-road conditions. Consumers need to make turns, slow down when in different speed zones, accelerate from near idle after going over a hump, etc.
3. The presence of inclines on roads. Going uphill requires more power to be delivered from the engine to compensate the gain in potential energy. However, during the downhill movement, this energy is not fully converted into mechanical energy which moves the vehicle. The difference in the energy imbalance is due to the potential energy being dissipated and wasted.
4. Aggressive driving behaviour. As everyone is different, each consumer has their own style of driving or handling a vehicle. This means each individual vehicle will have its own level of acceleration and deceleration depending on who is the

handler. This is not a standardized factor and so, can never be accurately recreated in any experimental sessions.

Generally, there are two different mathematical approaches currently used to estimate second-by-second fuel consumption namely modal models based on vehicle speed vs acceleration profile and power-based models. The former does not take into account a test vehicle's characteristics (mass, volume, etc.) while the power-based models do account for the vehicle's characteristics and consider physical laws revolving around an operating engine [9]. In this paper, the former is used whereby the engine is taken out of the vehicle and mounted onto the test bed. This allows for more controllable conditions (temperature, air velocity) for which the experiments are carried out in.

In another paper by Dr. Muhammad Iftishah Ramdan titled 'Perodua Myvi engine fuel consumption map and fuel economy vehicle simulation on the drive cycles based on Malaysian roads', the fuel consumption map was created using city and highway drive cycles on Malaysian roads. In the paper, the units used for fuel consumption rate was in km/L. This unit is the general unit used when major car brands sell their vehicles' fuel-related economic features. It was not mentioned which type of gasoline was used in the paper. The results from the paper show that the vehicle is able to run for 9.77km per litre of fuel on a city drive cycle while 12.77km per litre was observed when on the highway drive cycle.

CHAPTER 3 METHODOLOGY

3.1 Flow chart

PHASE 1 – FUEL MIXTURE

- Figuring out the most efficient way to mix both RON 95 and RON 97 fuels
- Purchasing all parts and components and putting them in place
- Determining the density of each fuel
- Assembling the parts and check for leakages
- Check all sensors and ports to make sure they emit and receive signals

↓

PHASE 2 – TESTING AND REFINING

- Determining the temperature of the engine whereby overheat is almost achieved using thermocouple
- Refine the method of collecting data (i.e. position of burette to prevent parallax errors)
- Make sure all the engine parts are working as should be to ensure smooth flow of experiments
- Test run using dynamometer before beginning data collection phase

↓

PHASE 3 – EXPERIMENT AND PERFORMANCE EVALUATION

- Measurement of fuel consumption rate
- Plot graphs and maps
- Analysis of data collected through graphs and maps
- Performance evaluation based off analysis

Figure 3: Project Flow Chart

3.2 Engine

The engine used in this paper is the Perodua Myvi 1.3 litre K3-VE engine with four in-line cylinders and port fuel injection system.

Figure 4: Perodua Myvi 1.3L K3-VE

3.3 Dynamometer

The eddy current dynamometer is connected to a controller where the engine speed or torque can be controlled. For example, for a fixed engine speed (controlled by the dynamometer controller) of 1500 rpm, the maximum allowable speed attainable by the engine will be 1500 rpm. Any increase in throttling will cause an increase in load torque which is measured by the dynamometer. It is the same when it comes to a fixed load torque. Fixing a load torque means that the dynamometer is constantly applying a load on the engine. Any increase in throttling will increase the engine speed but not the load applied to the engine.

Figure 5: Eddy current Dynamometer

3.4 Dynamometer controller

The dynamometer is coupled with a controller which receives speed and load cell signal as input signals and manipulates the current to the dynamometer to apply torque. The inductive speed sensor reads changes in magnetic flux from a gear mounted to the dynamometer's shaft. The gear has teeth which provide changes in magnetic flux and hence produce a sinusoidal wave signal. It is equipped with an internal strain gauge amplifier to condition the low voltage signal from the load cell. In an effort to create the performance curve of an engine, the engine speed is usually fixed using this controller while the engine runs on wide open throttle (WOT).

In this experiment, the fuel consumption map of the Myvi engine is the objective and so the feature of the controller used is to fix the torque induced onto the engine. When a torque of certain value is selected, the dynamometer will make sure that the engine does not run with a load torque of more than the selected value. The only few major parameters which will change are the engine speed (which is controlled by the throttle) and the temperature of the engine.

Figure 6: Dynamometer controller (DC2AP)

3.5 Miscellaneous apparatus

3.5.1 Storage tank

A small 4L* plastic storage tank was used to capacitate the mixture of fuels in the experiment. A hose with a valve is connected at the bottom of the tank where when the valve opens, the hose transports the fuel mixture to the burette. The mixture then flows into the pump and is fed into the engine.

Figure 7: Storage tank

3.5.2 Measuring cylinder

The capacity of the measuring cylinder is 1L with a resolution of 10 ml. It is also used in determining the density of each fuel (RON 95 and RON 97).

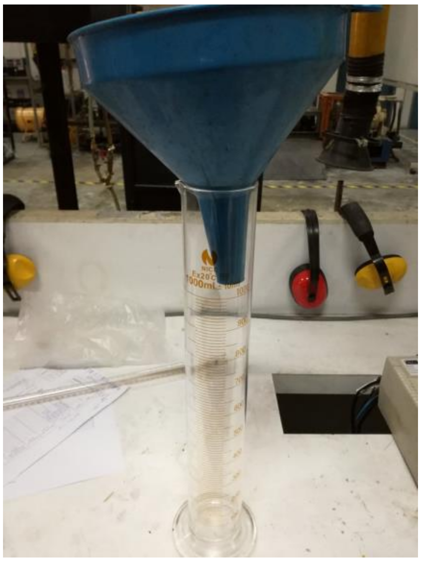

Figure 8: Measuring cylinder

3.5.3 Burette

A burette is used as the measuring tool to determine the amount of fuel consumed after a selected volume of fuel is burnt during the run of the experiment. At lower speeds, there is no need for the engine to run for extensive periods of time. This will help save time and costs of buying and mixing the fuels. For example, at 1500 rpm and 15 Nm, the time taken to consume 20 ml of the fuel mixture was found to be around 40 seconds. Using a fixed volume of 40 ml would have required the engine to be run for more than 80 seconds at the same settings, consuming more fuel than needed.

Figure 9: Burette

$$\text{Flow rate} = \frac{V}{t}$$

Where

V = Volume of fuel consumed

t = Time taken to consume the fixed volume of fuel mixture used

3.6 Cooling tower

A cooling tower is used to remove heat generated in the eddy current dynamometer to prevent the dynamometer and engine from overheating and negatively affecting the testing operation. The dynamometer is connected to the cooling tower through piping. The cooling agent is water as it is being pumped through the dynamometer and cools the dynamometer down. The system feeding the water to and from the dynamometer is a closed loop system to prevent wastage of water.

Figure 10: Cooling tower

3.7 Load cell

A load cell is used in measuring the torque produced by an engine. The rotation of the dynamometer from the engine is resisted by the load cell, causing a small compression or tension force on the load cell. After the load cell is mounted on the dynamometer, the load cell is connected to a load cell amplifier, generating an electrical output to be read by the dynamometer controller. The load cell was installed by using rod end ball-joint on the side of dynamometer.

Figure 11: Load Cell

3.8 Density of fuels

In this experiment, the fuel source fed into the engine is a half mixture of both RON 95 and RON 97 petrol. The density of both fuels was determined using a measuring cylinder to measure the volumes of both fuels and a digital weighing scale was used to measure the weight of both fuels. The properties of fuels were measured separately (before mixing).

A clean empty measuring cylinder of capacity 1L was placed on a digital weighing scale and the reading on the scale was taken. RON 95 fuel was poured into the measuring cylinder up to the 1L mark and the fully filled measuring cylinder was placed onto the digital scale for a second reading to be taken. The difference in the two readings on the digital scale shows the weight represented by 1 litre of RON 95 petrol. Taking the division of this difference by the volume (1L), the density of RON 95 petrol was determined. The measuring cylinder was cleaned out and dried using an air gun before repeating the same procedure with RON 97.