ANALYSIS OF ARTIFICIAL SIGNALS OF CPS, SPARK TIMING, AND FUEL INJECTION TIMING TOWARD THE ENGINE BEHAVIOUR.

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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STATEMENT 1

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

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CPS	Crank Position Sensor
RPM	Revolution per Minutes
IC	Internal Combustion
EC	External Combustion
SI	Spark Ignition
CI	Compression Ignition
ECU	Engine Control Unit
DAQ	Data Acquisition
AFR	Air Fuel Ratio
N_2	Nitrogen
CO_2	Carbon Dioxide
TBI	Throttle Body Injection
MPI	Manifold Port Injection
TF	Time Frequency

ABSTRAK

Enjin pembakaran dalaman (IC) digunakan secara meluas dalam automotif. Antara jenis enjin yang boleh didapati di mana-mana automotif ialah enjin pencucuhan percikan (SI). Pertumbuhan peranti elektronik dalam sistem enjin meningkat sepanjang masa. Sistem mekanikal di dalam sistem enjin digantikan oleh sistem elektronik secara berperingkat. Unit kawalan enjin (ECU) adalah peranti yang digunakan untuk mengawal semua parameter enjin sama ada percikan api, bahan api, kelajuan, dan aplikasi yang lain. ECU juga memainkan peranan penting bagaimana enjin berfungsi. Ketukan enjin memberi kebimbangan utama dalam sistem enjin. Fenomena ini berlaku kerana pembakaran tidak lengkap berlaku di dalam kebuk pembakaran. Ketukan enjin adalah kecacatan yang boleh menyebabkan prestasi kecekapan enjin berkurang dan merosakkan komponen enjin. Perkara ini boleh dikawal dengan mengubah masa percikan, menyesuaikan masa suntikan bahan api, atau menggunakan bahan bakar oktana yang tinggi. Penyelidikan ini dijalankan bertujuan untuk menganalisa isyarat buatan CPS terhadap tingkah laku enjin dan mengkaji masa suntikan bahan api ke arah fenomena ketukan enjin. Sebuah katil ujian untuk enjin Modenas GT128 direka dan dipasang pada rangka go-kart. Dengan menggunakan pengawal-mikro, kod diprogram bagi menjana isyarat buatan dan isyarat tersebut akan dianalisa. Keputusan menunjukkan bahawa isyarat buatan mampu mengubah tingkah laku enjin. Ketukan enjin boleh berlaku pada kelajuan melahu dan juga pada keadaan operasi kelajuan tinggi.

ABSTRACT

Internal combustion (IC) engine is widely used in automotive. The mainstream engine that can be found in any automotive is spark ignition (SI) engine with four stroke cycle. The growth of electronic device in engine system is increased throughout the time. Mechanical system inside the engine system slowly being replaced by the electronic system. Engine control unit (ECU) is a device that being used to control all the engine parameters whether it for is spark, fuel, speed, and other applications. ECU plays a vital role on how the engine performs. Engine knock is the major concern in the engine system. This phenomenon occurs due to an incomplete combustion inside the combustion chamber. Engine knock is a defect that may lead to less efficiency of the engine performance and damage to the engine components. This defect can be controlled by altering the spark timing or adjusting the fuel injection timing. This research is carried out with the aims to analyse the artificial signals of CPS and spark toward the engine behaviour and to study the fuel injection timing toward the knocking phenomenon. A test bed for the Modenas GT128 engine is fabricated and it is mounted onto the go-kart chassis. By using the microcontroller, a programmable code is used to generate the artificial signals and the signals will be analysed. The results show that the artificial signal is capable to alter the engine behaviour. Engine knock is possible to occur at idling speed and also at high speed operating condition.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Throughout the world transportation is part of our life whether on the land, sea and air. Any types of automobiles utilize the internal combustion engines and being developed into a variety of design for their own specific purpose. Internal combustion engine is known for their simplicity and has good power-to-weight ratio which enable it to be implemented in automobiles. In internal combustion engine the energy is released by burning or oxidizing the fuel inside the engine. The working fluids of internal combustion engine are the fuel-air mixture before the combustion and the by-product after the combustion process. The work transfers which provide the desired power output occur directly between these working fluids and the mechanical components of the engine. There are two types of internal combustion engine that presence in automotive world which are spark ignition (gasoline) engine (SI) and compression ignition (diesel) engine (CI). In the context of SI engine, it consists an engine cycle with four piston strokes. Four stroke engine involves intake stroke, compression stroke, expansion stroke and exhaust stroke in its system. However for the CI engine in general it only consists of compression stroke and power or expansion stroke[1].

Carburettor system is the common device and widely used in automobiles engine for a long time. This system is used to control the fuel flow into the intake manifold and distribute the fuel across the air stream. Venturi is a converging-diverging nozzle that the pressure of air flow through it. The pressure differences between the carburettor inlet and the nozzle throat will supplied the fuel from the high pressure position (float chamber) to the lower pressure position (throat venturi). The fuel will be atomized by the air stream and entering the intake manifold[2]. Nowadays, the carburettor is highly develop and becoming more complex device which enable it to meter the appropriate fuel flow into the air stream throughout the complete engine range. Another system that can be implemented in the engine is fuel injection system. Fuel injection system fits into two categories which are multipoint port injection and single point throttle body injection. These systems functioned in the same manner where the fuel is injected into the intake port for each engine cylinder and required one injector per cylinder. These systems both utilize mechanical injection systems and electronically controlled injection systems. Two basic approaches to the fuel injection system have been developed and the difference between the two approaches are the method to determine the air flow rate.

This project is carried out in both manner, designing and experimental. Fabrication is involved in this project where the engine mounting for Modenas GT128 engine is needs to be fabricated and mounted on the car chassis. The material for the engine mount is mild steel plate with a thickness of 3mm. CAD software is used to design the 3D model of the engine. Autodesk Fusion 360 and SolidWorks software are used in this project. Two CAD software will be used as to ease the designing process of the 3D model and to enhance my skill in CAD software. MIG welding machine will be utilized to assemble the engine mount and this machine is available in Machine Workshop School of Mechanical Engineering. After done the fabrication, the analysing of fuel consumption will be carried out by using microcontroller. Arduino MEGA also will be used in this project and the program code will be done by using MATLAB software.

There are several studies has been carried out to monitor the engine behaviour. One of the studies shows the author's ability to achieve good result in microcontroller. The microcontroller is successful to control the fuel injection into the cylinder and almost to obtain an ideal air-fuel ration which is 14 with 95.3% of engine performance. In other study on processing signal, the author is able to determine the peak signal-to-noise ratio for the filter. The peak signal-to-noise ratio is calculated for each cut-off frequency that been carried out throughout the experiment. In the study of engine knock, the author developed a calibration for a knock sensor.

1.2 Problem Statement

Spark ignition engine (SI) utilizes the fuel injection system to supply the fuel to the combustion chamber. This system is a closed loop system with the aid of an engine control unit (ECU). The usage of the ECU system is to control the amount of fuel that need to be supplied to the combustion chamber. Complete combustion is very essential in every engine system where the quantity of air and fuel inside the engine are balance which indicate a complete combustion process with no excess oxygen. However, the ideal system is hard to achieve and incomplete combustion process sometimes may occur inside the engine system. SI engine is widely used for automobile engine and based on the journal of Development of Fuel Metering Techniques for Spark Ignition Engines (2017), there is approximately 6 billion automobiles operating worldwide and there will be an increment of 35% by 2020. The rapid increase of automobile may lead to short demand issue where the supply of crude-oil cannot cope with the demand because the fossil sources will be depleted in due course[3].

The current issue happening in Malaysia is that we experienced the up and down situation in oil price significantly. This matter is concerning everyone in every aspect especially the fuel consumption for their vehicle. The utilization of fuel efficiency system is very essential to be implemented in engine system. The fundamental of fuel saving is based on the efficiency of the dedicated engine to convert fuel chemical energy to power. The imperfection of combustion process inside the engine will affects the reaction between the fuel and the oxygen and cause the imbalance air-fuel ratio. Due to this issue the engine performance will be depleted and less efficient.

Engine knocking also contribute to less fuel efficient system. Knocking can cause damage to engine components and affect the engine behaviour. The result of knocking phenomenon can be observed through the high frequency pressure oscillations which causes the depletion of power density and increase the fuel consumption.

1.3 Objectives

The objectives of the project are as below:

1. To design and fabricate the engine mounting for Modenas GT128 engine.
2. To analyse the effect of artificial signals of CPS and Spark toward the engine behaviour.
3. To study the timing of the fuel injector toward the knocking phenomenon.
4. To modify the carburettor engine system into the fuel injection engine system.

1.4 Scope of Work

The project is focused more on the study of artificial signals of crank position sensor (CPS), spark plug timing, and fuel injection timing. The timing for the fuel injector and spark plug are controlled by using the microcontroller. This project is carried out to modify the carburettor engine system into the fuel injection engine system. The ECU system will be replaced by the microcontroller as its control system. The balance amount of fuel entering the combustion chamber will be monitored to enable the engine to be operated at optimum performance and become more efficient especially in fuel consumption.

This project viewed the effect of engine knock to the engine behaviour by analysing the potential damage that may cause by the knocking. Engine knock will cause damage to the piston ring, erosion at cylinder head, and exhaust valve melt. Cylinder pressure is the parameter to be measured because the cylinder pressure will increases twice when knocking happen. The fabrication of the engine mounting also included in this project. Simple and compact engine mounting design is required to fit the engine into the car chassis. The assembly of the engine mounting will be carried by using MIG welding machine.

1.5 Thesis Outline

This thesis consist five chapters that describe the overall information and detail regarding this final year project. The description of the project is written in the introduction up to the conclusion with the title of Analysis of Artificial Signals of CPS, Spark Timing, and Fuel Injection Timing toward the Engine Behaviour. Chapter 1 is the introduction of the project where the background of the research, problem statement, research objectives, and scope of the project being described.

Chapter 2 highlight the literature review which the fundamental component of the project structure. A review on the journal, articles, books, and webpages is done with the research materials are related to the project that being carried out. While in Chapter 3, the methodology of the project will be explained in this section regarding the procedure, calculation, and analysis on how the project being conducted.

Next, the result and discussion that been obtained from the experiment will be briefly described in Chapter 4. The data of the artificial signals and the result of static stress simulation will be displayed in this chapter. Lastly, final piece of this thesis is Chapter 5 which conclude the project and summarised the achievement and implementation of this project. Future suggestion and limitation will be briefly explained for further improvement. Figure 1.1 shown the overall outline of this thesis.

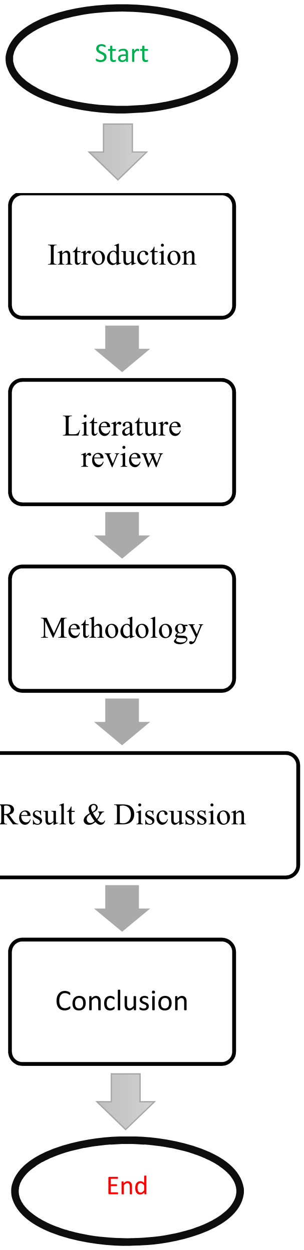

Figure 1.1: Thesis Outline

CHAPTER 2

LITERATURE REVIEW

2.1 Internal Combustion Engine

Internal combustion engine is the common engine or the prime mover in automobiles. The operating principle of the internal combustion engine is performed when the combustion occurred and applied direct force to the engine components that involved in the system. The combustion is produced due to the expansion of the high-temperature and high-pressure gasses inside the combustion chamber[4]. The rapid growth of technology in automobile affected the development of the internal combustion engine. The future of internal combustion engine lays on the cost and availability of suitable fuels, and the development of an alternative power plants which can enhance the operating principle of internal combustion engine. There are two types of internal combustion engine that are available to be used which are spark ignition and compression ignition engine. The consideration of two factors above is essential when developing these two types of internal combustion engine[5].

Gasoline is a popular choice for the people to go for their automobile. Spark ignition (SI) engine used gasoline as the fuel of the system. The operating principle for SI engine showed the combustion occurs when the electrode of the spark plug sparks and ignites the fuel inside the combustion chamber. Fuel metering study is carried out for the development of SI engine. Fuel-metering approach covered, from the least to the most modern, include carburettor, throttle body injection (TBI), manifold port injection (MPI), and gasoline direct injection (GDI). Based on the comparative study it showed a significant variations in cylinder to cylinder mixture distribution for both liquid and gaseous (LPG) phases. The result verified the power and efficiency advantages of liquid phase injection over gaseous phase injection and the analysis showed the charge state at the end of compression is the major contributor to the performance difference. The lower temperature combustion with liquid phase LPG delivers substantial NOx emission reduction. The results suggest that there are many factors beyond injection type that influence the comparison of the single-cylinder engine. The difference between-LPG and G-LPG behaviour is not only dependent on the cylinder to cylinder variation but also on the combustion chamber shape, the thermal conductivity of the materials used to produce the engines, the spark plug location and the piston shape. Improvement on the mixing gas is the key to achieve an equal performance of G-LPG and L-LPG[5].

Emission legislation has become progressively tighter and make the development of new internal combustion engines very challenging. New engine technologies for complying with these regulations introduce an exponential dependency between the number of test combinations required for obtaining optimum results and the time and cost outlays. The implementation of trained neural networks in combination with Design of Experiments (DoE) methods shows promising potential in engine calibration. The advantages of artificial neural networks, it performs better in satisfying a majority of the modelling requirements for engine calibration. In the area of spark-ignition engine calibration, these networks have been applied in the areas of system identification for rapid prototyping, use of neural networks as look-up table surrogates, emerging control strategies and other applications. The use of recurrent neural networks makes the execution of the neural network faster and relatively easy to implement. Even though there was a variation in the number of inputs to the various neural networks for the various applications, all the inputs were within the range (5–10 inputs) considered appropriate for engine calibration tasks. The Gaussian process modelling holds a promising future for modelling for the purpose of engine calibration because it also satisfies almost all the aforementioned calibration requirements[5].

2.2 Fuel Injection System

There are two types of fuel injection system that available:

Multipoint Port Injection (Indirect Injection).

This system requires one or more injector per cylinder to supplement the fuel flow during starting and warm-up. This system can be controlled mechanically and electronically. Port fuel injection is capable to increase the power and torque through volumetric efficiency and uniform fuel distribution. In general, fuel injection allows the amount of the fuel being injected to the combustion chamber to be varied in response to inputs derived from the sensors. Figure 2.1 shows the schematic of a speed-density system. In this system the engine speed, manifold pressure, and air temperature are used to calculate the engine air flow. The electrical driven fuel pump will delivers the fuel to the fuel line and the pressure regulator will maintains a constant fuel pressure drop across the injectors[1].

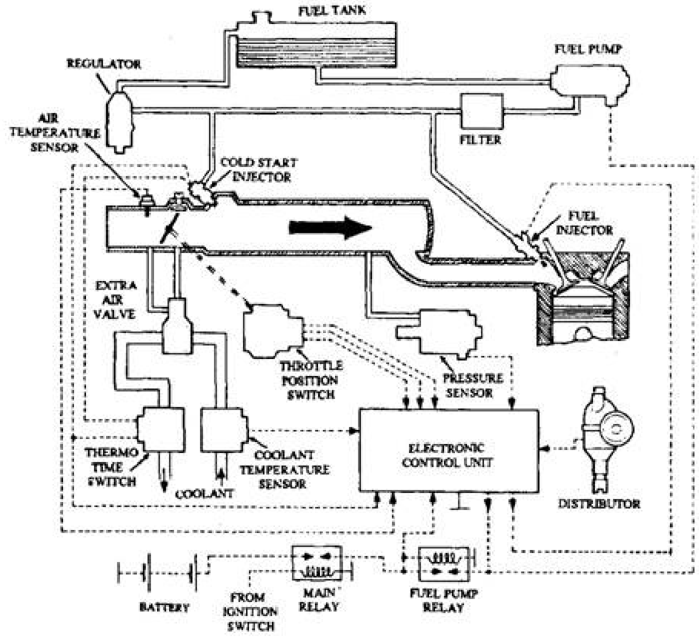

Figure 2.1: Speed-density system: Bosch D-Jetronic System [13]

Y. Zhuang (2009) reported that the combination of gasoline port injection (GPI) and ethanol direct injection (EDI) which can provides a solution to fuel blending problem. This problem will leads to knocking phenomenon and it is crucial to overcome this matter in the development of downsizing and high efficiency SI engine. EDI + GPI has great potential in anti-knocking. By directly injecting ethanol into the combustion chamber, blending ratio can be adjusted according to the engine conditions and the engine’s anti-knocking ability will be strengthened by not only the ethanol’s high octane rating but also its great latent heat. The result shows the combination of EDI and GPI also showed benefits to combustion, indicated thermal efficiency and emissions due to the advanced spark timing and ethanol’s oxygen content and fast laminar flame speed[6].

Single-point Throttle-Body Injection (Direct injection)

Figure 2.2 shows the schematic diagram of the single-point throttle-body injection. This system uses one or two electronically controlled injectors meter the fuel into the air flow above the throttle body. This configuration provides straightforward electronic control of fuel metering. However it associated with slower transport of fuel then the air from the upstream of the throttle plate. The smoothness of fuel injection pulse is achievable over the time by proper placement of fuel injector assembly above the throttle bore and plate.

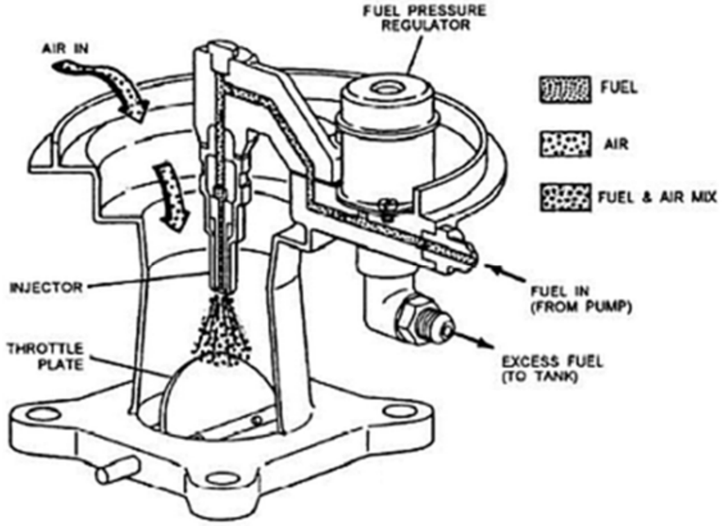

Figure 2.2: Cutaway drawing of one injector throttle body fuel injection system [14].

T. Wang (2017) stated that the later the fuel being injected, the in-cylinder velocity magnitude increase and enriched the fuel mixture which contribute to better combustion. This result is observed through the Large-eddy simulation of fuel injection and combustion in direct-injection natural gas engine. The combination of port injection and direct injection systems show a potential to increase the thermal efficiency of a single cylinder engine and reduce the engine knock [1][7]. The development of fuel injection system is widely conducted to optimize the operating condition of the engine and the fuel injection system. Both multipoint port injection and single-point injection are affecting the combustion process and it shows the possibility to combine both configuration to obtain much better fuel injection system.

2.3 Engine Knock

Engine knock is a phenomenon that occurred due to auto-ignition of the end gasses. This phenomenon is caused when the temperature or the pressure in the unburnt air/fuel mixture exceed the critical level. There are several plausible causes of engine knock which are high compression of air-fuel mixtures, overheated spark plug, lean fuel mixture, engine that running in high working temperature than normal working temperature, self-ignition engine oil droplet, and ignition timing too far advanced [8]. Figure 2.3 showed the comparison between normal combustion and self-ignition combustion.

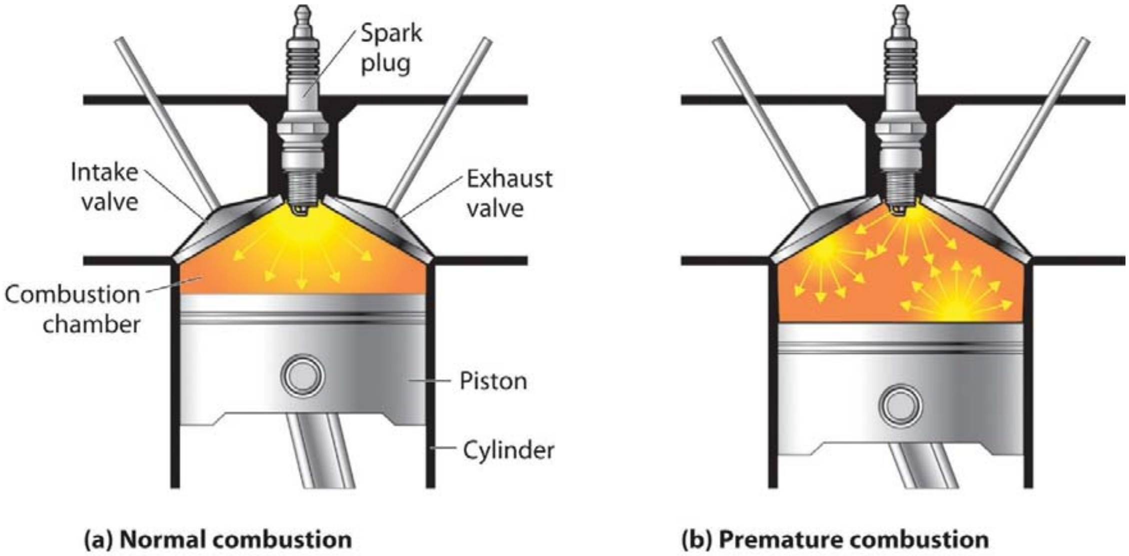

Figure 2.3: Comparison between normal combustion and premature combustion [15]

In normal combustion, the detonation occurred when the piston reached top dead centre and the spark will ignite the fuel. Meanwhile, the characteristic of premature combustion is the detonation occurred before the piston reach its top dead centre and the compress fuel will automatically ignites.

Detection of engine knock is essential to monitor the emission performance of the engine and several researches have been conducted in this area. Current spark ignition (SI) engines suffer from both normal knock and super-knock. Normal knock limits the raising of the compression ratio to improve thermal efficiency due to end-gas auto-ignition. Super-knock limits the desired boost to improve the power density of modern gasoline engines due to detonation. The research that been conducted is focused on the relationship between pre-ignition and super-knock, source analyses of pre-ignition, and the effects of oil/fuel properties on super-knock. The mechanism of super-knock can be found in rapid compression machines (RCM) under engine-like conditions and the detonation can occur in modern internal combustion engines under high energy density conditions. The effect of shock compression and negative temperature coefficient (NTC) combustion on ignition delay are compared and the result showed shock wave reflection is the main cause of near-wall auto-ignition/detonation [9].

Time-frequency is used to characterize the knocking phenomenon. The research proposed a new knock event which compares the excitation of the cylinder resonance produced by the autoignition of the end gas to that associated with the combustion. This new knock event permits a more consistent differentiation between knocking and not knocking cycles. It also allowing the improvement of the knock control strategies. The new knock index analysed the frequency spectrum of the pressure signal in two locations near the maximum heat release and near the end of combustion. Fast Fourier transform and a window function are used to make a comparison between the classical MAPO definitions which consists on finding the maximum pressure oscillation in the time domain. The results show that the improved knock index definition can substantially reduce the variability of the spark advance angle control, avoiding strong knocking events and reducing engine vibration [10].

Signature analysis consists of the extraction of information from measured signal patterns. Time-frequency (TF) analysis methods is used to construct mechanical signature analysis. Mechanical signature analysis is a mature and developed field although TF analysis methods are relatively new to the field of mechanical signal processing. This signal detection concepts in the joint TF domain can be applied for the detection of internal combustion engine knock. The intrinsically transient nature of the signal and the time-varying characteristics of its spectral content, with resonance frequencies dependent on in-cylinder gas temperatures, make the application of TF analysis suitable for engine knock detection [10].

Three researches on the engine knock above have their strength and limitation. Normal knock and super knock are able to be analysed. The effect of oil/fuel mixtures can be analysed to determine the super-knock phenomenon. Time-frequency is widely used in engine knock detection. This method is able to characterize the knocking phenomenon and construct a mechanical signature analysis. However, the limitation that present in these researches are the method that been used is complicated to be applied for this final year project and it has some constraints to it. These three researches can be used as guide to obtain and analyse the knocking phenomenon for this project.

2.4 Spark Ignition Timing

The fundamental of ignition is the spark will produced an arc at the plug electrode when sufficient voltage is applied and starts the combustion process. Spark timing is essential during the compression stroke and spark timing is set to give maximum brake torque. In automotive applications the spark ignition system is required to change the spark timing automatically vary to the engine speed and load. Spark plug is the common part in conventional ignition system. In spark plug design there are three key components which are insulator, electrodes, and a shell. Figure 2.4 shows the design of the spark plug.

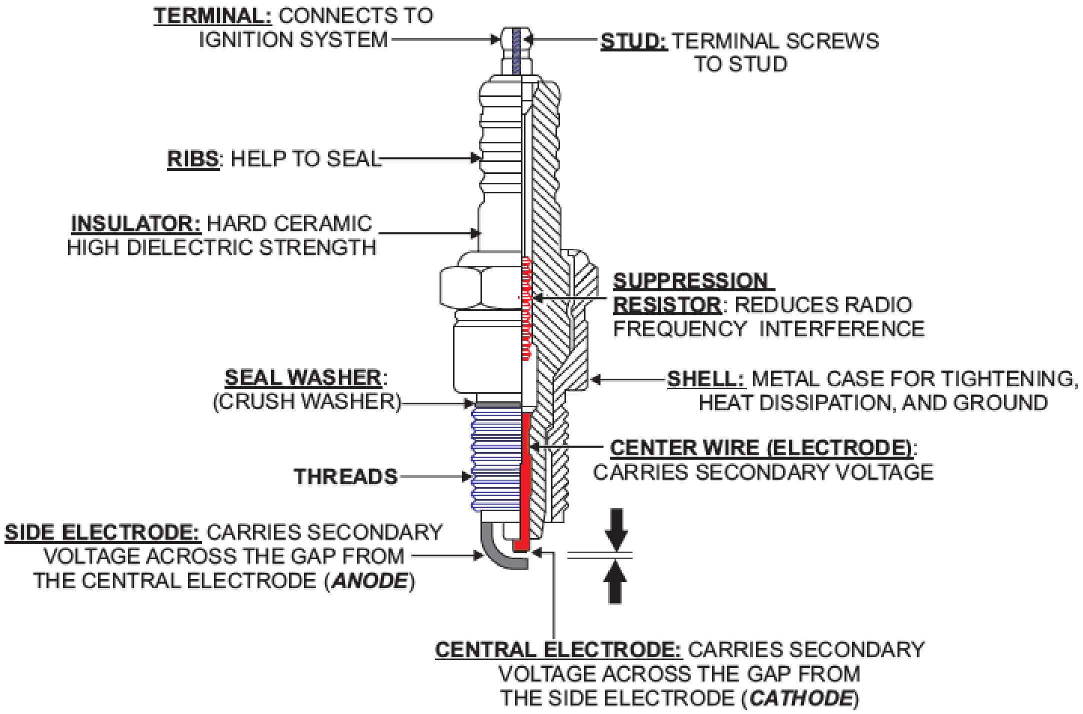

Figure 2.4: Cutaway drawing of conventional spark plug [16]

Each component of the spark plug has their own specification which adequate to thermal shock resistance, able to withstand high ignition voltage and temperature, and has special conductive seal. Spark ignition system will affect the performance of the engine. Optimal injection and ignition timings and the effects of injection and ignition timings on performance and emissions from a high-compression direct-injection stratified charge spark-ignition methanol engine have been studied and the results show that the direct-injection spark-ignition methanol engine in which a non-uniform mixture with a stratified distribution can be formed. Both methanol injection timing and ignition timing have significant effect on methanol engine performance, combustion, and exhaust emissions. For methanol engine, the optimization of injection timing and ignition timing can lead to an improvement of brake specific fuel consumption of more than 10%.At optimal injection and ignition timings a compromise between thermal efficiency and exhaust emissions is achieved [10].

Minimal advance for best torque (MBT) timing for an internal combustion spark SI engine is an approach for the best fuel economy. However, MBT timing is often limited by engine knock in the advanced direction and spark timing is also constrained by partial burn and misfire in the retard direction. Although, it is preferred to operate IC engines at MBT timing. During cold start conditions it is desired to operate IC engines at its maximum retard limit subject to combustion stability constraints to reduce catalyst light-off time. Traditionally, both MBT timing and retard spark limit are open-loop feedforward controls whose values are experimentally determined by conducting spark sweeps at different speed and load points, and at different environmental conditions. Using in-cylinder ionization signals both borderline knock and retard spark limits are regulated using closed-loop stochastic limit controls. MBT timing is also controlled closed-loop using an MBT criterion derived from in-cylinder ionization signals. The control strategy and architecture is used to validate the 3.0-L V6 engine for steady state and slow transient conditions. A closed-loop ignition control architecture is created to combine three closed-loop ignition control strategies into a single one which are closed-loop MBT timing control, borderline knock limit control, and retard limit control. The integrated ignition control architecture allows the engine to operate at its true MBT timing. The improvement of transient performance can be carried out by combining the quasi-steady-state oriented ignition timing control strategy with a feedforward controller [10].

Spark timing is essential to determine the engine behaviour. MBT timing is a good approach because it has a merit of fuel consumption and can be used to improve transient performance. Optimal ignition timing has a merit of thermal efficiency of the engine. The optimization of injection and ignition timings is capable to improve the brake fuel consumption. Hence, the performance and behaviour of SI engine can be studied through spark timing.

2.5 Microcontroller

Microcontroller is a powerful single board computer and easy to use. This device is widely used by the hobbyist and also has good traction in professional market. Arduino microcontroller is well known device due to its open source computing platform [11]. Microcontroller has great potential to be used in automotive applications. The implementation of electronic controlled dual-fuel system is introduced to replace the mechanical injection system. The new system consist of two different injectors which are injector supplies the LPG (liquefied petroleum gas) and the other one supplies the diesel. All injectors were controlled by Programmable Logic Controller (PLC). The PLC is utilized as ECU and it is an unorthodox solution for engine control systems. However, for single cylinder engine it has economical merit. The result showed that electronic injection system and dual fuel operations is capable to increases the quality of the combustion in the engine [12].

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This section will discuss the method that involved in this project. The development of the artificial signals, signal processing, fabrication, and characterizing the engine knock are method that will be discussed. This project was carried out to obtain the data from the Modenas GT128 engine and monitor the engine behaviour. The signals of CPS, spark, fuel injection timing are recorded by using the Instrustar Oscilloscope and the data will be analysed for further process. The knocking phenomenon was studied and observed when the engine was operated under its operating condition. Knock signal was recorded using the oscilloscope via knock sensor. Hence, it is important that the methods above to be carried out in order to study the effect of artificial signal and knocking phenomenon toward the engine behaviour.

3.2 Project Flowchart

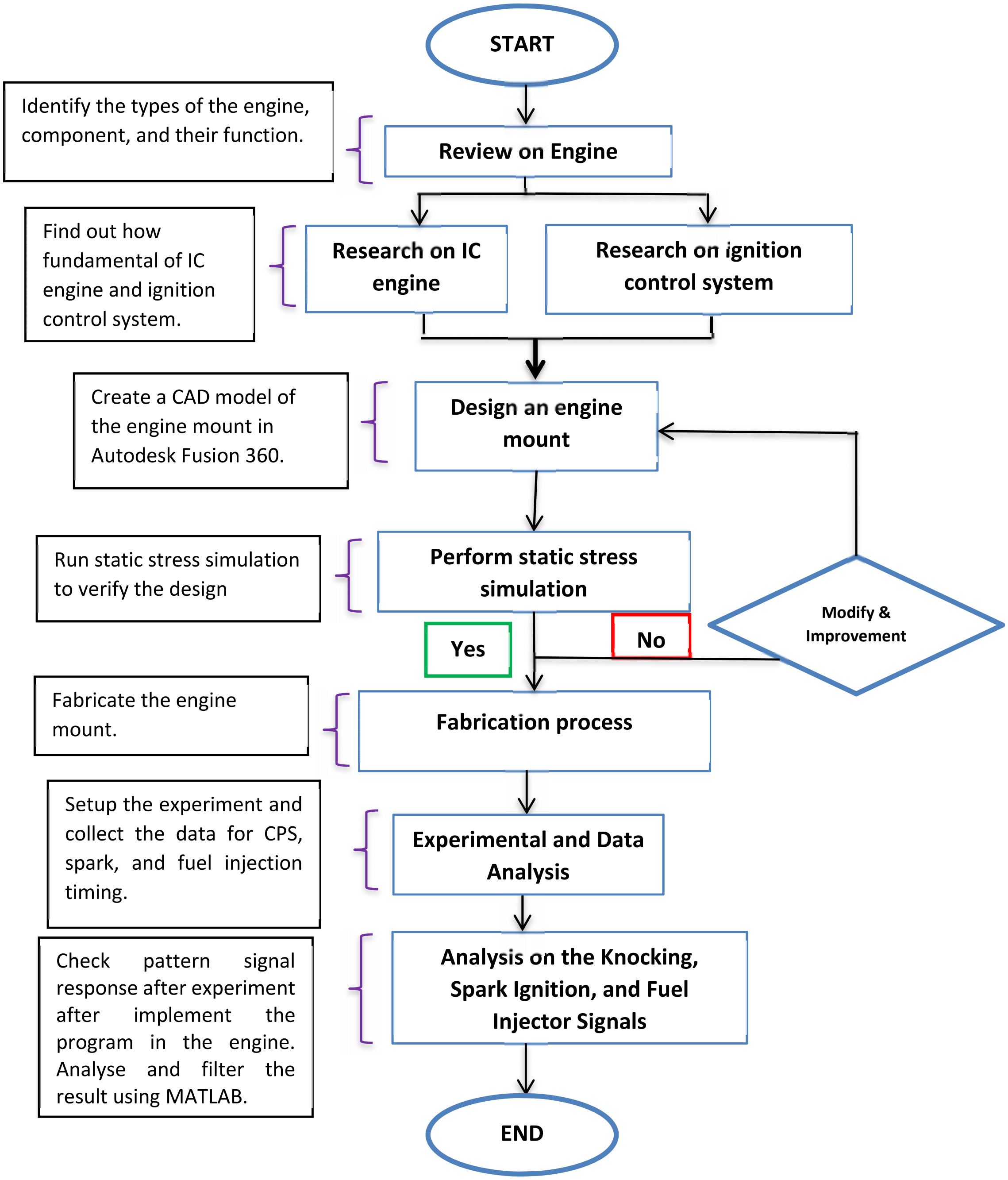

Figure 3.1: Project Flow Chart

3.3 Methodology

3.3.1 Design and Fabrication

The experiment for this project is carried out at the Hanger of School of Aerospace. In this experiment, the engine that being used is Modenas GT128 which is a Spark Ignition Engine and has four stroke cycle configuration. The first step in this experiment is to fabricate the engine mounting for the Modenas GT128 engine. This engine mounting will be mounted on the go-kart chassis. The selection of material is crucial for this equipment because the material need to be able to withstand the static stress that been acting on it. The material design considerations are the availability, machinability, weld ability, and flexibility. Based on the requirement and the considerations, hollow square mild steel and mild steel plate are chose as the structural material for this engine mounting.

After the material has been assigned, a conceptual design of the engine mounting is created. The idea of the engine mounting concept is derived from the previous test bed that has been created in previous Final Year Project. The test bed is used to mount the Yamaha 135LC engine. The design of test bed is an overhang design where the engine only mounted on the top connection. However, this conceptual design of the engine mounting only utilize the bottom part of the engine. Next, CAD model is created in the next process. Fusion 360 is another CAD software that available for the student to use included SolidWorks. Technical drawing of the engine mounting also being generated by using Fusion 360. Static stress simulation is carried based on the CAD model. The load of the engine is assigned to contact surface of the engine mounting and the simulation is carried out for stress, displacement, and strain.

Next process is the fabrication of the engine mounting, the processes that involved in this fabrication are cutting, drilling, grinding, and welding. First process is cutting process, the mild steel plate of 5mm thickness is cut to the respective dimension and Table 3.1 shows the dimension and quantity for each part needed.

Table 3.1: Cutting Dimension of the Required Part

Part	Dimension	Quantity
Base Plate	30mm × 366mm	2
Support Plate	30mm × 50mm	4
Square Beam 1	25mm × 200mm	2
Square Beam 2	25mm × 376mm	2

The material is cut by using shear cutting machine that available in Workshop of School of Mechanical Engineering. After the cutting process is carried out, the plates are drilled using drill bench machine. All the support plates are drilled with the same diameter of 8mm. The process is carried out by using 4 different drill bit size. The table 3.2 showed the drill bit diameter that being used.

Table 3.2: The size of drill bit of drilling process.

No. of drill Bit	Diameter
1	3.5mm
2	5.0mm
3	7.0mm
4	8.0mm

After all the part have been drilled and cut, assembly process was carried out. The parts were assemble by using welding method. MIG welding was used to weld all the parts together to create the engine mount. Figure 3.2 showed the complete engine mount. Grinding process was carried out to deburr the weld bead and smoothed the welding and part surfaces.

Figure 3.2: Flat base engine mount

After done the welding process, the engine mount was installed to go-kart chassis as shown in Figure 3.3. The engine mount was placed between the triangle pillars of the go-kart chassis. The orientation of the engine mount was orientated horizontally due to the limited space. Figure 3.4 showed the overall experiment setup.

Figure 3.3: Installation of engine mount on go-kart chassis

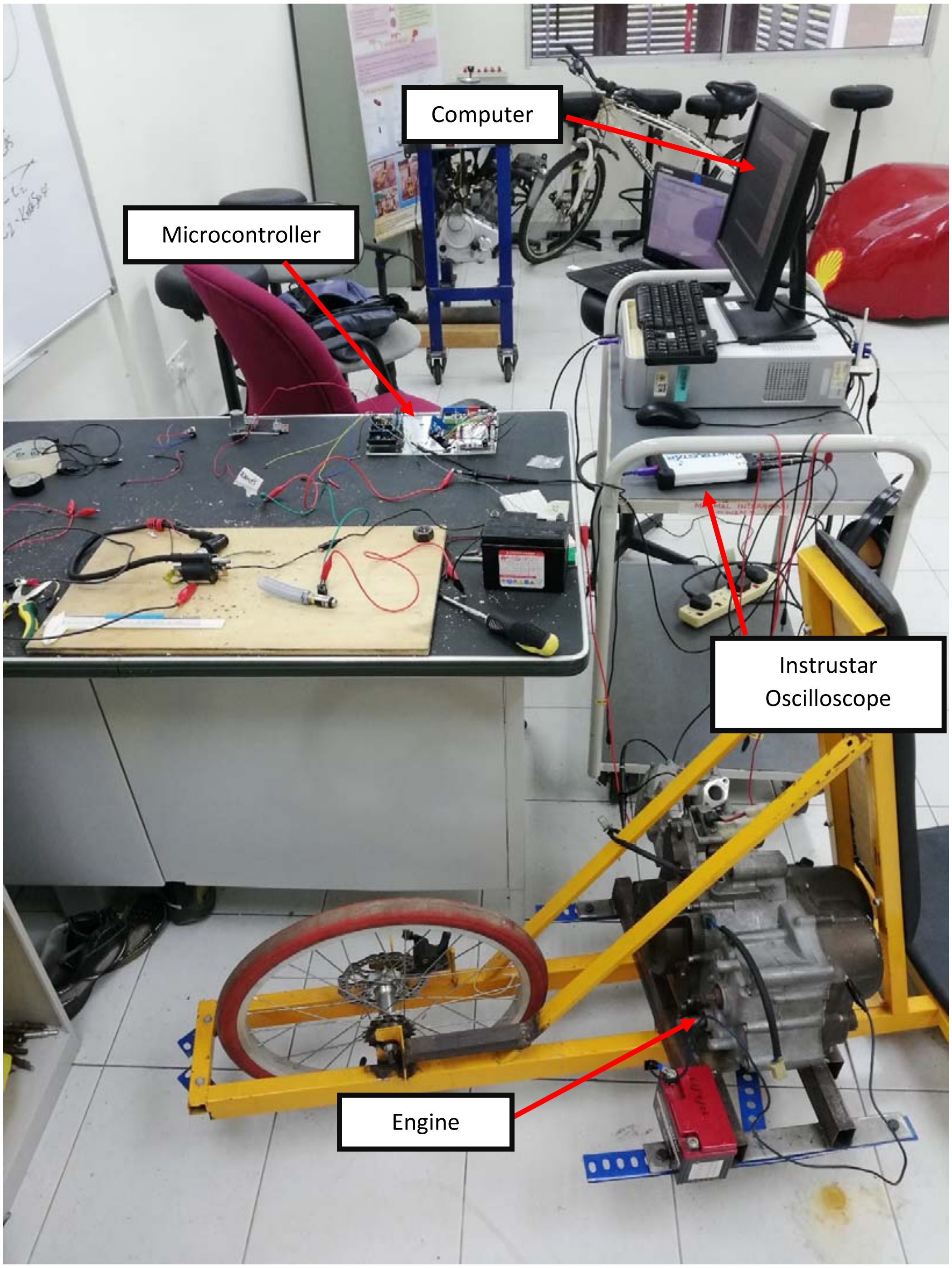

Figure 3.4: Overall experiment setup

3.3.2 Engine Review

The engine that been used for this project is from Modenas GT128 which is a 4 stroke single cylinder engine. This engine has gasoline or petrol fuel system which utilized the carburettor system. Carburettor system is common on 4 stroke single cylinder engine. However, a modification is carried out to the carburettor system of the Modenas GT128 engine where a fuel injector is installed to the air intake of the carburettor system. The carburettor is functioned as the throttle body for the fuel injector. Table 3.3 showed the specifications of Modenas GT128 engine.

Table 3.3: Modenas GT128 engine specifications

Type	**4-stroke, 1 cylinder, SOHC**
Bore X Stroke	53.0 x 59.1 mm
Displacement	130 cc
Compression Ratio	10:1
Carburettor	KEIHIN NCV24
Ignition System	DC-CDi
Starting System	Kick and Electric starter
Cooling System	Air cooled
Lubrication	Forced lub, wet
Fuel Tank Capacity	4.3 L
Fuel Consumption	64.4 km/l @ 80km/h

3.3.3 Microcontroller Board

Arduino Mega was used in this project as the microcontroller board. As an overview Arduino Mega has 54 digital input/output pins, 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with AC-to-DC adapter or battery to get started. This microcontroller also compatible with most shields designed for the Arduino Duemilanove or Diecimila [18]. Figure 3.5 showed the microcontroller board Arduino Mega 2560.

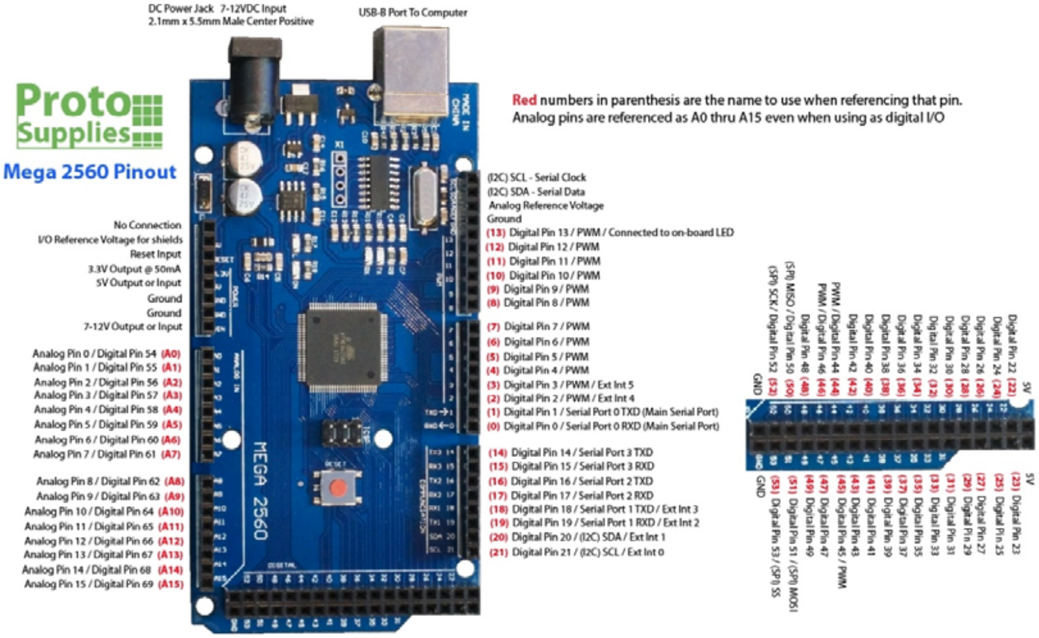

Figure 3.5: Arduino Mega 2560 configuration [17]

A motor shield was installed to the microcontroller board. A circuit consist of mosfet is implemented onto the motor shield. Figure 3.6 showed the configuration of the circuit. The configuration of the microcontroller circuit used Arduino digital port 13 to connect the transistor to the ground. A 12V power supply from the alkaline battery was used as the power supply for this circuit. The ignition coil wire was connected to the mosfet number 2 pin (drain) while pin number 3 was connected to the ground. The mosfet will produce a spark signal for 1ms when the transistor is off. When the transistor is on the mosfet will seize for 120ms. Figure 3.7 showed the motor shield setup with the Arduino Mega 2560.

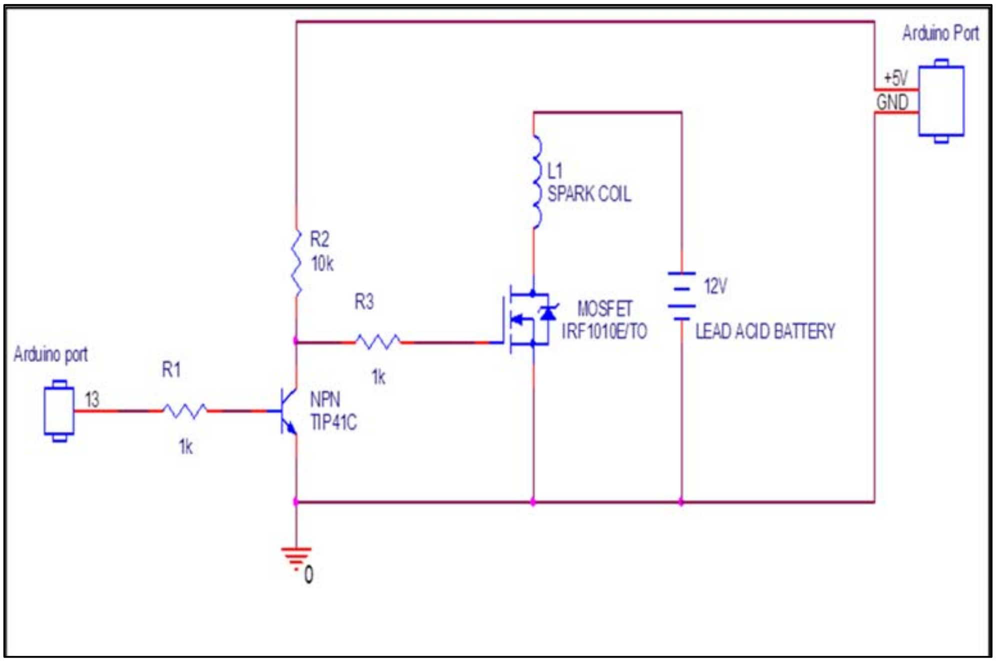

Figure 3.6: Microcontroller circuit on the motor shield

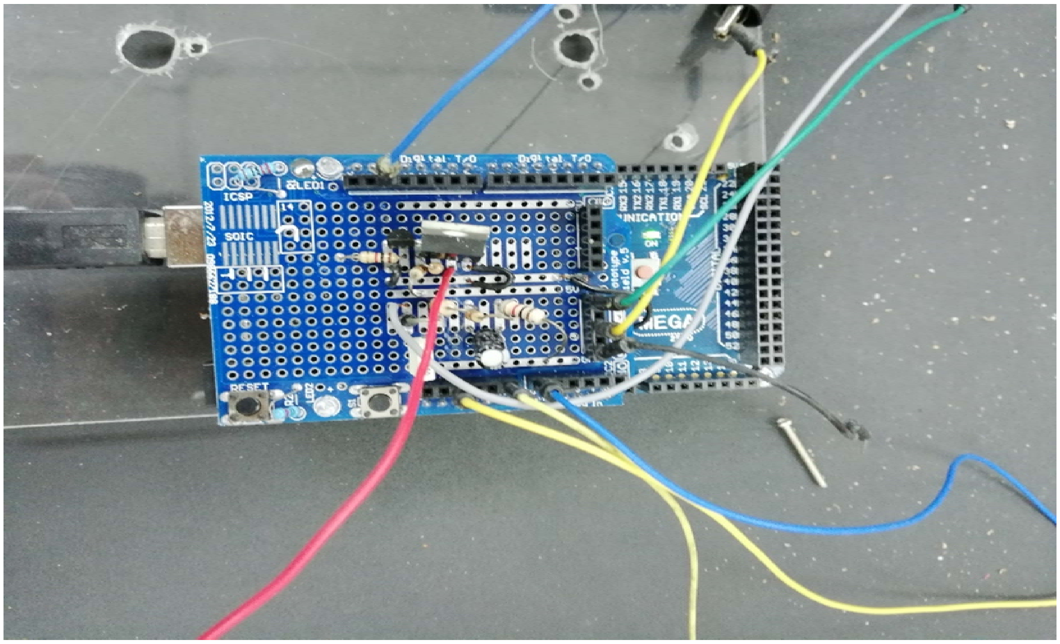

Figure 3.7: Motor shield setup