PJP/2012/FKM (16A)/S1092

DESIGN AND SETUP OF LOW COST SMALL ENGINE DYNAMOMETER

MUSTHAFAH BIN MOHD TAHIR

RESEARCH VOTE NO:
PJP/2012/FKM (16A)/S01092

Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

2012

PJP/2012/FKM (16A)/S1092

DESIGN AND SETUP OF LOW COST SMALL ENGINE DYNAMOMETER

MUSTHAFAH BIN MOHD TAHIR

FAKULTI KEJURUTERAAN MEKANIKAL
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2012

Abstract

DESIGN AND SETUP OF LOW COST SMALL ENGINE DYNAMOMETER

(Keywords : Chasis and Frame, formula Varsity race car, chasis frame fabrication)

ABSTRACT (120 words)

This paper will discuss about the design and development of a low cost small engine dynamometer for engine testing to measure engine performance i.e. power, torque and specific fuel consumption. The data and result were achieved by using a small hydraulic engine dynamometer with several considerations and standard that should be followed in order to have good engine dynamometer. Small engine had been used by coupling it with the hydraulic pump that come with the control valve and pressure gauge. Control valve was set to build back pressure inside the pumping area. When the engine starts, the pressure gauge will give a reading which can be used to calculate the engine torque. By using the engine torque, engine power can be obtained by multiplying the angular speed with engine torque. From the experiment data, the brake power of the single cylinder engine showed that it is almost similar to the specification given by the manufacturer. The low cost hydraulic engine dynamometer, which is less than RM 15,000 can be used to measure an engine performance. The engine power, torque, engine speed and air fuel ratio data can be achieved from our developed engine dynamometer.

Key Researchers:

Dr. Musthafah bin Mohd Tahir

Dr. Yusmady bin Mohamed Arifin

En. Safarudin Gazali Herawan

Dr. Muhammad Zahir bin Hassan

En Mohd Azli bin Salim

Muhamad Syahir bin Ali

Abdul Muhaimin bin Mohd Shafie

Table of Contents

List of Figure

List of Tables

1.0 INTRODUCTION

The engine performance is one of the criteria that very important to the engine. Today, engine inventor is very focused on the performance of the engine before it introduces to the user. The criterion of this engine is tested by using engine dynamometer. Engine dynamometer is equipment that use to measure performance (power, torque, moment of force, etc.) of the engine. The first dynamometer was developed by Gaspard de pony in 1828. This dynamometer is called as Prony Brake. Based from this earliest dynamometer, this device becomes more advanced and a lot of improvement made by another person. The next generation of dynamometer from Pony Brake is Hydraulic Dynamometer and finally in 1931, first eddy current dynamometer was introduced by Martin and Anthony Winther. The Eddy current dynamometer is the current dynamometer, which very famous in engine performance testing today.

Engine dynamometer has different types based on the system use in dynamometer. The famous or advanced dynamometer is eddy current dynamometer. The eddy current dynamometer system where the electronic devices which connect to the engine. This type of dynamometer normally use in chassis dynamometer where the engine performance is test with the vehicle chassis.

Hydraulic pump also had been used to study the engine performance and this type of dynamometer is called a hydraulic dynamometer. This type of dynamometer where the engine is coupled with the hydraulic pump and the load is applied by hydraulic pump based on back pressure. Hydraulic dynamometer is commonly used in small testing engine performance. Compare to eddy current dynamometer, it's more easy to use and only require a small cost to complete all the equipment needed.

Therefore, the hydraulic dynamometer was selected to develop in order to be used in engine testing and CNG engine testing. This type of dynamometer was selected due to easy to develop and require only low budget compare to eddy current dynamometer. Besides that, hydraulic dynamometer is easier to assemble compare with eddy current which are needed more knowledge in term of electronic devices. However, in hydraulic dynamometer is more to mechanical knowledge in order to complete the assembly of this dynamometer.

1.1 OBJECTIVES

The main objectives of this project are stated below:

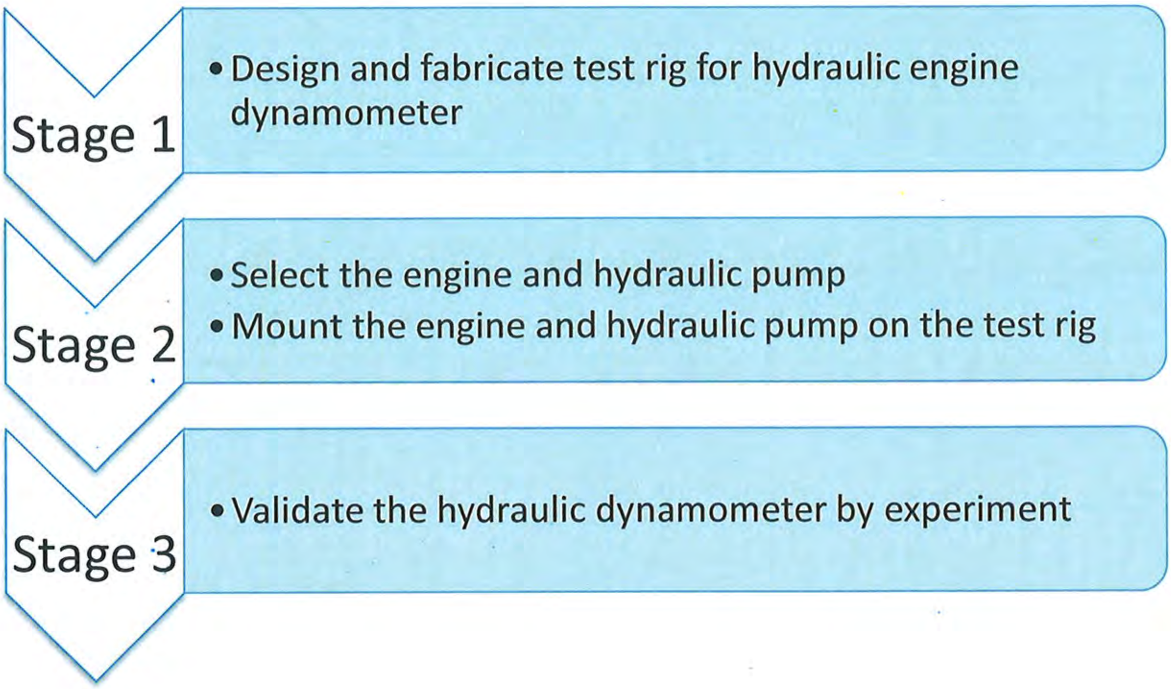
a) To build a low cost and small engine dynamometer to analyze single cylinder engine performance
b) To make a test rig for future engine efficiency study between CNG fuel and gasoline fuel.

During this project, the hydraulic dynamometer will be built in order to study the performance of the single cylinder engine when gasoline fuel and CNG fuel apply to this single cylinder engine. The data collected from the testing will be evaluated this own made hydraulic dynamometer. In future research which is CNG efficiency and performance, it is very useful if this hydraulic dynamometer is suitable for single cylinder engine performance test.

1.2 SCOPE

The focus of this project is to design and fabricate a small test rig and to build a small engine dynamometer which is hydraulic dynamometer. This hydraulic dynamometer will be used to test performance of gasoline fuel in a single cylinder engine. All results obtain from the test are used to validate this hydraulic dynamometer and also use in further study of CNG performance. Therefore, the first step in this project is designed and fabricate, test rig and the second step is to set up the hydraulic dynamometer. The final step is validating the fully set up hydraulic dynamometer.

2.0 PROJECT STAGES



The stages above show the stage to finish this project where it starts from design and fabricate the test rig for hydraulic dynamometer. In this stage, this test rig will be undergoing material selection in order to find a suitable material and shape to build this test rig. Additional features also will be implemented at this stage, which is the color of this test rig. The second stage consists of two main points which are engine selection, hydraulic pump selection, and mounting these two equipment on the test rig. The critical point at this stage is the coupling section between the engine and hydraulic pump. The final stage is validation of this hydraulic dynamometer. The experiment will undergo in order to obtain the engine performance data. The result of this experiment will determine whether this hydraulic dynamometer is successfully built or not.

3.0 DESIGN AND FABRICATE THE TEST RIG

The first stage of this project is to design and fabricate, test rig for hydraulic dynamometer. The design of this test rig by using Catia software that already provided by Universiti Teknikal Malaysia Melaka. In the design process, the suitability test rig shape from upside view is a rectangular shape. This shape also can be referred from the other test rig. The shape of rectangular gives more stability for test rig. Figure 3.1 below shows the 3D view of test rig that had been designed by using Catia software.

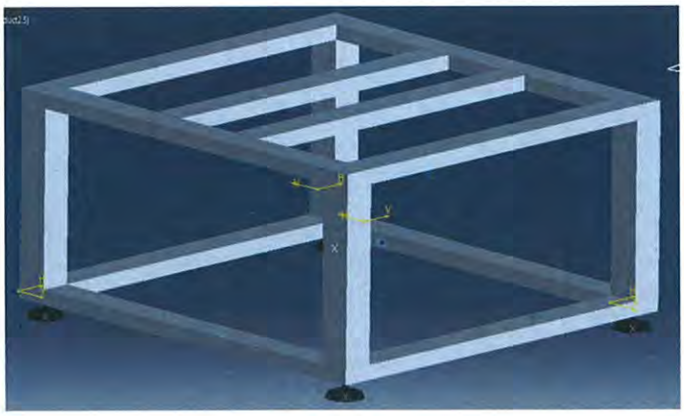


Figure 3.1: 3D view of test rig

Based from the Figure 3.1, the crossbar at middle of test rig is the position where the engine and hydraulic pump will be installed on this test rig. Each bottom of this test rig also will be equipped with a soft rubber in order to reduce the vibration during engine testing. The detail view and dimension of this test as shown as in Figure 3.2 below:

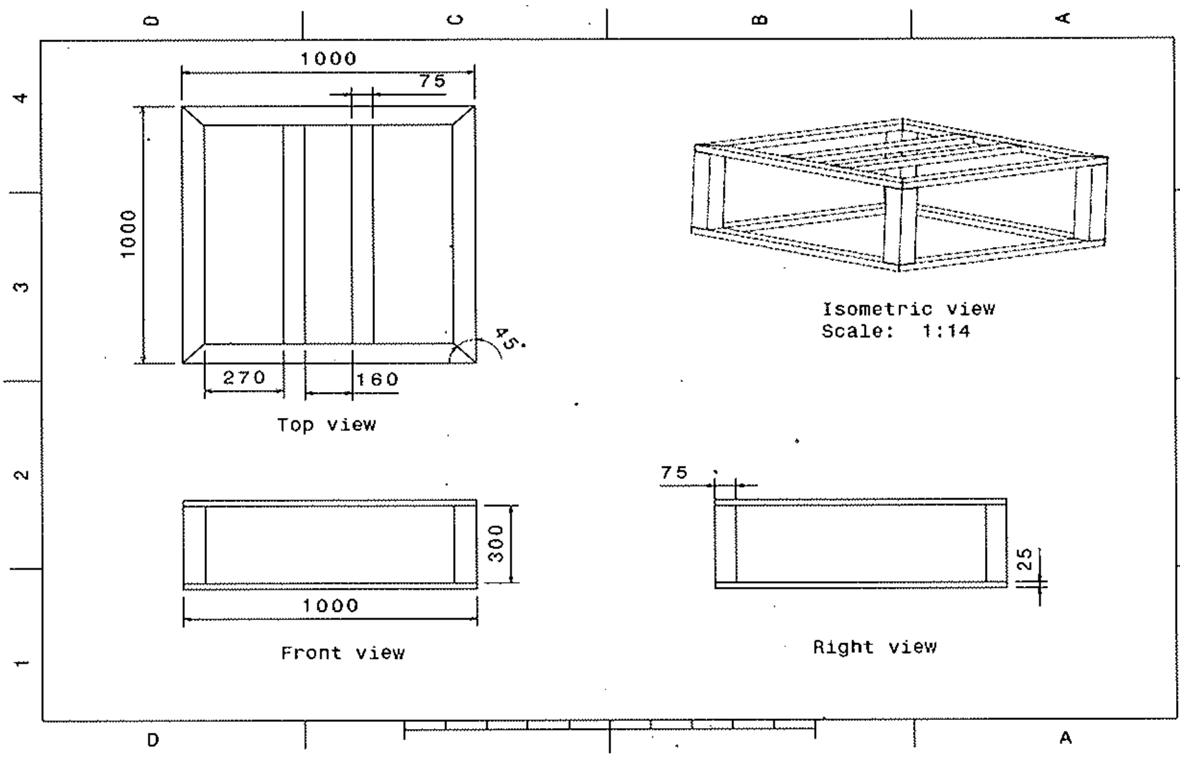


Figure 3.2: Detail drawing of test rig

During design process, the problem need to overcome is dimension of the test rig. The first design dimension are 1000 mm x 1500 mm x 700 mm. Based on this first dimension, the height of this test rig very high. The height of this test rig was reduced by 400 mm and the new design was made. Commonly, the engine will produces very high vibration, especially in high speed combine with hydraulic pump. This will result the test rig become unstable during engine running. The reduction in height for this test rig will increase the stability of this test rig. The new height design is comfortable for the student to use in the experiment. The final dimension for final design was 1000 mm x 1000 mm x 300 mm.

Material selection for this test rig, there are many suitable materials, especially stainless steel and mild steel. However, based from another test rig, the best material for this test rig is mild steel rectangular hollow bar. This raw material costs about 10 m to complete this test rig. Reason use this material for this test rig is based on the weight of the engine and hydraulic pump. The estimated weight for both equipment are about 32 kg, which are equal to 313.92 N. Based from this assumption, the suitable material as mentioned before is mild steel rectangular hollow. The properties of this material as shown as in Table 3.1 below:

Table 3.1: Properties of mild steel

properties	value
Yield strength	193 MPa
Ultimate strength	424 MPa
Strength fracture	729 MPa

The selected material come out with length 10 m and this material was cut by piece based on the drawing. In this process the length of material was cut by two different lengths which are 0.8 m and 0.85 m. The total material for 0.8 m is ten pieces and for 0.85 m are two pieces. The entire cutting process use bend saw as shown in Figure 3.3:

Figure 3.3: Cutting process using bend saw

All the pieces that had finish cut was placed in one location to joint by using welding process. The total pieces of mild steel for this test rig are 14 pieces including the support pole. Figure 3.4 below shows the mild steel rectangular

Figure 3.4: Material already cut

The next process after design and cutting is the fabrication of the test rig. For fabrication process, all the material that had been cut is joined together by using MIG welding. The MIG wire use for this is mild steel material which SG2 (G3Si1), is based on the American spec AWS ER70S-6. This type of welding wire material is suitable for welding which the general fabrication is like this test rig structure. Then, the welding method must be accurately applied because to differentiate the good welding, finishing, it can be seen from the bead condition. Then, the flow of the welding bit is not broken and straight. In this test rig fabrication process, it consists of two main joints which are square butt joint and T-joint. These two joint types very suitable in this test rig because it can withstand with high load. The square butt joint is applied to join the main rig base and the engine base. While for the T-joint, it is applied when to join the support which is the position is 45^0 angles from the edge of the main rig base. The welding process is started with the spot weld this is because to ensure the welding method and the configuration of the test rig is in the right position. After that, the full welding joint is proceeding with an appropriate feed wire speed which is 360-260 ipm, electric current = 85-170 amp, voltage = 23-27 V and Argon/1-5% O_2 = 25. Then, the welding process is proceeding until the complete model shows in the drawing. The final process is painting the test rig. The color of this test rig is black and the painting using spray paint. Figure 3.5 below shows the finish fabricated test rig for this project

Figure 3.5: Test rig already finish fabricate

4.0 ENGINE AND HYDRAULIC PUMP SELECTION

The test rig is completely fabricated and ready to mount the engine and hydraulic pump. However, there are lots of engines that had been developed by the industry nowadays. This starts from a single cylinder engine until six cylinder engine. Therefore, this project only for small hydraulic dynamometer and based from this title, the single cylinder engine had been selected. The engine that had been selected for this project is Robin EY20D 5.0 single cylinder engine as shown as in Figure 4.1 below:

Figure 4.1: EY20D engine

Each of engines has their specification. The specification of this single cylinder engine can be referred in Table 4.1 below:

Table 4.1: Specification of EY20D engine

Model	EY20
Type	Cir-cooled, 4cycle, vertical, single cylinder gasoline engine
Bore × Stroke (mm)	67 × 52
Piston displacement (cc)	183
Compression ratio	6.3
Continuous rated output	3/3000 3.5/3600
Max. Output (HP/rpm)	5/4000
Max. Torque (kg.m/rpm)	0.96/2800
Rotation	Counter clockwise as view from P.T.O shaft side
Cooling system	Forced air cooling
Lubrication	Splashing type
Lubricant	Automobile oil class SC
Carburetor	Horizontal draft, float type
Fuel	Automobile gasoline
Fuel consumption ratio (gr/HP.h)	280 at continuous rated output operation
Fuel feed	Gravity type
Fuel rank capacity (L)	3.8
Speed governor	Centrifugal flywheel type
Ignition system	Flywheel magneto type
Spark plug	NGK, 8.6HS

Light capacity (V-W)		12V, 15W (available if required)
Starting system		Recoil starter
Dry weight (kg)		15
Dimensions	Length (mm)	319
	Width (mm)	317
	Height (mm)	392

This specification is very important especially for this project because all the result from the experiment will refer to this engine specification. The main specification in this table is power, torque and fuel types. The fuel types for this engine can be changed from liquid fuel or gasoline to natural gas or CNG. This is very useful in this project because this hydraulic dynamometer will be used in CNG study. The power and torque in this specification will become as references for the result in experiment by using this hydraulic dynamometer. Finally, the advantages choose this single cylinder engine other than multi cylinder engine are:

1. Ease in maintenance and use
2. Lightweight and suitable for this test rig
3. Easy to study the performance of this engine, compare with multi cylinder engine

Besides engine selection, the hydraulic pump also needs to choose wisely because this hydraulic pump will couple with the engine. The wrong pump selection may occur damages to internal component of the engine due to overload apply by the pump. In this case, the only small hydraulic pump was selected to use as testing equipment for the engine. The hydraulic pump in this project is Wu Li W-45B as shown in Figure 4.2:

Figure 4.2: Wu Li-W-45B hydraulic pump

This pump is a plunger pump which is in the reciprocating positive displacement pump that has three single acting reciprocating plungers. The pump includes one or more single acting plunger, sealed with packing against cylinder walls. The pump has an inlet an outlet check valve for each plunger. This type of pump can achieve very high pressures when pumping. The specification of this hydraulic pump can be referred in Table 4.2 below:

Table 4.2: Hydraulic pump specification

	Operating Pressure (kgf/cm^3)						
Suction volume	20		35		50		Revolution
Liter/Min	M	E	M	E	M	E	rpm
16.0	0.9	1.3	1.5	2.2	2.0	3.2	430
19.5	1.0	1.6	1.8	2.7	2.5	3.9	520
24.5	1.3	2.0	2.2	3.4			650
32.0	1.7	2.5	2.9	5.0			850
Dimensions (L × W × H) 40 × 31 × 37 (cm) Weight 16/17 (kg)							
*M-Required motor power (HP) *E-Required engine power (HP)							

After analyzing the engine and hydraulic pump, both equipment will be set up on the test rig. However, the coupling between engine and hydraulic pump need to choose wisely. Currently, there are two types of coupling that were used in engine dynamometer, which are using belting and direct coupling. In order to obtain the best result for this hydraulic dynamometer, the direct coupling was used to connect between the engine and hydraulic pump. The equipment use for direct coupling is shown in Figure 4.3:

Figure 4.3: Equipment for direct coupling

The equipment in Figure 4.3 contains two flywheels which is will be attached to the engine shaft and hydraulic shaft. Advantages of this type of coupling are:

1. Easy to align properly between the engine and hydraulic pump
2. The mechanical loss of the pump to the engine is low
3. Can hold up high load applied by the hydraulic pump

Direct coupling where the others shaft will connect directly with a driver shaft. Based from Figure 3, there are two same flywheel with the same diameter outlet. The diameter inside the flywheel can be chosen based on the diameter of driver shaft and driven shaft. Positively, in this project, the inside diameter of the flywheel is same between driver shaft and driven shaft (20 mm). The complete setup for this type of coupling into this hydraulic dynamometer as shown in Figure 4.4:

Figure 4.4: Complete installation direct coupling

Previously, the flywheel will be attached for each shaft and based on figure 4, the shaft from the engine and hydraulic pump connect properly by using this direct coupling. Another benefit from this coupling, the engine speed can be considered same as pump speed because of direct shaft of engine coupling with a shaft of the hydraulic pump. Within that, it ensures the amount of pressure apply to the engine is satisfied with engine speed.

After finalizing the engine, hydraulic pump, and coupling use, the hydraulic dynamometer is set up on the test rig. The location of the engine and hydraulic pump is located at middle of test rig and side by side between the engine and hydraulic pump. Figure 4.5 shows the complete hydraulic dynamometer setup:

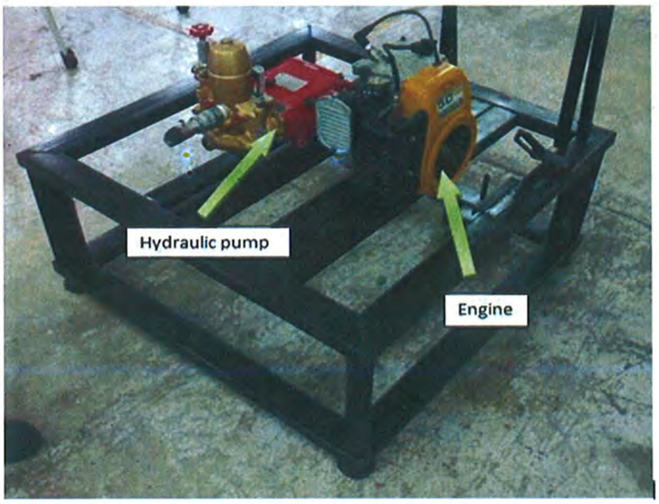


Figure 4.5: Complete setup of hydraulic dynamometer

Benefit from this engine, it can be started by using motor starter, which uses an electric starter with minor modification at the pulley. The flywheel from gear box was attached to the pulley and an electric motor starter used to start the engine. All this electrical system provided for this engine safety in case of emergency. The system here equipped with emergency stop that will shut down the engine immediately without cut off the throttle. The main board of this electrical system as shown in Figure 4.6:

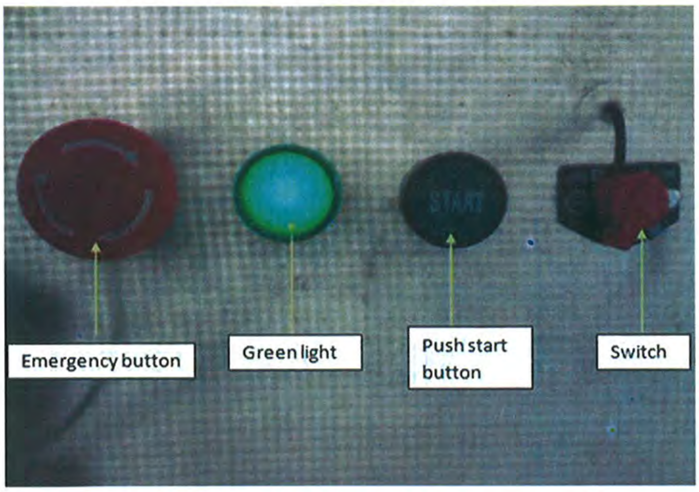


Figure 4.6: Main board of electrical system

According to the main board in Figure 4.6, there are four buttons that attached in this electrical system which are emergency button, indicator light, push start button, and switch. The indicator light shows the electrical system is connected well or not based on the light. Push start button will start the engine by push the button. The complete hydraulic dynamometer with electrical system can be referred in Figure 4.7 below:

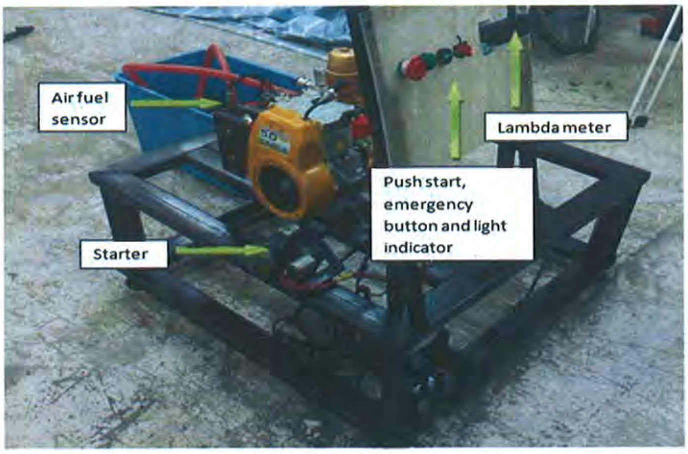


Figure 4.7: Hydraulic dynamometer with electrical system

This hydraulic dynamometer operation as equal as eddy current dynamometer and different only the devices use to apply the load. The load basically to determine how much the engine power output by using the equation available in hydraulic dynamometer. The detail view of operation by this hydraulic dynamometer as shown in Figure 4.8 below:

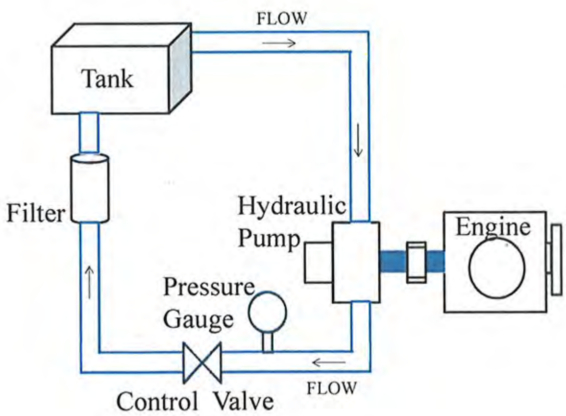


Figure 4.8: Schematic diagram of hydraulic dynamometer