EXPERIMENT AND ANALYSIS OF MOTORCYCLE EXHAUST DESIGN

ABDUL MUIZ BIN JAAFAR

Report submitted in partial fulfilment of the requirement
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

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EXAMINERS APPROVAL DOCUMENT

UNIVERSITI MALAYSIA PAHANG
FACULTY OF MECHANICAL ENGINEERING

I certify that the report entitled 'Experiment and Analysis for Motorcycle Exhaust Design' is written by Abdul Muiz bin Jaafar. I have examined the final copy of this paper report and in my opinion, it is fully adequate in terms of scopes and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering. I herewith recommend that it be accepted in fulfilment of the requirements for the degree of Bachelor of Engineering.

Signature :
Name of Examiner :
Date :

SUPERVISOR'S DECLARATION

I hereby declare I have checked this report, which written by Abdul Muiz bin Jaafar, and in my opinion, this report project is adequate in terms of scopes and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

Signature :
Supervisor : DR. AHMAD SYAHRIZAN BIN SULAIMAN
Position : LECTURER
Date : 27 JUNE 2013

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own, except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any other Degree and is not concurrently submitted for award of other degree.

Signature	:
Name	: ABDUL MUIZ BIN JAAFAR
Matric No.	: MH09016
Date	: 27 JUNE 2013

DEDICATION

Specially dedicated to
My beloved family and those who have
Encourage and always be with me during hard times
And inspired me throughout my journey of learning

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Special thanks to my lovely parents for their support, love, dream and sacrifice throughout my life. I would like to appreciate their devotion, support, and faith in my ability to attain my goals.

ABSTRACT

Internal combustion engine is one of beautiful engineering knowledge in engineering scope. Internal combustion consists of two type categories which are Spark Ignition (SI) and Compression Ignition (CI). Based on internal combustion engine, a lot of research can be done to improve the performance of engine, fuel consumption, and emission. One of the researches is Experiment and Analysis for Motorcycle Exhaust Design. The main objective is to study the variable design length to increase the performance of the engine. The second is to obtain high power and torque at low speed of engine (rpm) based on the change of exhaust parameter. The experiment is handle by utilize the Eddy Current Dynamometer 15kW. There are two difference length of exhaust pipeline which is 570mm and 1140mm. The length that change are from manifold until before the silencer. Before undergo the experiment, test rig of the engine need to fabricate because the engine that use is difference from previous experiment of dynamometer. To fabricate the test rig, four elements involve which are sketching, designing, analysis, and fabrication. These experiments consist of three different result which is baseline graph, length of exhaust 570mm and length of exhaust 1140mm. The graphs are plot for power and torque graph versus speed of engine. When there are changes of the length of the exhaust the torque graph will be change according to the difference length. The shorter the length, the result of torque and power graph will be more improve. But there are limit to make sure the exhaust pipe length not give bad impact to the engine. The result conclude that, the better length of exhaust pipe is the shorter one which is 570mm and this result can be applied to student formula race.

ABSTRAK

Enjin pembakaran dalaman adalah salah satu daripada pengetahuan kejuruteraan yang indah. Pembakaran dalaman terdiri daripada dua kategori salah satunya adalah “Spark Ignition” (SI) dan “Compression Ignition” (CI). Banyak penyelidikan yang boleh dilakukan untuk meningkatkan prestasi enjin, penggunaan bahan api dan pelepasan bahan pembakaran. Salah satu daripada kajian tersebut ialah Eksperimen dan Analisis untuk rekabentuk ekzos motosikal. Objektif utama projrk ini ialah untuk mengkaji panjang ekzos yang pelbagai untuk meningkatkan prestasi enjin. Yang kedua adalah untuk mendapatkan kuasa dan tork yang tinggi pada kelajuan enjin (rpm) yang rendah berdasarkan perubahan ekzos parameter. Eksperimen ini menggunakan mesin Dynamometer 15kW. Terdapat dua jenis panjang ekzos yang akan di kaji iaitu 570mm dan 1140mm. Panjang ini diukur dari manifold sehingga sebelum penyerap bunyi. Sebelum menjalani eksperimen, tapak enjin untuk di ujikaji perlu dibina kerana enjin yang digunakan adalah perbezaan dari eksperimen sebelumnya. Untuk pembinaan tapak enjin, empat elemen terlibatkan secara langsung ialah lakaran, reka bentuk, analisis, dan fabrikasi. Daripada eksperimen yang dibuat terdapat tiga graf yang berbeza mengikut jenis-jenis ekzos pertama ialah graf asas, kedua ialah graf utk panjang ekzos 570mm dan panjang ekzos 1140mm. Graf ini ialah untuk graf kuasa dan graf tork berdasaekan kelajuan enjin. Jika terdapat perubahan panjang ekzos,graf tork akan berubah mengikut panjang perbezaan. Ekzos yang pendek akan menghasil bacaan graf tork dan graf kuasa lebih baik jika dibandingkan dengan yang asal. Tetapi ada had untuk memastikan panjang paip ekzos tidak memberi kesan buruk kepada enjin. Secara konklusi nya, ekzos yang terbaik bagi meningkatkan prestasi enjin GT128 ialah ekzos 570mm dan keputusan ini boleh digunakan untuk perlumbaan formula pelajar.

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF SYMBOLS

D	Diameter of exhaust pipe
ET	Exhaust valve duration
L_i	Intake length
L_e	Exhaust length
kW	Kilowatt
L	Length
mm	milimeter
rpm	Rotational per minute

LIST OF ABBREVIATIONS

1D	One Dimensional
CC	Centimeter Cubic
CI	Compression Ignition
CO_2	Carbon Dioxide
FEA	Finite Element Analysis
MAI	Malaysia Automotive Institute
NOx	Nitrogen Oxide
SAE	Society Automotive Engineering
SI	Spark Ignition
SOHC	Single Overhead Camp

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Motorcycles are two-wheel vehicle that powered by internal combustion engine either two-stroke or four-stroke. According to the latest statistics in Table 1.1, motorcycles population has increase about 11.6% from 54,619 units in January 2011 to 60,956 units in January 2012.

Table 1.1: Population of Motorcycle in January 2012

Engine Capacity (cc)	Units
50 cc or under	7076
51 – 125	1817
126 – 250	8086
Over 250	43977

Source: Malaysia Automotive Institute (MAI), 2012

These populations show that many people in Malaysia usually use motorcycle as their transportation. A power source for motorcycle is internal combustion engine. Internal combustion engine is combustion that occur in the combustion chamber by ignite the mixture of compress of air and fuel. The combustion produce power can move the motorcycle from one place to another.

Other than produce power as a power source to move the motorcycle, it is also produce emission of NOx and CO_2 gas that dangerous to humankind and environment. All manufacture of engine especially automotive engineer in this world doing research on improvement of internal combustion engine for both CI and SI engine. Their researches focus on the improvement power of the engine, decrease emission of NOx and CO_2 gas and fuel consumptions.

There are many parameters that can increase the power of the engine such as change the size of the bore of the cylinder block and change the cylinder head to performance standard. Nowadays, researcher want to increase the performance the engine without change the bore size, but change other parameter that have relation before the combustion chamber and after it. The important variables that can increase the performance of the engine are gas flow through the four-stroke engine, and discharge coefficients of flow within four stroke engine (Blair, 1999).

Gas flow through four-stroke engine is process of into, through, and out of an engine. The gas involve is unsteady which the pressure, temperature, and gas particle velocity in a duct are variable with time. In the case of exhaust flow, the unsteady gas flow behavior is produced because the cylinder pressure falls with the rapid opening of the exhaust valve or valves. This gives an exhaust pipe pressure that change with time. In the case of induction flow into the cylinder through an intake valve whose area change with time, the intake pipe pressure alters because the cylinder pressure is affected by the piston motion causing volumetric change within that space.

1.2 PROBLEM STATEMENT

In performance of racing engine, each parameter is very important to get the best engine performance. Investigations of the engine performance characteristics, especially for power and torque need to considered. The characteristic are gas flow through and discharge coefficient of flow in four-stroke engine. There are two parameters that usually involve in the gas flow thought engine, intake and exhaust valve.

1.3 PROJECT OBJECTIVE

a) To study the effect of the variable exhaust design length to the performance of the engine.
b) To obtain high power and torque at low speed of engine (rpm) based on the change of exhaust parameter.

1.4 SCOPE OF PROJECT

a) Literature review on the performance of 200cc engine and below based on the exhaust parameter change.
b) Design and fabricate variable exhaust length for engine Modenas GT128.
c) Test the engine performance by utilizing engine dynamometer.
d) Plot graph of the engine performance.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Quality design of an exhaust system requires an understanding of its contribution to both the overall power output of an engine and to noise attenuation (Blair, 2009). Good design of exhaust is to increase the performance of engine without unharmed to human kind and environment. A well designed exhaust system is one of the cheapest ways of increasing engine efficiency, and then increasing engine power. In a four stroke cycle engine, only one stroke out of the four does useful work which is the power stroke. The other three strokes which are intake, compression and exhaust will absorb some of the power that was produced during the power stroke. If the amount of power that is lost by these idle strokes can be minimized, more power will be available to drive the wheels, which is what the engine is supposed to be doing (Mohideen, 2008).

It is also important to understand the mechanisms that enable these contributions as well as their significance. A wide variety of sources were studied to determine current exhaust theories, design and analysis methods as well as to better understand the restrictions imposed by SAE noise regulations.

2.2 EXHAUST DESIGN FOR ENGINE SCAVENGING PERFORMANCE

Performance considerations of exhaust design are a result of the nature of the gas exchange process in a four stroke engine (Blair, 2009). This process includes a period of valve overlap where both the intake and exhaust valves are open simultaneously as seen in Figure 2.1. Without due regard by the designer this period could see the induction of exhaust gases into the cylinder as shown in Figure 2.2 , effectively reducing the amount of fresh combustibles ingested and therefore overall power.

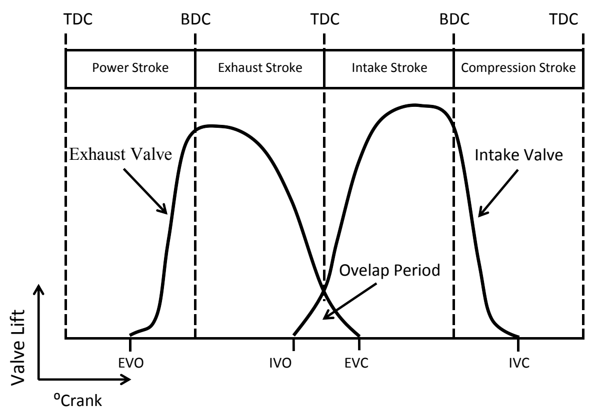

Figure 2.1: Valve timing event showing valve overlap

Source: Blair, 1999

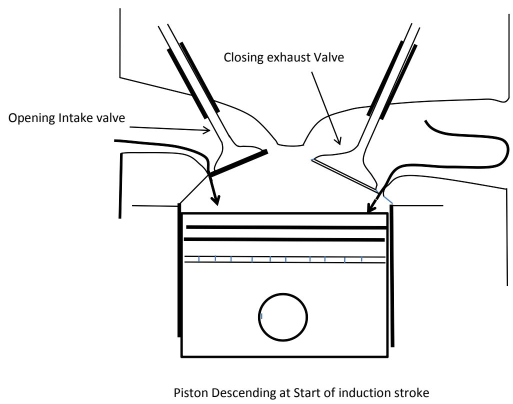

Figure 2.2: Tuned engine ingest exhaust gas into the cylinder during the overlap

Source: Blair, 1999

Performance aspects of exhaust design are concerned with minimizing residual quantities or otherwise maximizing scavenging efficiency of the engine. To achieve the maximum efficiency, the pressure of exhaust valve must reduce during valve overlap such as to bias this exchange process to achieve this scavenge. Exhaust scavenging is achieved via two methods. Firstly, scavenging is achieved through techniques wave tuning and inertial scavenging depending on which of these mechanisms that utilize.

The aim of wave tuning is to tuned exhaust pipe harnesses the pressure wave motion of the exhaust process to extract a greater mass of exhaust gas from the cylinder during the exhaust stroke and initiate the induction process during the valve overlap period. This scavenging effect is possible if a pressure wave originating from the exhaust valve travel at the local acoustic velocity, over a tuned length such that it is reflected back to the valve face as a rarefaction wave, as seen in Figure 2.3, in time to assist the gas exchange process during valve overlap.

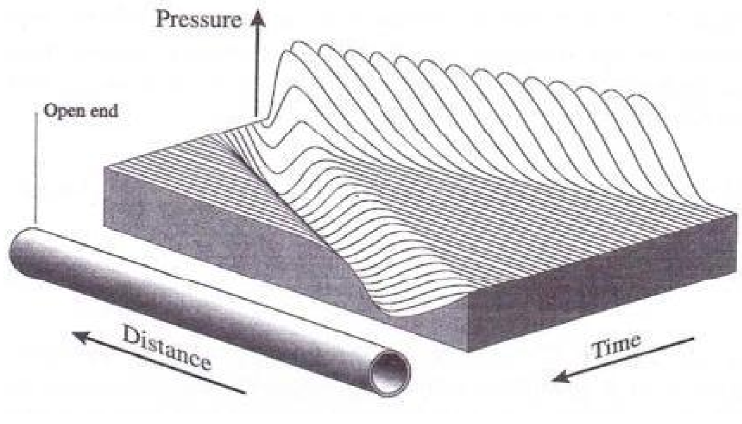

Figure 2.3: Reflection of rarefaction wave at exhaust pipe end which returns to the exhaust valve

Source: Morrison, 2009

Another perspective of the priorities of exhaust system design is provided by a parameter (Sammut and Alkidas, 2007). This study utilizes the engine simulation software Ricardo WAVE to quantify the effects of and interactions between exhaust, intake and valve timing parameters. For a constant valve timing and engine speed, shows a comparison of the scavenging effect of the intake and exhaust measured in volumetric efficiency.

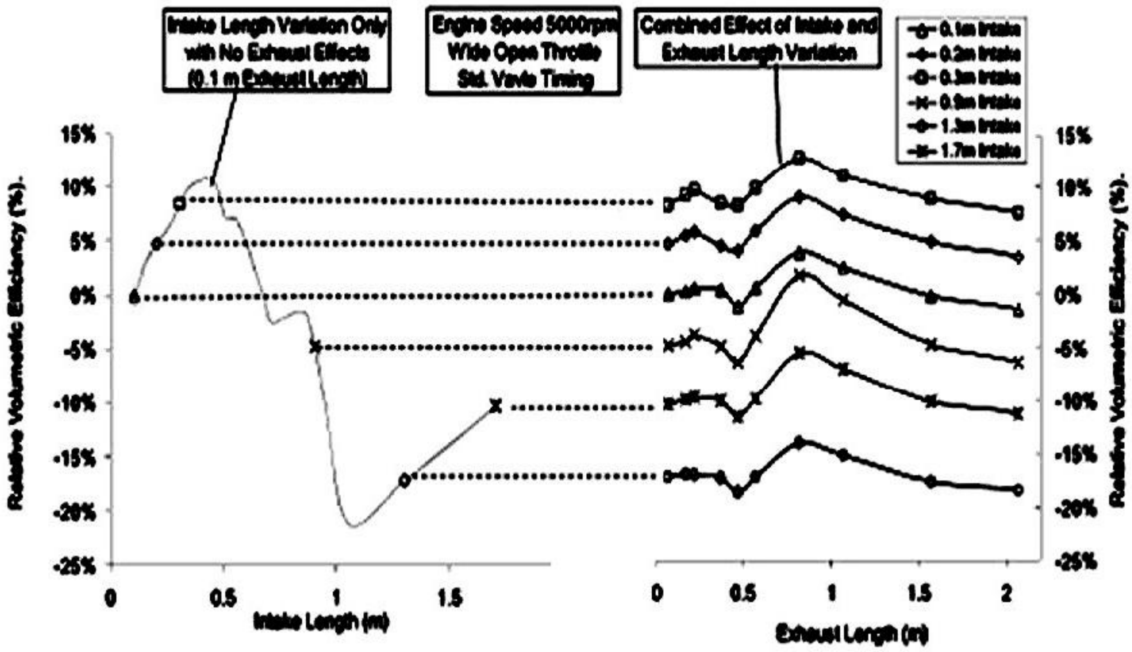

Figure 2.4: Variation of volumetric efficiency with intake and exhaust length

Sources: Sammut and Alkidas, 2007

The data presented firstly shows that the individual contributions of the intake and exhaust are independent as the contribution made by the exhaust is relatively constant for any intake length. All data presented here in illustrating variation in scavenging as a function of tuned length is obtained for constant valve timing. Variation in valve timing would inevitably change the characteristics of the overlap period and therefore the action of exhaust scavenging. Secondly, data presented in Figure 2.4 also concludes that the effect of exhaust tuning is relatively small compared to the benefits of intake tuning.

As a consequence of the diminishing significance of exhaust scavenging benefits, minimizing the losses conceded to increased pumping losses whilst achieving sufficient noise attenuation becomes of relatively high importance if a maximum amount of power is to be derived from the engine.

2.3 EXHAUST PIPE LENGTH

According to 1D-Simulation method, the output power and pressure in the intake-exhaust system can be calculated. Engine that use for dynamometer are 150cc with air-cooled system. The parameters for tested are refer to pipe length exhaust. The parameter that changes is pipe length before the catalyst (Horikawa et al., 2010).

Figure 2.5 show the measured and calculated output power for this type of engine that tested using dynamometer. Those graphs indicate that when the length of the piping system is change the performance of the engine for torque and speed also change. The measured result indicates that output power increases at low engine speeds and decreases at high engine speeds when the exhaust pipe becomes longer, and the opposite when the exhaust pipe becomes shorter. A similar trend is found in calculation, and the rate of output power change is also close to the measurement (Horikawa et al, 2010).

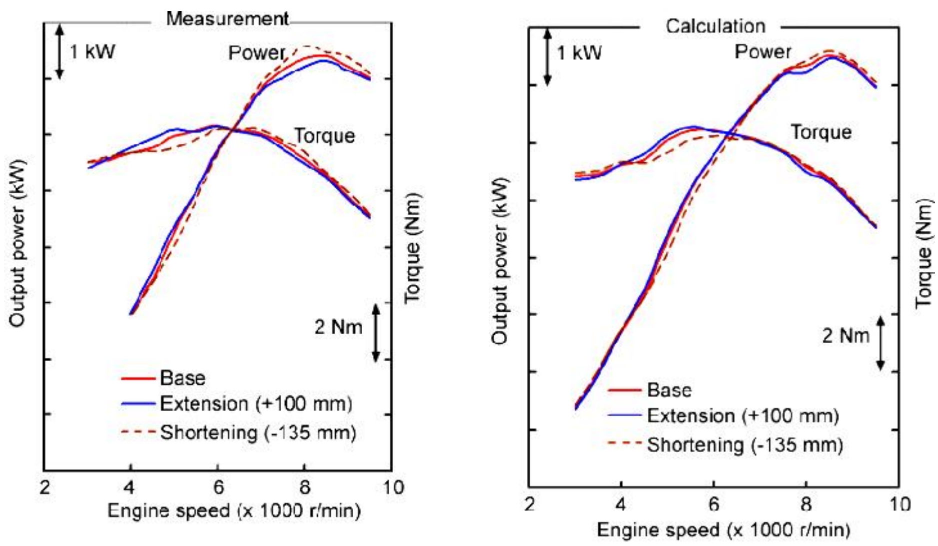

Figure 2.5: Measured and calculated power and torque when change exhaust length

Sources: Horikawa et al., 2010

2.4 INTAKE AND EXHAUST TUNING

It is important to understand that the resonant length of the intake and exhaust systems should be tuned separately. It is suggested that the intake system be tuned for the desired speed range and then the exhaust system should be adjusted to compliment the intake system (Blair, 1999).

An experiments were executed with the variables intake primary length (L_i) and exhaust length (L_e) using 450cc by 1-Dimensional Simulation (Correia, 2009). Results from three of the most outstanding instances are presented. The three configurations of intake and exhaust system settings are indicated in table 2.1.

Table 2.1: Intake and Exhaust Configuration

	L_i(mm)	**L_e(mm)**
Config 1	198	660
Config 2	254	1194
Config 3	198	381

Source: Correia, 2009

Figure 2.6 and 2.7 shows that the configuration 2 has the longest intake and exhaust lengths and exhibits a wider spread of torque from 4500rpm onwards. Configurations 1 and 3 both have the same intake primary length to highlight the effect of exhaust tuning on performance.

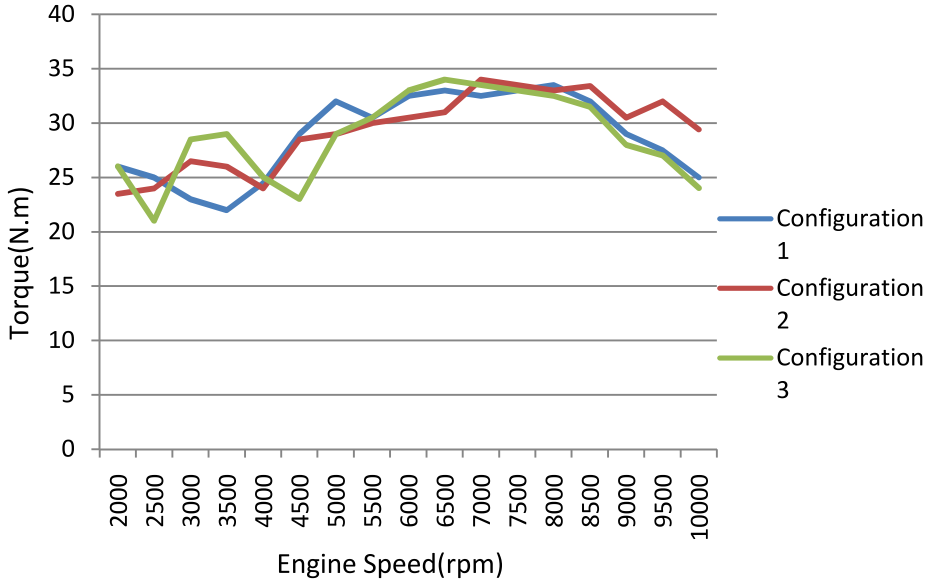

Figure 2.6: Torque Curve for Intake and Exhaust Tuning

Source: Correia, 2009

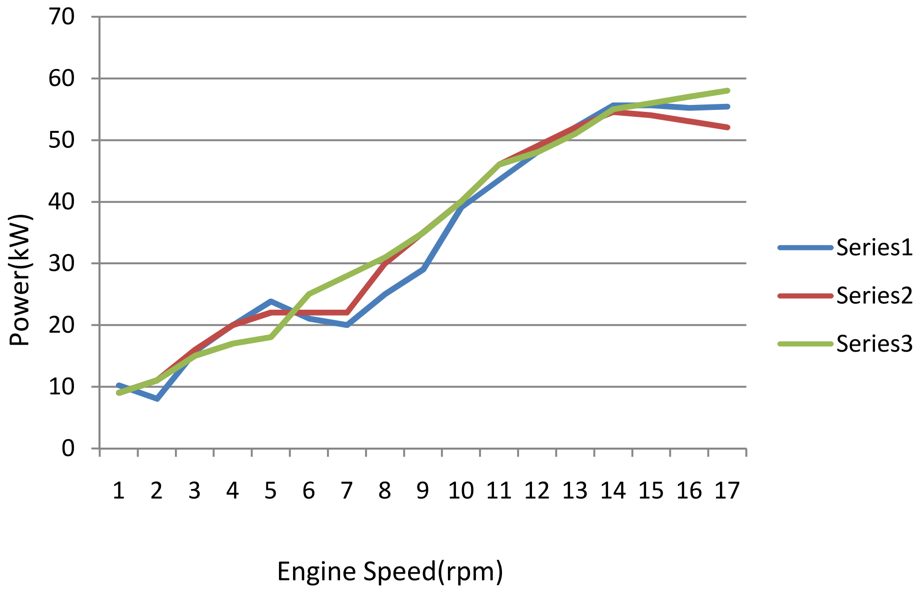

Figure 2.7: Power Curve for Intake and Exhaust Tuning

Source: Correia, 2009

2.5 EXHAUST MEGAPHONE

Exhaust diffusers (also referred to as megaphones) are sometimes used on highly tuned four stroke engines (Blair, 1999). There are analogy between the wave phenomenon active with an exhaust megaphone and the behavior of ocean waves as they approach the beach. As ocean waves approach the beach and water depth becomes shallow, the conservation of wave energy forces the waves to increase in amplitude. In a similar fashion, as reflected exhaust pulses travel back along the megaphone the amplitude of these pressure waves increase as the cross section of the duct decreases progressively.

The advantage of an exhaust megaphone is evaluated by modeling it to the optimize horsepower from 6,000 to 10,000rpm. According to the Figure 2.8 the factors that adjusted were the secondary length L_e2, and the secondary diameter D_e2 of the exhaust megaphone in addition to the exhaust primary length Le1. The final values chosen were L_e1 = 510mm, L_e2 = 770mm and D_e2 = 150mm.

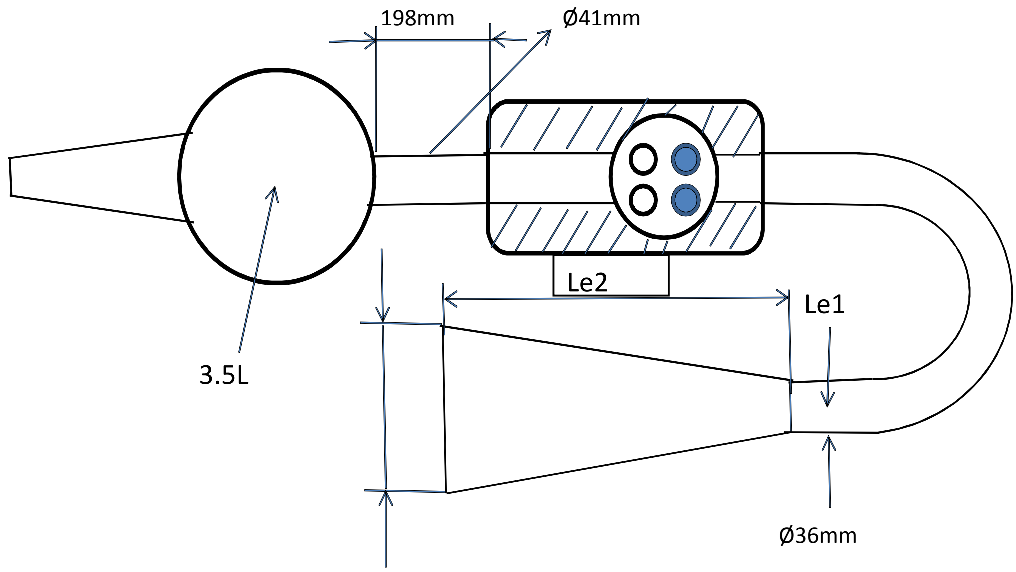

Figure 2.8: Exhaust Diffuser/Megaphone

Source: Correia, 2009

The Figure 2.9 and 2.10 show the resulting performance trends offered from an exhaust diffuser. Configuration 3 has length of exhaust 381mm. According to the graph both systems offer high peak horsepower numbers compared to configurations 1 and 2. However the exhaust diffuser delivers about 3% more power between 7,500 and 8,500rpm, whilst output remains virtually comparable onwards (Correia, 2009).

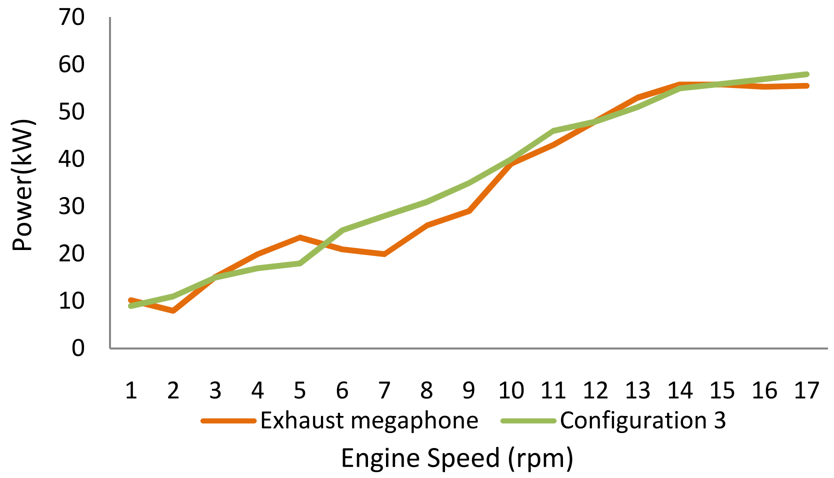

Figure 2.9: Horsepower for Exhaust Megaphone

Source: Correia, 2009

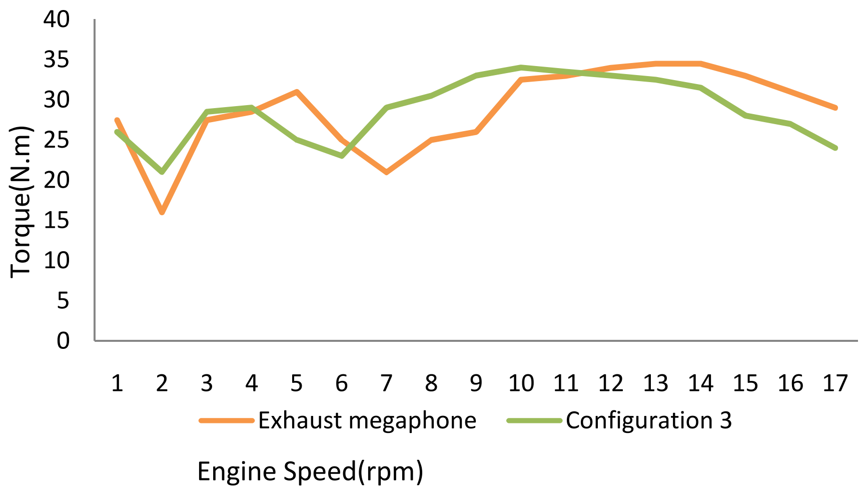

Figure 2.10: Torque for Exhaust Megaphone

Source: Correia, 2009

2.6 NOISE AND SILENCER

Noise can be describe as unwanted sound, but in producing exhaust noise cannot be remove but can only reducing the noise from the exhaust. When tuning race engines, silencer design or selection is often not considered a priority, though it is an integral part of tuning the exhaust system (Blair, 1999).

Formula SAE requires cars to be tested for noise at an angle of 45 degrees and 0.5m away from the silencer outlet. The noise level must not exceed 110dB (A scale) at any time during the noise test. A car will not be allowed to compete unless it passes the noise test. A simulated version of the Formula SAE noise test was setup in WAVE and two silencer designs were compared along with the scenario of not fitting a silencer to the exhaust. The simulation was conducted from 5500rpm upwards as it is time intensive and it was expected that the greatest noise intensity would occur at the higher speeds (Correia, 2009).

Figure 2.11 and 2.12 compares the engine performance change from fitting of the silencers. The two silencers have similar output with the absorption model outperforming the two-box design marginally from about 7,000 to 8,000rpm. The un-silenced power curve is different in nature likely due to fact that the silencers affect exhaust tuning.

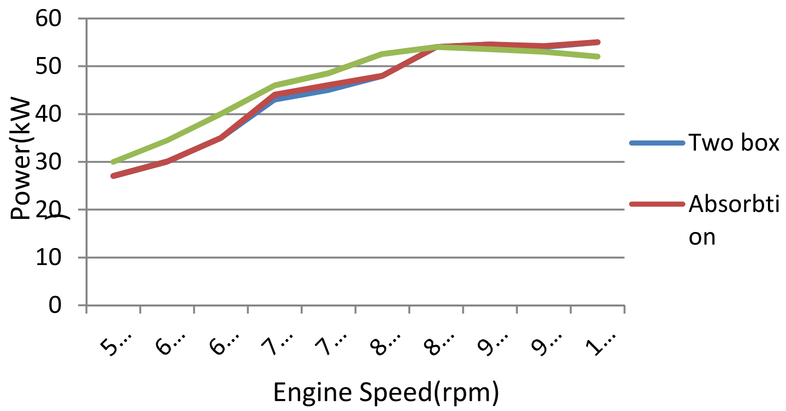

Figure 2.11: Power curve for silencer

Source: Correia, 2009

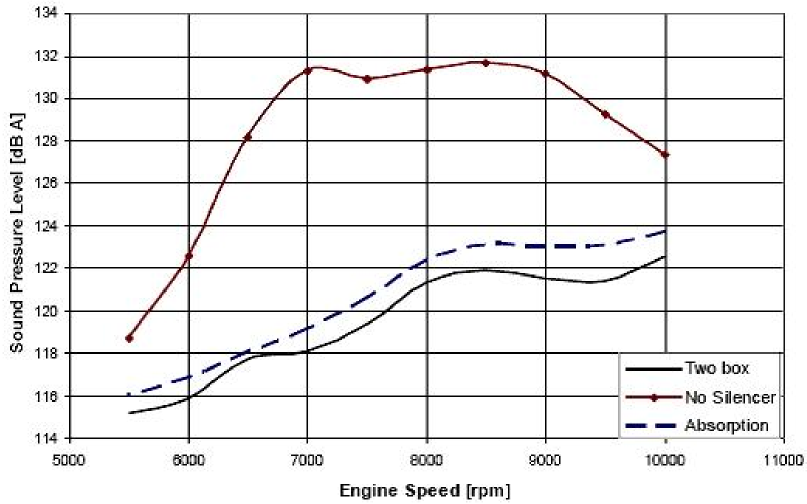

Figure 2.12: Noise level for silencer

Source:Correia, 2009

The results of the simulated noise test, all plots exceed the 110dBA noise criteria. Nevertheless the trends of the results are noteworthy. As expected the un-silenced noise is excessively loud. At this point the reader is reminded that the decibel is a logarithmic scale and that 20dB is an order of magnitude greater than 10dB.

The two box silencer outperforms the simple absorption silencer over the entire speed range. Thoughts the largest reduction in noise level is a mere 1.4% at 9,500rpm. The two-box silencer seems to be the obvious choice because its negligible performance reduction in a small speed range is outweighed by its superior noise attenuation ability. Furthermore it will be marginally lighter than an absorption silencer of equivalent length since the diffusive chamber is not surrounded by packing.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTIONS

In this chapter describe the methodology from beginning of the project until finish work. Methodology used in present study to achieve all target objectives within given scope is discussed. It is covered four elements for completed the project which is sketching, design, fabrication, testing and experiment. Every element has step and procedure to fulfill the target objective.

The project starts with the design of the new test rig that suitable with new engine model which is Modenas GT128. Then project continue with fabrications of new test rig and assemble test rig with base of the dynamometer. If it is fit correctly according the drawing, hence proceed to another step which is design the exhaust with different length. Next proceed to experiment utilizing dynamometer using difference length of exhaust and recorded the data. The overall methodology is as summarized in flow chart in Figure 3.1.

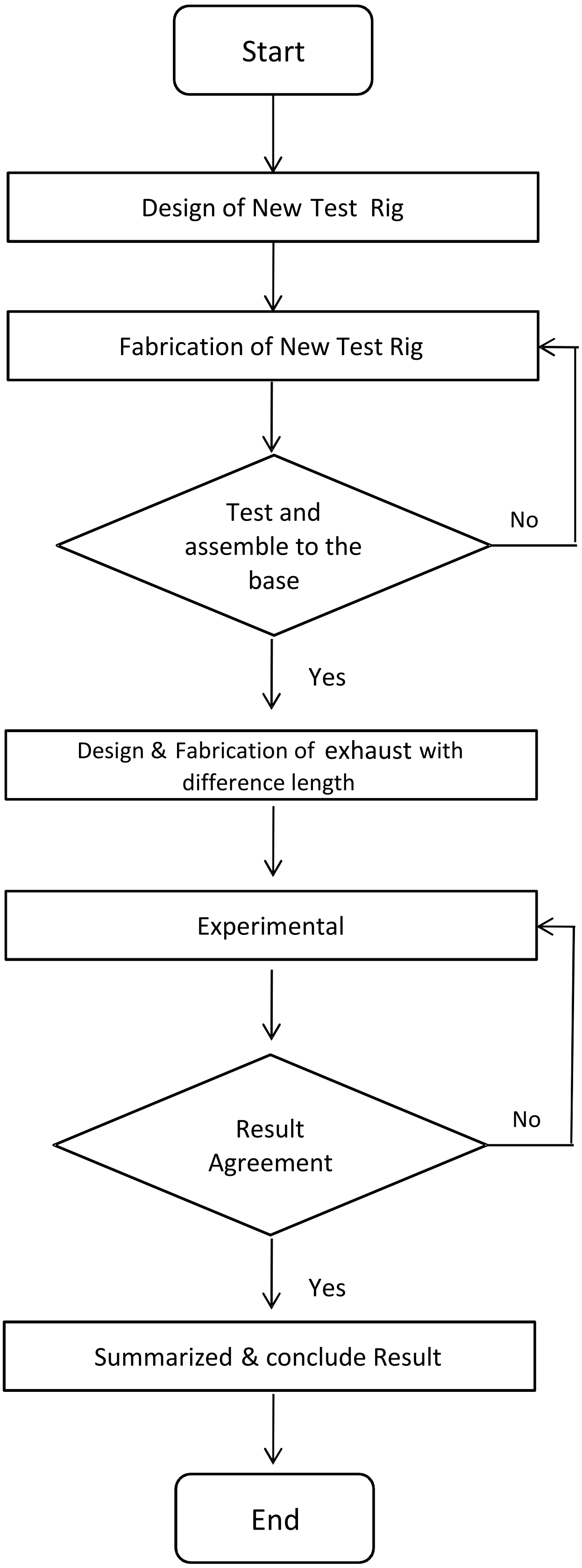

Figure 3.1: Flow Chart of Methodology

3.2 DESIGNING THE TEST RIG FOR FOUR STROKE ENGINE

Engine test rig is the stand that holds the engine for going through the experiment by using engine dynamometer. The dimensions for new test rig actually follow the previous dimension. All the dimensions are same except the material that use for the test rig and the design. Previous test rig are only specific for FZ150i, hence it cannot be use for this experimental because it is use engine from GT128. First thing first before make a possible sketching for new design of the test rig is takes the dimension of the previous test rig including the height, width and length. Everything needs to be specified because it will connect to the dynamometer shaft to undergo the experiment. If the dimension is not correct the output shaft from engine that need to assemble with the input shaft of dynamometer are cannot mesh or connected. Figure 3.2 show the test rig of FZ150 that already connected to the input shaft of dynamometer.

Figure 3.2: Previous test Rig for FZ150i

Source: Dynamometer Lab FKM

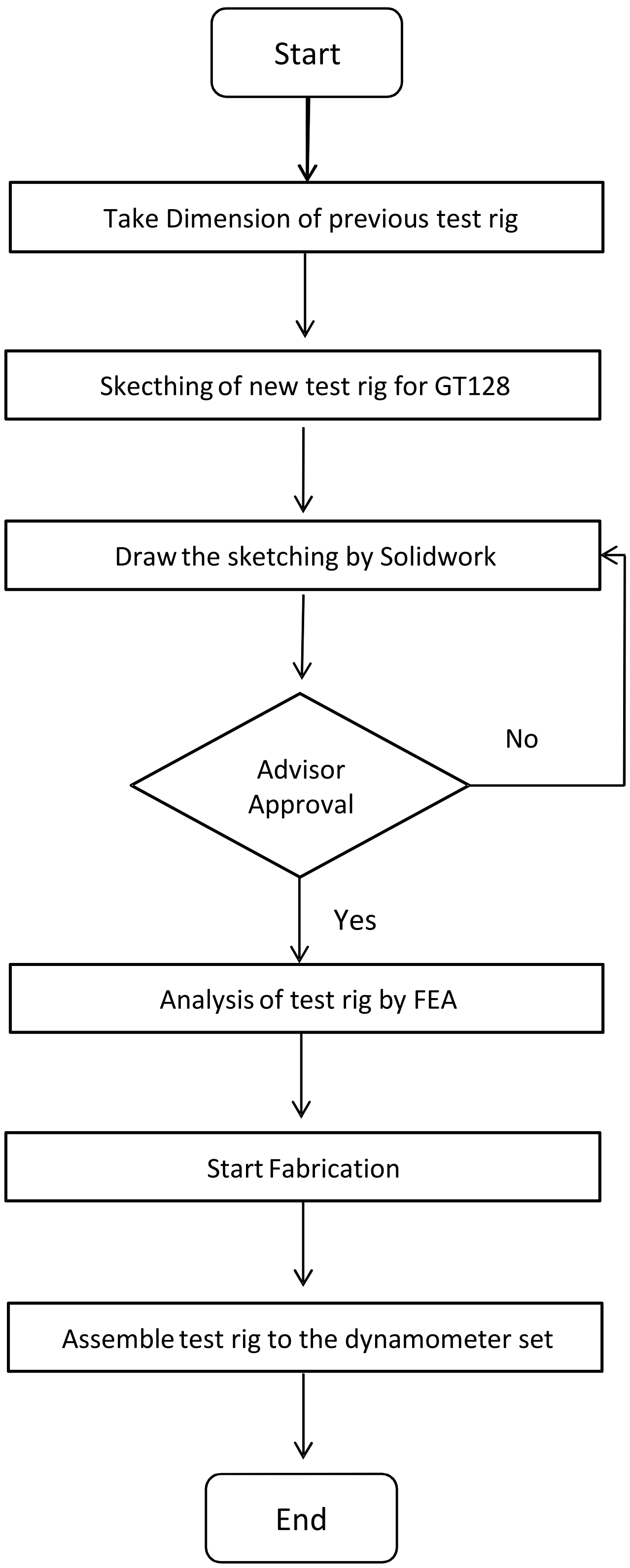

Figure 3.3: Flow Chart of designing New Test Rig GT128

Figure 3.3 show the flow chart of the designing new test rig. First step of development new test rig is take dimension of previous test rig FZ150. Then from the dimension make a sketching of new test rig, the test rig must be suitable with the engine Modenas GT128 and can assemble to the dynamometer. The sketching must be included the material that want to use for the developing of test rig such as square hollow, C-channel and bolt and nut. Table 3.1 show the detail of the list of material use for the fabrication of test rig GT128.

Table 3.1: List of material to fabricate Test Rig

Type of Material	Size(mm)	Quantity
Mile Steel Square hollow bar	20x20x2	6m
C-channel	80x2	3m
Bolt and Nut	M12	0.2kg

From the finish sketching, make a better drawing by using SolidWork software. In the software, build the actual test rig that want to develop with complete dimension and material that need for the fabrication of the test rig. Figure 3.4 show isometric view of GT128 test rig that draw by using SolidWork. Drawing by SolidWork is more precise and can predict the design of actual test rig. More than that, the advantages of drawing by SolidWork is the test rig can undergo analysis for tensile and strain by using Finite Element Analysis (FEA). The purpose of the analysis is to predict the sustainable of the product when load are applied. SolidWork also can reduce cost for fabrication because everything needs to be considers specifically.

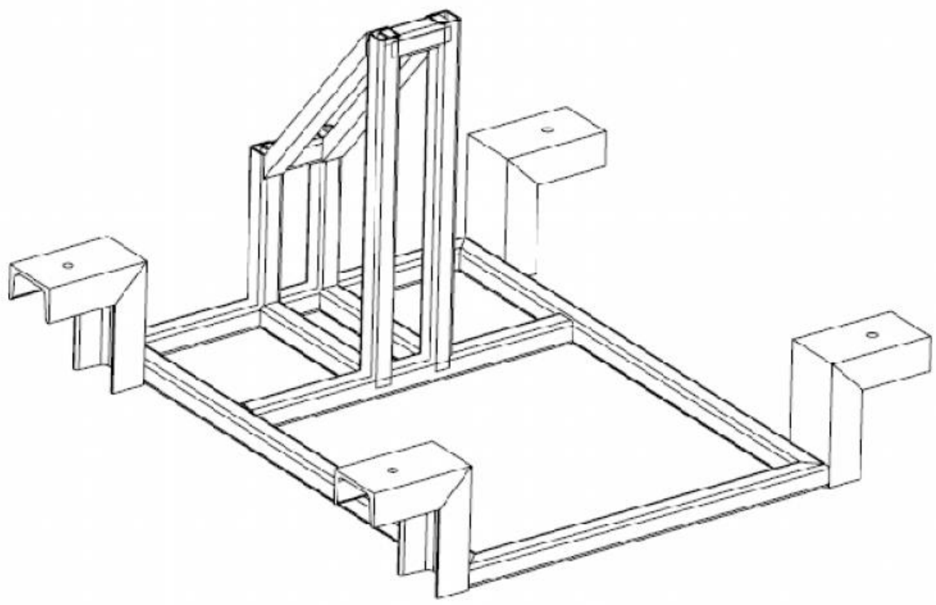

Figure 3.4: Isometric view of GT128 Test Rig

Figure 3.5 show the complete drawing of test rig with dimension. The drawing included front view, side view and top view. There are two part of the drawing, first is the test rig second is the base stand. Two of it using difference materials which are square hollow for test rig and C-beam for base stands. Material selection for this project is to make sure it is stand the vibration, and load of engine and force from the dynamometer. It is also to make work of fabrication of the test rig is easy and smooth according the plan.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Test Rig	Square 1.5 inc	1
2	base stand	C Beam 80x8	4

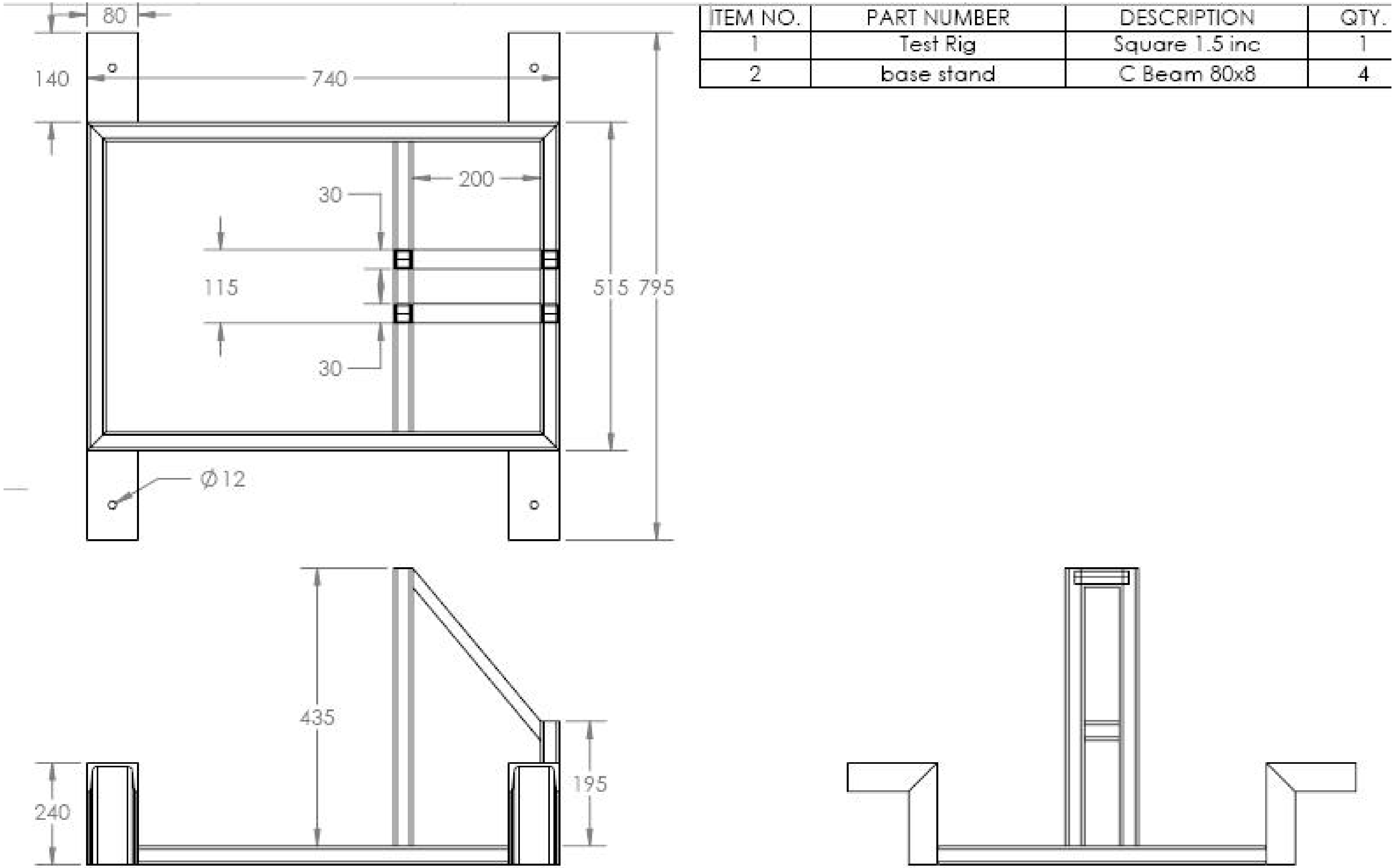

Figure 3.5: Drawing of the test RIG

3.2.1 Analysis of Test Rig by Finite Element Method (FEA)

Finite element method is one of the software for analysis of the product either for tensile, strain or torsion. New design of test rig will be tested on the tensile and strain because it is involve of load from the engine component and torsion from the dynamometer. The load been applied to the test rig is about 500N and 800N. Load of 500N is the considering of weight of the engine GT128 about 50kg that assemble to the test rig. While load of 800N is to test either the test rig can stand more than 50kg and more. Table 3.2 below show the material properties of AISI 1005 steel that use as the material of the test rig and base stand in the analysis.

Table 3.2: Material Properties of AISI 1005 Steel

Material Properties	Value
Modulus of elasticity(N/mm^2)	20000
Poison Ratio	0.29
Shear Modulus Elasticity(N/mm^2)	80000
Mass Density ($N*s^2/mm/mm^3$)	0.000000007872

This type of material has been chosen because it is standard grade and usually use in design of simple part. It is suitable for this project that build test rig with simple design and light.

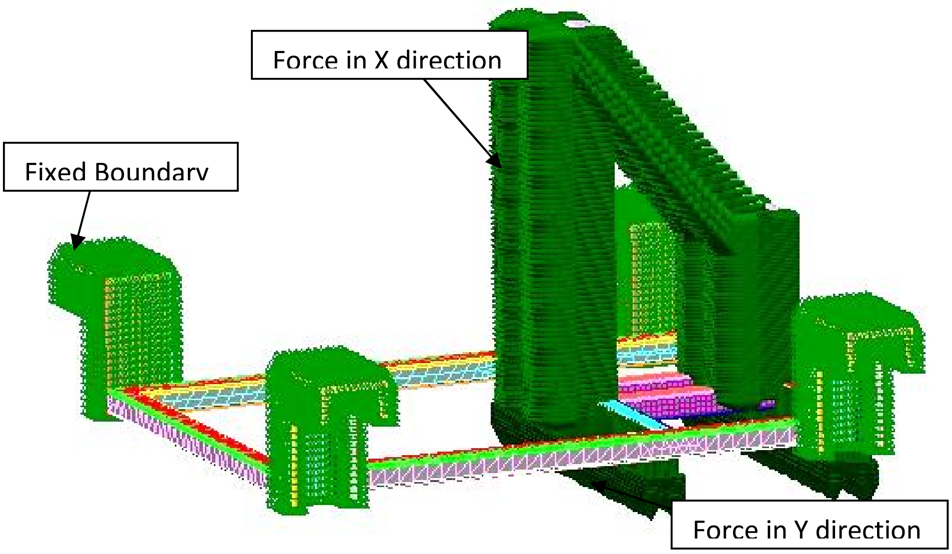

Figure 3.6: Boundary condition and force applied to test rig

After the drawing by SolidWork are finished, the drawing will analyst by using Finite Element Method. The drawing must be imported to this software and make the meshing of the drawing. Meshing type for this test rig is medium type. After that, the test rig must set the boundary condition and applied force to be tested to the test rig. Figure 3.6 show the boundary condition and force that applied to the test rig. There are three type of boundary condition need to setup such as fixed boundary, force in x-direction and force in y- direction.

Fixed boundary is important because it is just like the test rig already assembles with base of dynamometer. Fixed boundaries also to make sure the test rig is rigid and not moves. Part that considered as rigid and fixed is the base stand. Four of the base stands with boundary condition fixed and rigid. After that, set for another boundary condition which is the applied force for y-direction and x-direction. For y-direction the load is about 500N in the negative direction or gravitational force. 500N is the weight of the engine that assembles to the test rig. While for x-direction the load is assumed to be a force that comes from the rotational of the dynamometer. After all the boundary condition already setup, run the simulation and record the data and the analysis

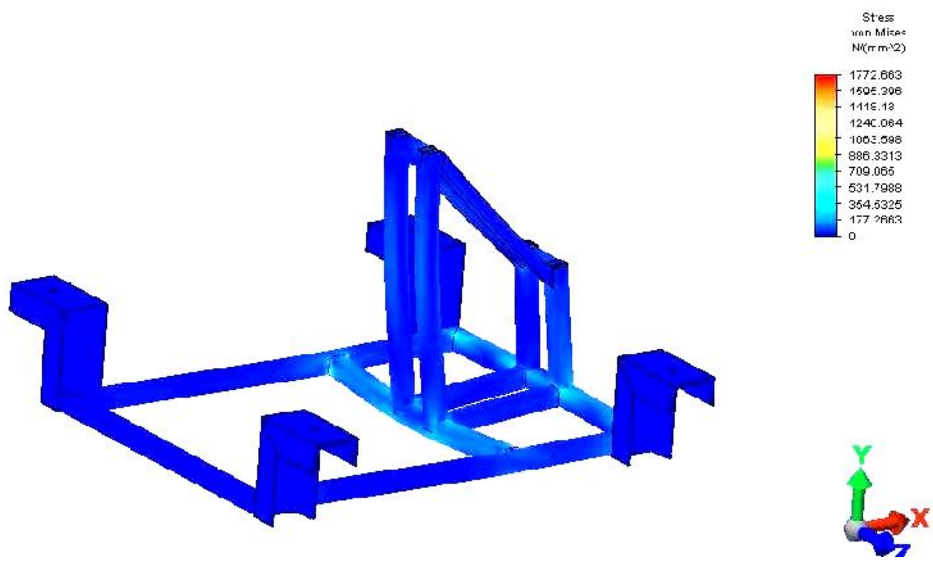

Figure 3.7: Result of Stress von mises

. Figure 3.7 show the result of the analysis based on the stress von mises. It is illustrate the maximum value of the test rig can stand if the applied force is about 500N. Maximum stress for 500N load applied is 1772.663N/mm^2. Figure 3.7 show region of effect after the load are applied to the test rig but the test rig still can sustain the load and not fail or break. The bending only occur at the base of the test rig and engine stand but not very critical. Hence new design of test rig is suitable and can stand larger load than engine weight and rotational force.

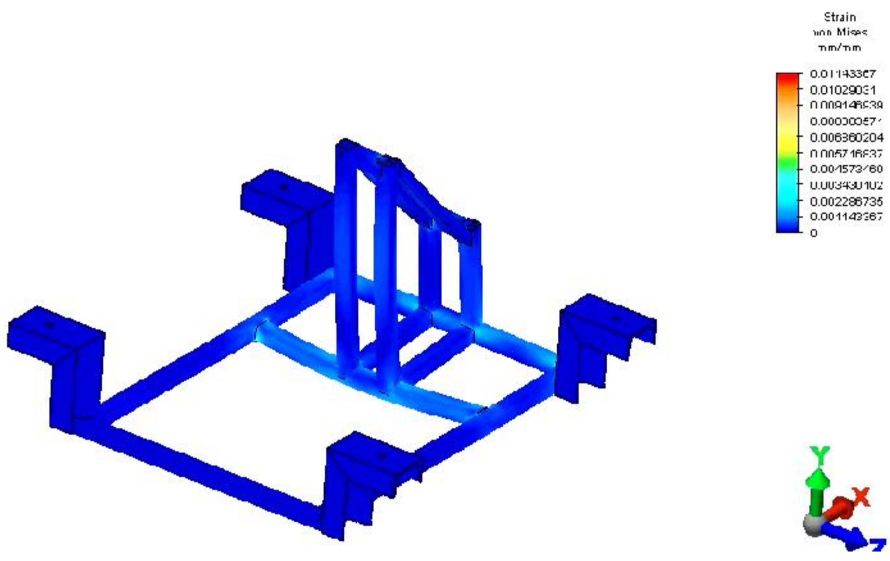

Figure 3.8: Result of strain von mises

Figure 3.8 illustrate the result of strain von mises from finite element analysis. Maximum value of stain analysis is 0.0114337mm/mm when load apply is 500N. The deflection value of the test rig is very small only 0.01mm/mm, hence this test rig is reliable and suitable for load 500N.

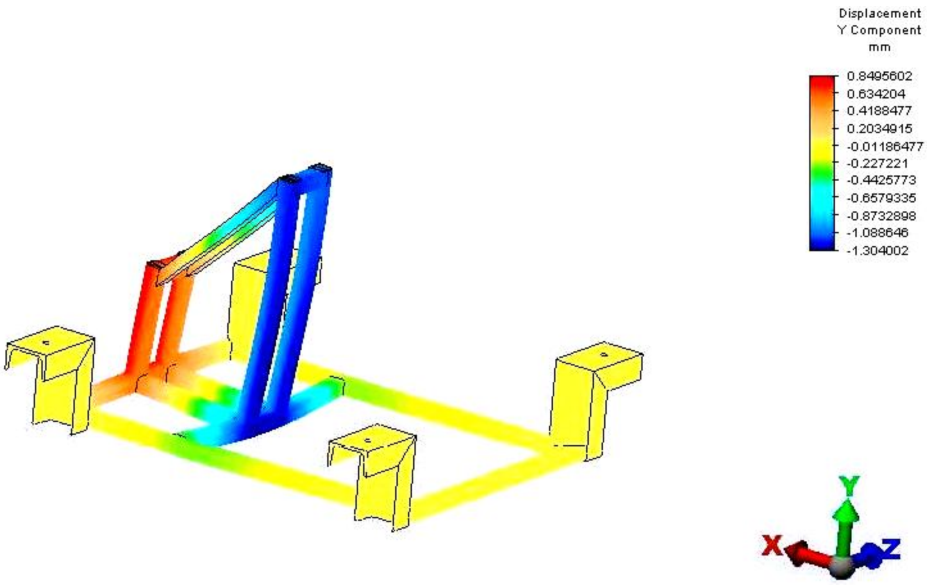

Figure 3.9: Displacement of Y component

Figure 3.9 show the result of analysis of test rig for displacement of Y component which the direction is negative direction. From the figure 3.9, the maximum value for displacement of Y component is 0.84956mm which means less than 1mm. The displacement of Y component can be seen on the base of test rig according the colour of the contour. Displacement value that large usually in red colour, hence the large displacement of Y component is at the back of the drawing and the lowest is at the stand of the engine. The displacement of test rig is very small and can sustain the load applied the base. As a conclusion, the material and the design of new test is reliable and suitable to conduct experiment using dynamometer. Next step for designing of new test rig can be proceeding to fabrication of the test rig.

3.2.2 Fabrication of Test Rig GT128

Fabrication process of test rig for engine GT128 is the next process after all design and analysis is done. The fabrication is using suitable tool and technique. The fabrications start with collect main material from store of material, cut according the dimension in the drawing and joint it by welding. The main material is square hollow and c-channel. To complete the task of fabrication some tool need to use. Tools that use for fabrication is show in the table 3.3 below.

Table 3.3: Tools used for fabrication

Tool name	Description
High cutter	To cut the square hollow into specific dimension (740mmx2), (515mmx2),(440mmx1), (230mmx2), (435mmx2), (210mmx2)
Hand Grinder	To remove the sharp edge of square hollow after cut and remove burr and to make angle edge(45^o)
MIG welding	To assemble and joint the square hollow according the drawing
Drilling	Drill hole of M12 for the base stand

The are safety precaution to use every tool, first of all need to wear personal protection equipment such as safety goggle, ear plug, and safety shoes before start any work of fabrications.

Figure 3.10: Test Rig that finish

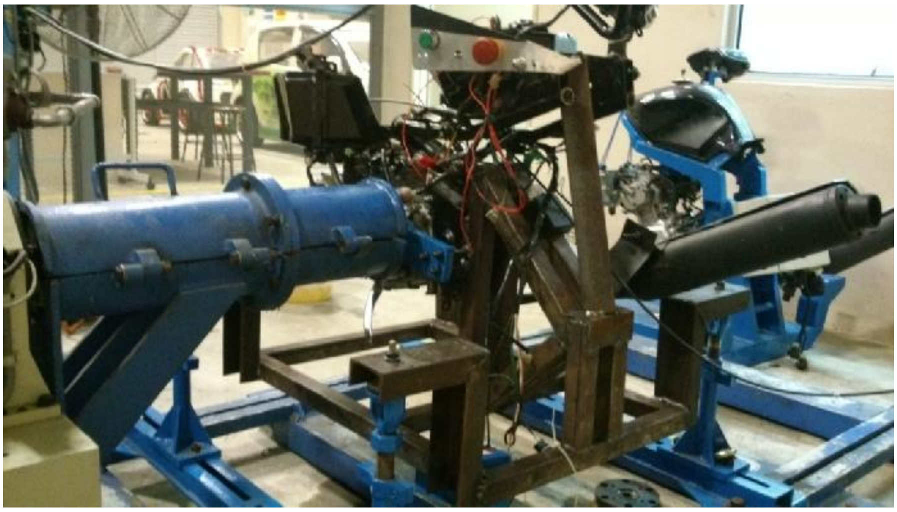

Figure 3.11: left view of test rig

3.3 ENGINE SPECIFICATION

Table 3.3: Engine Specification

Engine	Specification
Type	4-Stroke,1cyl,SOHC
Bore x Stroke	53.0 x 59.1mm
Displacement	130
Compression Ratio	10:01
Carburetor	KEIHIN NCV 24
Ignition System	DC-CDI
Starting System	Kick and electric starter
Cooling System	Air Cooled
Lubrication	Forced lub, wet
Fuel Tank Capacity	4.3L
Fuel Consumption	64.4km/l @ 80 km/h

Table 3.4: Engine Transmission

Transmission	Specification
Type	4-Speed rotary(down)
Clutch	Centrifugal and wet
Primary Reduction Ratio	3.000(69/23)
Final Reduction Ratio	2.800(42/15)
Driving System	Chain

3.4 EXHAUST DESIGN

To undergo this experimental, it need at least two design of the exhaust. First is long and second is short. This exhaust must use the same diameter pipe and same nozzle and diffuser. These designs are contribute from the formula of the exhaust pipe length. Formula of the exhaust length has been state in the four stroke performance tuning by A. Graham Bell (1998). The best length can be calculated by using this formula:

$$L= \frac{129540\ x\ ET}{RPM\ x\ 6} \tag{3.1}$$

Source: Bell, 1998

L = Primary pipe length in mms measured from the exhaust valve head.
E.T. = Exhaust valve duration in degrees from point of valve opening before B.D.C plus the full 180 degree stroke up to T.D.C.
R.P.M. = the estimated revs, at which max. power will be achieved minus five hundred
Example:
RPM= 7500rpm
E.T= 185

$$Rpm = 7500 - 500$$
$$= 7000$$
$$L = \frac{129540x185}{7000x6} \qquad L = 570m$$

Maximum power (kW) value of engine GT128 are defined from graph of power versus speed from result in figure 4.1. The maximum power is at engine speed of 7500 rpm. While the value of exhaust valve duration in degree from point of valve opening before bottom dead center (B.D.C) plus the full 180 degree stroke up to top dead center (T.D.C).

The value of exhaust valve opening is measure from cam profile, and the value is 5^{o} but to use the formula must added with 180^{o}. Hence from the formula, the best length of exhaust pipe length for this type of engine is about 570mm from the manifold until before the silencer. Figure 3.12 show the exhaust design with best pipe length of 570mm.

Figure 3.12: Exhaust pipe length of 570mm

The objective of this experiment is to obtain high power and torque at low speed of engine (rpm) based on the change of exhaust parameter. Hence, for another length of exhaust pipe is multiple the best length of exhaust of 570mm and become 1140mm. The length also measure from manifold until before the silencer. Figure 3.13 show another exhaust with difference pipe length which is 1140mm.

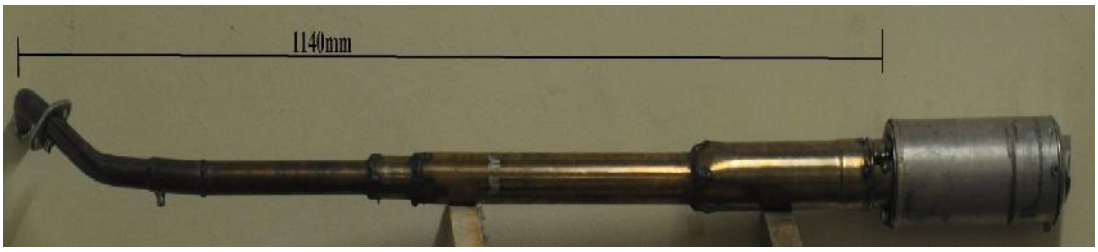

Figure 3.13: Exhaust pipe length of 1140mm

Each of the exhaust used the same type material, exhaust silencer and size of the manifold. Material for the exhaust pipe is stainless steel with difference size such as 1 in, 1.5 in and 2 in. The joining between the differences sizes of pipe is done by metal inert gas welding (MIG). After the exhaust fabrication are done and finish, the exhaust is ready to test. Standard exhaust from motorcycle Modenas GT128 becomes the reference exhaust.

3.5 EXPERIMENTAL STUDY OF DYNAMOMETER

3.5.1 Test Rig Preparation

Test rig that already finish and complete need to be assemble and set up on the dynamometer machine. To set up the dynamometer with new test rig of engine GT128, the previous test rig which is for engine FZ150 need to be dissemble and remove from the dynamometer set. Test rig of FZ150 must be place in good condition after it have been remove because after the experiment of dynamometer for engine GT128 are finish, test rig of FZ150 need to assemble back as before. Figure 3.14 show the test rig of FZ150 that have been removed from it base.

Figure 3.14: Test Rig of FZ150

Figure 3.15: Test Rig of GT128

Figure 3.15 show the test rig of engine GT128 have been assembled and place on the dynamometer base. Test rig of GT128 must be alignment their height, the distance between the output shaft of the engine and input shaft of dynamometer, and the distance between each stand of the test rig. This is an important part before the experiment are handle because if the output shaft of the engine and input shaft of dynamometer are rotating part. If the connection is loose and not alignment correctly, hazardous and dangerous situation will be occur during the experiment are handle. Input shaft of engine and output shaft of dynamometer is connected by connecter that fabricates according the size of the output and can be assemble to the input shaft of dynamometer. The connecter of the output and input shaft is show in the figure 3.16.

Figure 3.16: Connecter of input and output shaft

When the connector of the output shaft of engine and input shaft of dynamometer are connected correctly, make sure bolt and nut for each part around the dynamometer and test rig have been tighten. Then test running the engine of GT128 and check the condition of test rig and input shaft of the dynamometer. If the shaft rotate smooth and the dynamometer run perfectly, the test rig are ready for the experimental.

Engine GT128 is an engine that using air as cooling systems. Table 3.3 show the detail specification of engine GT128. Current engine of dynamometer which is FZ150 is an engine that uses water or fluid as a cooling system. Hence, the cooling system of current engine cannot be used for engine GT128. New cooling system for the engine GT128 must be created to make sure the engine is not over heating during the experiment. Air ventilation of dynamometer laboratory is very slow and not suitable to cool the engine. Hence to cover the problem, air ventilation in the dynamometer laboratory must be improved by using big fan during the experiment.

Last step in the test rig preparation before the experiment beginning is to setup the servo pump that controls the throttle valve opening. For this type of experiment, only 100% of valve opening will be conducted. To make sure throttle valve opening of this engine open up to 100%, the servo need to be setup properly because it is very difficult to setup it until it is fully open the throttle valve. Hence, the setup will undergo many times until it is suitable and the throttle valve is fully open. When all of the procedure for the test rig preparations is done, the experiment for the dynamometer of difference length of exhaust can be done properly without any problem.

3.5.2 Experiment Procedure of Dynamometer

For the experiment by using dynamometer, switch on the main switch of the dynamometer cooling tank and switch on the fan and the pump. If the cooling tank of the dynamometer is off, the experiment cannot be done because the panels switch for whole dynamometers controller will give an alarm with show the dynamometer is not ready. Figure 3.17 show the panel switch of the dynamometer cooling tank. After that, switch on the main control panels that control all the partition of the dynamometer machine. On the main control panel, it is consist of speed and torque controller for the dynamometer, throttle lever positions, indicator of speed and torque value and button to set type of the experiment to handle.

Figure 3.17: Cooling tank for Dynamometer

When the main control panels are on, the indicator of dynamometer is ready to use will appear. Figure 3.18 show the indicator of the dynamometer are ready to use. If the dynamometer is unready to use or the indicator show the dynamometer alarm, press the alarm reset button and the dynamometer will be ready to use. If it is still unready to use, check the dynamometer cooling system either it is switch on or not.

Figure 3.18: Indicator of Dynamometer is ready to use

After that, set the button on the main control panel for the torque and speed of the dynamometer to button number five. Number five is speed is control by dynamometer and load control by engine is the throttle lever. Then set the speed controller at 200 rpm but constant the value of the torque at zero and press the start button. After press the start button the dynamometer are ready to read the rotational force or known as torque on the torque indicator. Figure 3.19 show the control panel of speed, torque and button to set type of the experiment.

Figure 3.19: Control panel of speed, torque and button type of experiment

Next step of the experiment is start the engine GT128 and put the gear ratio at forth gear. Fourth gear is the suitable ratio for the dynamometer because the suppose ration between the engine the dynamometer is 1:1. Hence the best ratio value that near to the 1:1 is forth gear. After the gear ratio is relevant, increase the throttle lever until throttle valve totally open or 100% valve open. When the throttle valve is fully open, air will be suck into the combustion chamber because of the pressure difference and completed the combustion mixture. Figure 3.20 show the throttle lever position and controller for the throttle lever.

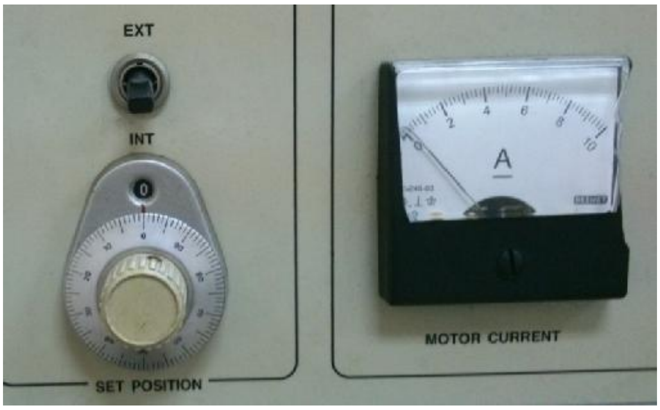

Figure 3.20: Throttle lever controller

Then take the reading of the torque on the main control panel indicator after all the setup to run the experiment is done. The speed of engine also must be recorded, the value of engine speed can be collected by engine speed indicator. The indicator of engine speed reader is show in the Figure 3.21.

Figure 3.21: Engine speed reader

Figure 3.22: Torque reading on the main control panel

Figure 3.22 shows the reading of the torque of the dynamometer when the speed of the dynamometer is set to 2200 rpm. When the speed of dynamometer is 2200 rpm, the torque reading that display on the torque indicator is 25.05Nm. While the reading of the engine speed is 5100 rpm, the reading can be read on the engine speed reader that display on the Figure 3.21. Then repeat the step from adjusting the speed of the dynamometer until torque and speed of the engine value recorded. Adjust the speed of the dynamometer form 200 rpm until 3200 rpm, the increasing of value is about 200 rpm each time to adjust the speed. Record the data of the torque of the dynamometer, speed of the engine, and speed of the dynamometer as the Table 3.5 below.

Table 3.5: Example data recorded

Dynamometer Speed(rpm)	**Torque Dynamometer(Nm)**	**Engine speed(rpm)**
200	26.54	3500
400	26.11	4000
600	26.24	4200

CHAPTER 4

RESULT AND DISCUSSION

4.1 EXPERIMENTAL RESULT

4.1.1 Baseline Result of Engine GT128 with Standard Exhaust

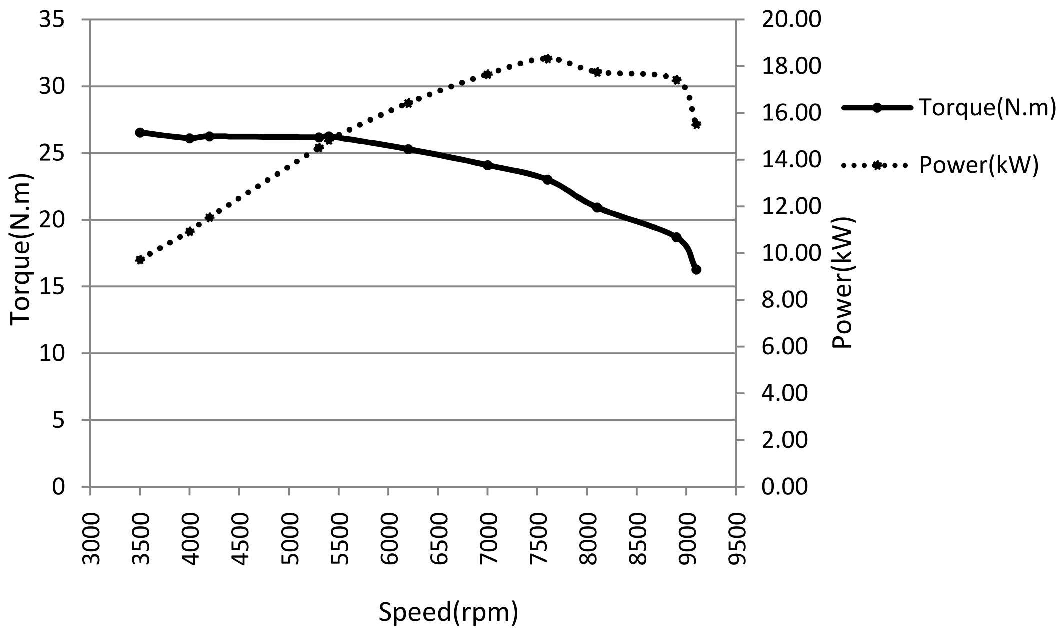

Figure 4.1: Graph Torque (Nm) and Power (kW) versus Speed for Baseline

Figure 4.1 show the baseline graph of GT128 that use standard parameter exhaust and intake pipeline. This result is very important because it is a reference result to compare with others experiment result. To plot this graph, standard or baseline parameter should undergo experiment of Dynamometer of 15kW. Based on the graph in

Figure 4.1, the maximum torque reading is 26.54Nm at speed of engine 3500 rpm and the maximum power is 18.32kW at speed of engine 7500 rpm.

The pattern of the graph for power (kW) is increasing rapidly from 9.73kW at speed 3500 rpm until 18.32kW at speed 7500 rpm, after that the graph is decrease to 17.75kW. The percentage of decreasing is about 3.11%. This is show that the limit of engine GT128 is about speed up to 7600 rpm, after that it will converge. All type of engine has their own limit same as human body, when it reaches the limit the energy will loss and fatigue. Based on torque graph the pattern show that it decrease rapidly from speed 3500 rpm until 9200 rpm, this is happened because when the engine are in highest speed, power will take place torque. Torque is use at the low engine speed to increase the acceleration. Point of exchange between torque and power is at engine speed 6100 rpm. The value of torque is 25.5Nm and power is about 16.29kW.

4.1.2 Result for Exhaust Length of 570mm

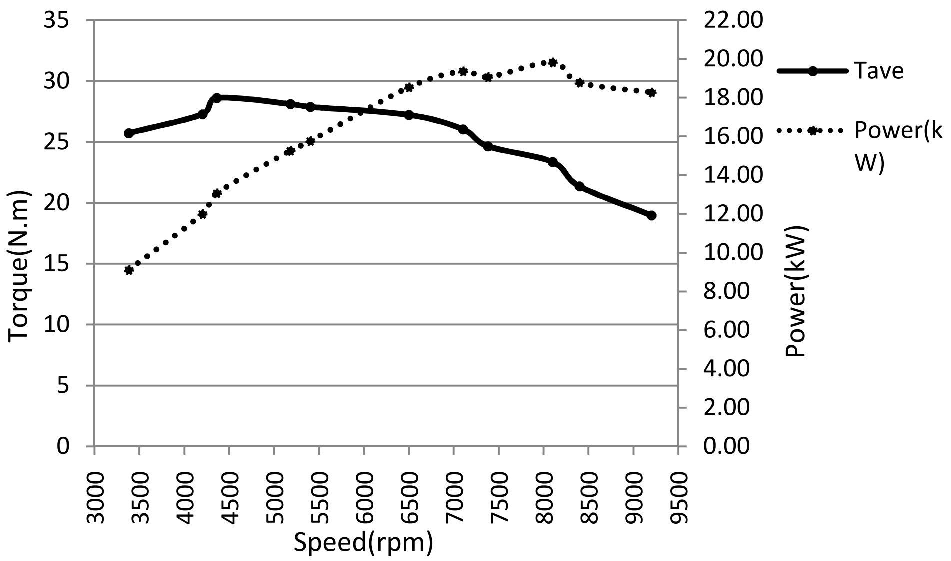

Figure 4.2: Graph of Torque (Nm) and Power (kW) versus Speed (rpm)

The graph above illustrate about graph of torque and power versus speed based on the changing of exhaust pipe length about 570mm before the silencer. When change the length of exhaust pipe, there are changing in the pattern of graph of torque and power. The changing of graph pattern can be seen at low range of engine speed between

3400 until 7500 rpm. Based on the graph, maximum value of torque is 28.63Nm at engine speed 4360 rpm while maximum value of power is 19.82kW at engine speed 8100 rpm. The lowest value of torque is 18.97Nm at engine speed 9200 rpm while minimum value of power is 9.10kW at engine speed 3400 rpm. The pattern of power graph is increasing from engine speed 3400 rpm until 7100 rpm, but after that the graph is decreasing about 1.6% until engine speed 7380 rpm. Then it is increasing for second time to maximum value of power which is 19.82kW at engine speed 8100 rpm. Point of exchange between torque and power is at engine speed of 6000rpm which is torque is 27Nm and power is 16.97kW.

4.1.3 Result for Exhaust Length of 1140mm

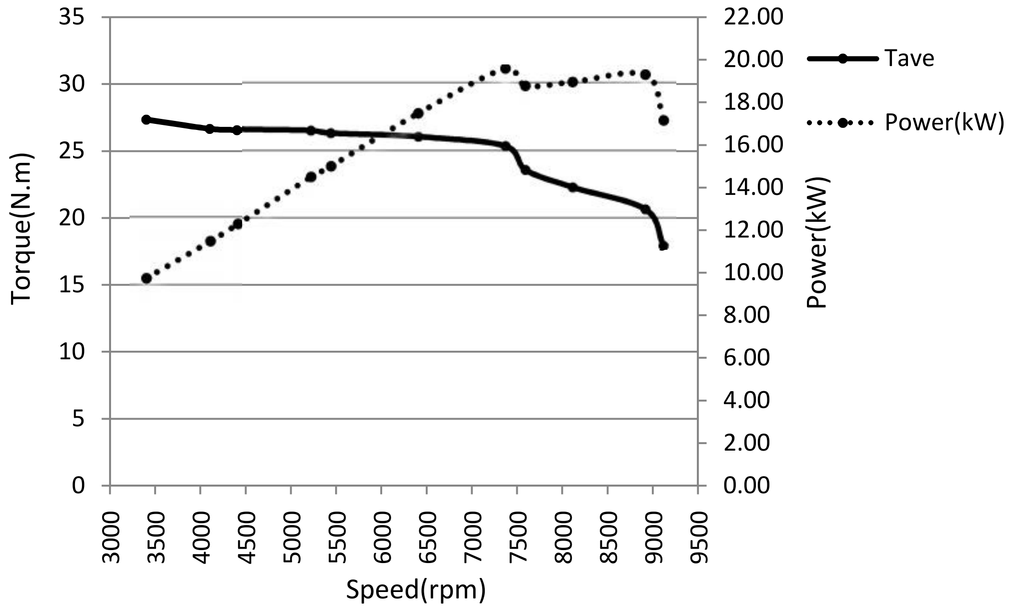

Figure 4.3: Graph of Torque (Nm) and Power (kW) versus Speed (rpm)

The graph above show the graph of torque and power versus speed based on exhaust pipe length of 1140mm before the silencer. According to the graph in figure 4.3, the maximum value of torque is 27.34Nm at engine speed 3400 rpm, while maximum value of power is 19.52kW at engine speed 7360 rpm. The pattern of graph is increasing from low engine speed 3400 rpm until 7360 rpm, and then the graph is decreasing about 4.2% from 19.52kW to 18.70kW. Meanwhile, for torque graph the highest is at low engine speed and then it is decreasing directly when the engine speed are increasing. Point of exchange between torque and power is at 6000 rpm with value of torque 26Nm and power is 17kW.

4.1.4 Result Comparison of Baseline Graph with Difference Length of Exhaust

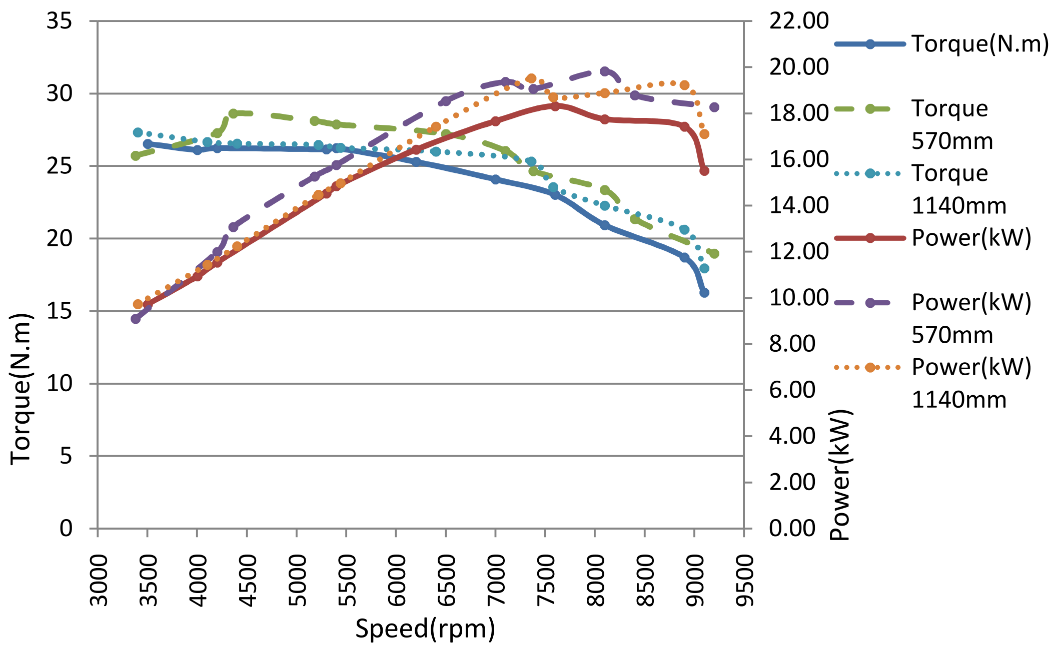

Figure 4.4: Graph comparison between baseline parameter and difference length of pipe length

Figure 4.4 illustrate about graph of comparison between baseline and difference length of pipe. According to graph comparison of torque, the highest value among torque graph is green line. Green line is for pipe length 570mm. While the highest value among green line is at engine speed 4360 rpm with value of 28.63Nm. The percentage of increasing of baseline with the maximum value of torque is 9.1%. This is happened because the changing of the pipe length before the silencer. Manifold and silencer for two types of exhausts which is 570mm and 1140mm are constant and used the same diameter. For the comparison graph of power within\ three graphs, the highest value among it is 19.82 at engine speed 8100 rpm. The highest value is for exhaust with pipe length of 1140mm. The percentage of the increasing between exhaust length of 1140mm and baseline is about 11.66%.

The important part of the result is the low range of the engine speed. The objective this project is to increase the torque and power of the engine GT128 at low speed range between the 3000 rpm until 7500 rpm. According to the Figure 4.4, the comparison graphs show that at low range of engine speed of Modenas GT128 has change when the lengths of the pipe are change. Graph of exhaust length 570mm show the best increasing of torque and power value at low engine speed. At the beginning of graph 570mm, the torque value is below than the baseline graph between 3500 rpm until 4000 rpm engine speed.

At engine speed 7500 rpm and above, the power graph readings are unstable for each type of graph. The pattern are no longer smooth and curve, it is also same goes to the torque graph pattern.

4.2 DISCUSSIONS

4.2.1 Backpressure

According to the comparison graph, the increasing of torque and power at low range of engine speed are occur when the exhaust pipe length are changing. The increasing can be observed at graph of exhaust pipe length 570mm. The increasing happened because of the exhaust pipe length is shorter that the original exhaust. When the pipe length is changing from original to 570mm, the factor that involve to increasing the torque value is backpressure. After the combustion is completed, the pressure at this situation is at high pressure gases. These gases have been used to transfer work to the crankshaft during the expansion stroke. These gases must be removed from cylinder through exhaust system. Exhaust gases is a non-steady-state pulsing flow that is often modeled as pseudo-steady-state. The flow of exhaust gases that going through the exhaust systems is in high temperature and high pressure.

Backpressure is occurs because there is interact of pressure with pipe junction and ends in the exhaust manifold and pipe. This interaction causes pressure waves to be reflected back toward the engine cylinder. Backpressure will causes the exhaust gases to remain in the engine cylinder after the exhaust stroke. A certain amount of backpressure is very important to optimum engine performance, but when too much backpressure the power and excessive engine temperature will be loss and affect the engine performance and fuel efficiency (Pulkrabek, 2004).

Excessive backpressure is commonly caused by one or more of the following factors:

(a) Exhaust pipe diameter is too small
(b) Excessive number of sharp bends in the exhaust systems
(c) Exhaust pipe system is too long
(d) Silencer resistance too high

One of the factor that make the excessive backpressure is exhaust pipe system is too long. Original exhaust pipe length of Modenas GT128 is the standard exhaust system for daily life uses. The simplest way to improve the performance of engine is by change the exhaust pipe length of the original to the best pipe length with is 570mm. When the pipe length is reduces to 570mm, the interaction between the internal pipe surfaces and the unsteady pressure will be reduces. When the interaction is reduces, engine performance will be increase and less fuel efficiency.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

Based on the result value of the experimental at the Figure 4.4, it shows the increasing of the torque and power value at low engine speed when the lengths of the exhaust pipeline are change. The increasing value of the torque value is about 9.1% from the baseline graph. It is occurs when the length of pipeline of the exhaust is 570mm. The increasing of the torque value is the range of engine speed 3000 rpm until 7500 rpm.

As a conclusion, there are affect to the performance of the engine when the length of exhaust are changes. Hence, both objective are achieve when the length of exhaust pipe length are change. The best exhaust pipe length between two design which is 570mm and 1140mm is 570mm. This is because at low range engine speed the value of torque is the highest. Performance of engine can be improve by changing the exhaust pipe length with various length.

5.2 RECOMMENDATION

From the present study, there are several recommendation which may be used to improve the results for similar studies in the future. The recommendations are listed as follow:

(a) Exhaust pipe length before the silencer should be in various to achieve an optimum engine performance.

(b) Utilize the engine speed (rpm) indicator from analog to digital engine speed indicator to achieve accurate result of engine speed.

(c) Installs a better cooling system to the engine because engine GT128 is air cooling systems.

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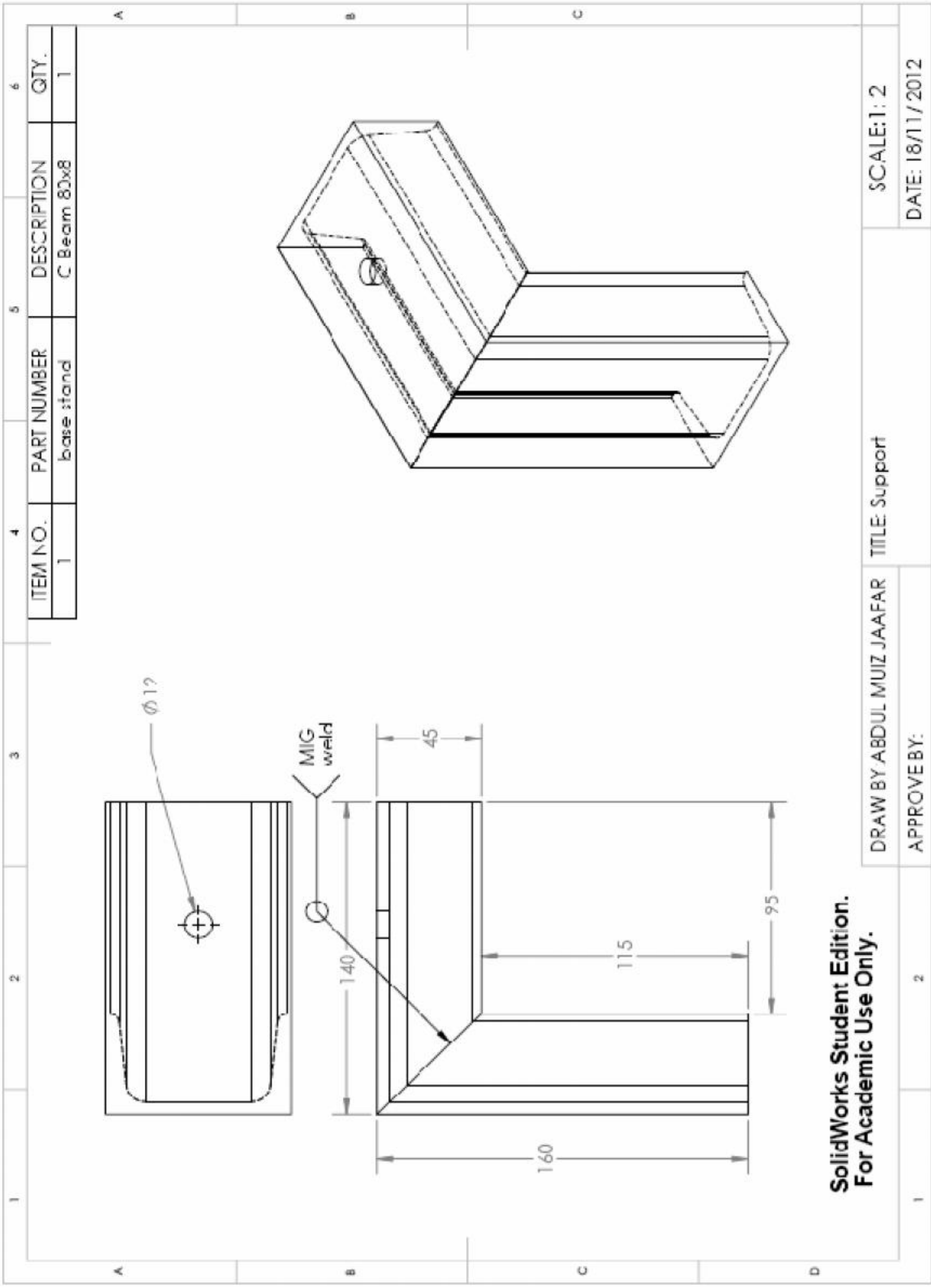
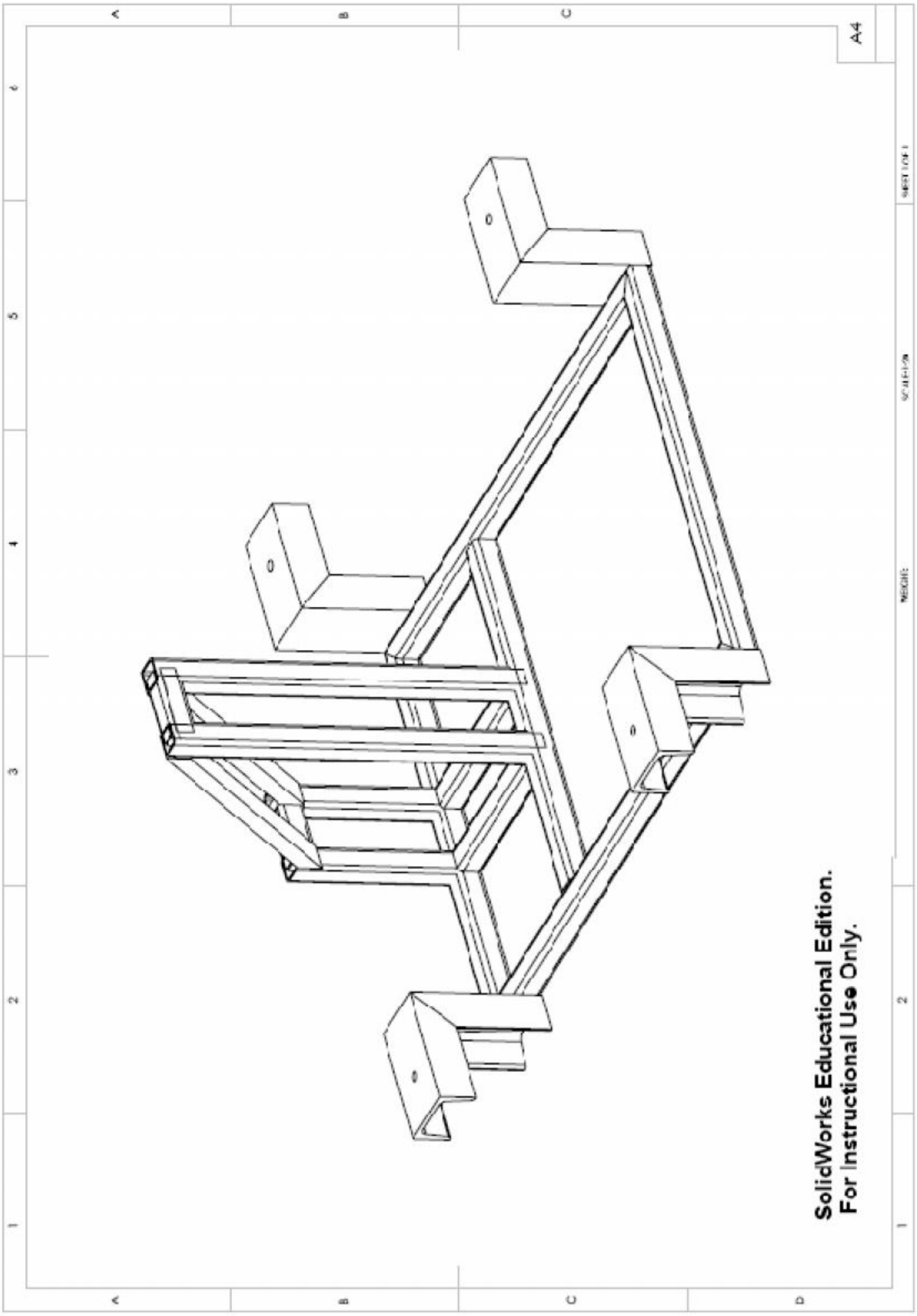
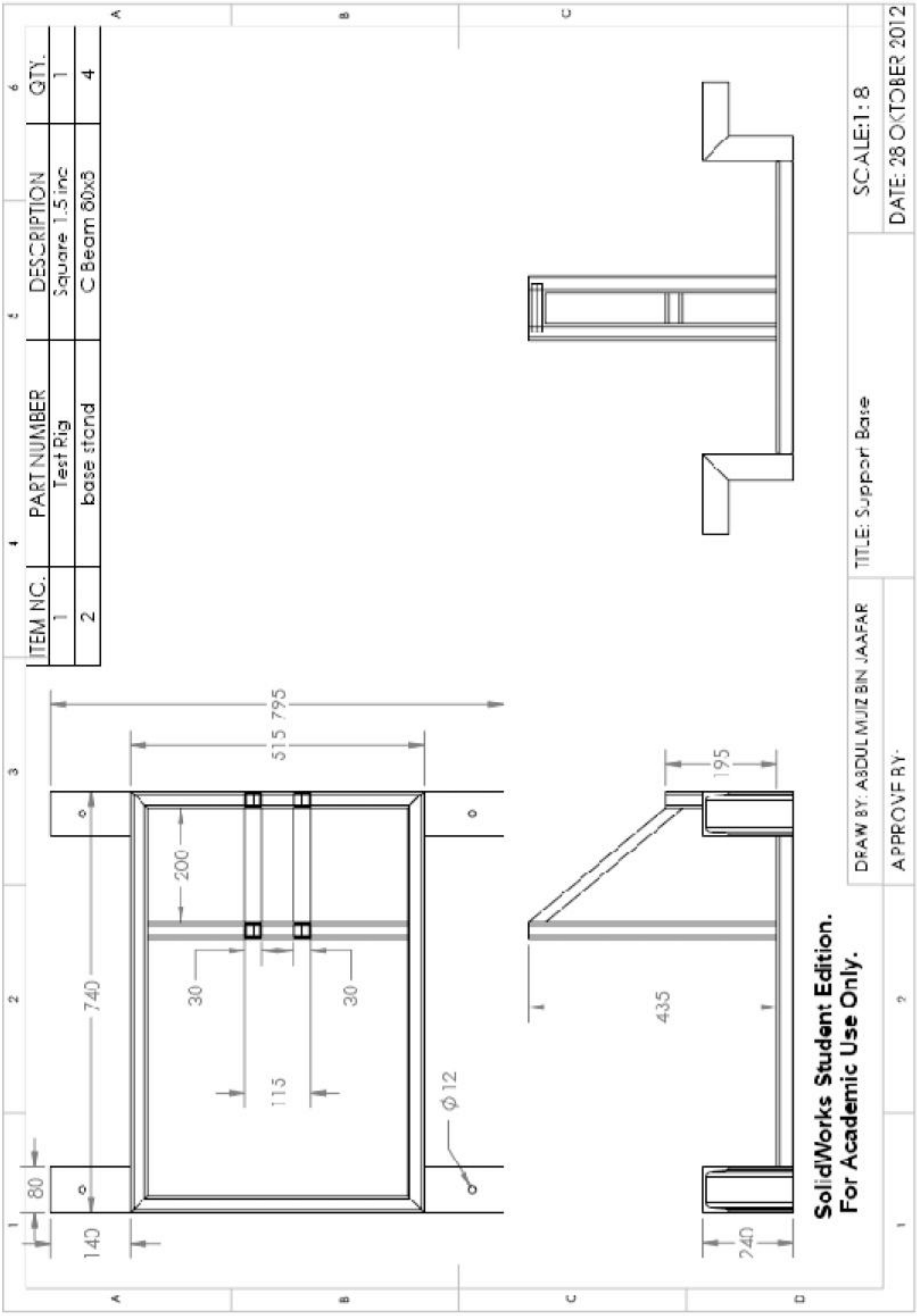
APPENDIX A1

ENGINEERING DRAWING OF TEST RIG




A4
SolidWorks Educational Edition.
For Instructional Use Only.


ITEM NO. | PART NUMBER | DESCRIPTION | QTY.
1 | Test Rig | Square 1.5 inc | 1
2 | base stand | C Beam 80x8 | 4
795
515
740
200
30
30
115
80
140
Ø12
195
435
240
SolidWorks Student Edition.
For Academic Use Only.
DRAW BY: ABDUL MUIZ BIN JAAFAR
APPROVE BY:
TITLE: Support Base
SCALE:1 : 8
DATE: 28 OKTOBER 2012

APPENDIX A2

RAW DATA OF EXPERIMENT

DATA OF BASELINE PARAMETER

Speed(RPM)	Torque(N.m)	Power(kW)
3500	26.54	9.73
4000	26.11	10.94
4200	26.24	11.54
5300	26.17	14.53
5400	26.26	14.85
6200	25.3	16.43
7000	24.09	17.66
7600	23.02	18.32
8100	20.93	17.75
8900	18.7	17.43
9100	16.28	15.51

DATA OF EXHAUST LENGTH 570mm

Rpm1	T1	Rpm2	T2	Rpm3	T3	Rpm4	T4	Rpm5	T5	RpmA	Taverage
3400	25.49	3300	26	3400	26.1	3400	25.69	3400	25.32	3380	25.72
4200	27	4200	27.12	4200	27.32	4200	27.42	4200	27.56	4200	27.28
4400	28.32	4300	28.69	4300	28.7	4400	28.49	4400	28.96	4360	28.63
5200	28.02	5100	28.32	5200	28.11	5200	28.1	5200	28.12	5180	28.13
5400	27.91	5400	28.01	5400	27.96	5400	27.7	5400	27.84	5400	27.88
6500	27.2	6500	27.2	6500	27.3	6500	27.29	6500	27.14	6500	27.23
7100	25.64	7100	26.49	7100	26.1	7100	26.02	7100	25.98	7100	26.05
7400	24.52	7300	25.01	7400	24.96	7400	24.32	7400	24.48	7380	24.66
8100	22.98	8100	24.52	8100	23.73	8100	22.86	8100	22.76	8100	23.37
8400	21.11	8400	22.1	8400	21.45	8400	21.02	8400	21.11	8400	21.36
9200	18.71	9200	19.1	9200	19.05	9200	18.96	9200	19.02	9200	18.97

Rpm1 = Speed for 1st running

T1 = Torque value for 1st running

RpmA	Tave	Power(kW)
3380	25.72	9.10
4200	27.28	12.00
4360	28.63	13.07
5180	28.13	15.26
5400	27.88	15.77
6500	27.23	18.54
7100	26.05	19.37
7380	24.66	19.06
8100	23.37	19.82
8400	21.36	18.79
9200	18.97	18.28

DATA OF EXHAUST LENGTH 1140mm

Rpm1	T1	Rpm2	T2	Rpm3	T3	Rpm4	T4	Rpm5	T5	RpmA	Taverage
3400	27.31	3500	27.65	3400	27.13	3400	27.49	3300	27.1	3400	27.34
4100	26.76	4100	26.76	4100	26.52	4100	26.58	4100	26.68	4100	26.66
4400	26.58	4400	26.52	4400	26.46	4400	26.68	4400	26.58	4400	26.56
5200	26.52	5200	26.44	5200	26.44	5200	26.51	5300	26.46	5220	26.47
5400	26.49	5500	26.24	5400	26.31	5400	26.12	5500	26.24	5440	26.28
6400	26.02	6400	26.09	6400	26.11	6400	25.83	6400	26	6400	26.01
7400	25.13	7300	25.46	7400	25.32	7300	25.1	7400	25.61	7360	25.32
7600	23.59	7600	23.61	7600	23.43	7500	23.61	7600	23.54	7580	23.56
8100	22.27	8100	22.17	8100	22.36	8100	22.1	8100	22.46	8100	22.27
8900	20.57	8900	21	8900	20.59	8900	20.43	8900	20.56	8900	20.63
9100	17.96	9100	17.86	9100	18.12	9100	17.89	9100	17.92	9100	17.95

Rpm A	Tave	Power(kW)
3400	27.34	9.73
4100	26.66	11.45
4400	26.56	12.24
5220	26.47	14.47
5440	26.28	14.97
6400	26.01	17.43
7360	25.32	19.52
7580	23.56	18.70
8100	22.27	18.89
8900	20.63	19.23
9100	17.95	17.11