# DESIGN AND DEVELOPMENT OF FIVE PARALLEL ENGINES FOR LUBRICANTSAND FUEL TESTING EXPERIMENTAL RIGS, PART 3

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# DESIGN AND DEVELOPMENT OF FIVE PARALLEL ENGINES FOR LUBRICANTSAND FUEL TESTING EXPERIMENTAL RIGS, PART 3

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## ABSTRACT

An engine test rig could serve for further analysis for researcher to study about engine which it isdepends on the type of applications needed. It is all depends on the properties and concept focused to be study for researcher about the engines and how the surrounding factors could affect the rate. Therefore a mechanical design of five parallel engine arrangement for lubricant and fuel testing experimental test rig have been develop. The purpose of this experiment is to study the rate of weariness effectson engines components such as crankshaft, pistons, and piston valves. Same type of five grass cutterengines were used and it is arranged parallel in thetest rig. In this test, the engines were run for few hours with the applied ofa solid cylinder rodwhich fixed to shaft connecting part of engine as a load for this experiment. The rate of weariness of each components of engines are further analysed based on the hours of engine run and the throttle turns that have been set up in Arduino software through computer.

**Keywords***:* Parallel; weariness; engine components; Arduino; test rig.

## INTRODUCTION

Heywood has mentioned that diesel cycleis a combustion process of a reciprocating internal combustion engine[1].Noor et al.said that in a combustion of engine process, three things steps or processes are required which is fuel itself, oxidizer and a heat or ignition source [2].Devarajanet al. has said that the fossil fuel such asdiesel, petrol and natural gas are a non-renewable energy source which can affect to the world when it is come to finite amount in earth [3].In the engine, fuel is ignited by heat generated during the compression of air in the combustion chamber of engine into which fuel is then injected [1]. Greenhouse effect, acid rain are developed as the amount of carbon dioxide is contributes to environment is in high rate due to the burning of fuel by internal combustion which releases pollutants in the air said by Devarajanet al. [3]. This is a contrast to igniting the fuel-air mixture with aspark plugas in theOtto cycleengine. In terms of applications, diesel engines are widely used in aircraft,automobiles,power generation,diesel-electriclocomotives, and both surfaceshipsandsubmarines[1].The diesel internal combustion engine differs from the gasoline powered. Eventually, Noor et al. has investigated that the combustion of fuel produces less carbon dioxide and other chemical as the combustion of engine is one of main issue given important on environmental concerns and issues [4].The large amount of fossil fuel which is about 80% is projected for the internal combustion as it is the most and important source of energy said by Noor et al. [5]. Otto cycle by using a higher compression of the fuel to ignite the fuel rather than using a spark plug which "compression ignition" rather than "spark ignition".Hottiet al. mentioned in the diesel engine, air is compressed adiabatically with a compression ratio typically 15 to 20 [6]. This compression raises the temperature to the ignition temperature of the fuel mixture which is formed by injecting fuel once the air is compressed[6].According to the performance by Mon et al. the temperature distribution in engines are influenced by material used to construct the engine part near the exhaust port near the cylinder head [7]. The ideal air-standard cycle is modelled as a reversible adiabatic compression followed by a constant pressure combustion process, then an adiabatic expansion as a power stroke and an isovolumetricexhaust said by CengalYunuset al. [8].Figure 1 shows the schematics diagram of single cylinder engine. The engine is running with single cylinder or piston for internal combustion.Asingle-cylinderengineisa basicpistonengineconfigurationofaninternalcombustionengine. Rahman et al. investigated the fatigue life prediction of a piston and on their performance said that a free piston linear generator of engine can integrates a combustion engine and linear electrical machine into a single unit without a crankshaft [9]. Some of the applications of single piston engine areoftenseenonmotorcycles,autorickshaws,motorscooters,mopeds,dirtbikes,go-karts, radio-controlled modelsand has many uses in portable tools andgarden machinery[10]. Warganteet al. has mentioned that a single-cylinder engines are simple and compact, and will often deliver the maximum power possible within a given envelope[10].According to Pulkrabek cooling is simpler than with multiple cylinders, potentially saving further weight, especially if air cooling can be used [11]. Pulkrabek also mention that the single-cylinder engines require more flywheel effect than multi-cylinder engines, and the rotating mass is relatively large, restricting acceleration and sharp changes of speed [11].A variation known as the split-single makes use of two pistons which share a single combustion chamber.The vibration generated is acceptable in many applications, while less acceptable in others. According to McIntosh, counterbalance shafts and counterweights can be fitted but such complexities tend to counter the previously listed advantages[12].Components such as the crankshaft of a single-cylinder engine have to be nearly as strong as that in a multi-cylinder engine of the same capacity per cylinder, meaning that some parts are effectively four times heavier than they need to be for the total displacement of the enginementioned by Siuru[13]. Chase said that the single-cylinder engine will almost inevitably develop a lower power-to-weight ratio than a multi-cylinder engine of similar technology[14]. This can be a disadvantage in mobile operations, although it is of little significance in others and in most stationary applications.

Machine is an apparatus that uses mechanical power to do work which having several parts that plays a very important role. Each part is definite functions and performing togetherfor a particular task. Nowadays gasoline powered rotary machine such as land mower machines are used for early stage for construction and machineries fieldsthat plays an important role for our country economy development through its business said by Kareem [15]. Generally, land mower machines is used to cut the excessive grass growth at home compound, school fields and other application, depends on application needed. Land mower or known as grass cutter machine is the most common machine that found in market due to its availability and low cost too. Eventually, Kareem said that crankshaft is main engine component of machinery system because its machinery movement that would seize if it fails[15]. Saniet al. mention that crankshaft is the most important part in internal combustion of an engine generally [4]. Rotational motion is done in order for the power generation from the piston is by translating the crankshaft linear motion [4]. The crankshaft failures would led to increase in death and disability rates of people in many applications of this machine. For this land mower machine, it use single cylinder piston type engine stroke where it has a pair of crankshaft that connected to its single piston for the engine performance. Singlecylinder piston type of engine stroke is a basic engine configuration of an internal combustion engine used for most of machineries. It often seen in grass cutter, chainsaw, motor scooters, go-karts, dirt bikes, and has many usage in portable tools and garden machinery. Pulkrabek has said that in basic arrangement, they are prone to vibration though in some cases it may be possible to control this with balance shafts [11].Kareem also mentioned that crankshaft usually located below the cylinder on an in-line engine at V – type shape[15]. As the single cylinder piston move up and down, the crankshaft is turned continuously for the engine performance. Through this experiment, the factor of weariness of crankshaft is taken into consideration to be studied further and how it effects the engine's performance.NebojsaNikolicet al. has said crankshaft's main bearing is the load characteristics which is important for design of bearings and engine block as well [16]. This load can be optimize in terms of dimensions of the bearings which determines the stiffness of the engine crankshaft and the block. In addition, the main source of vibration in the engine is the crankshaft bearing load that changes rapidly during the engine operation [16]. In this experiment, all the engines are treated independently of each other which controlled by the throttle turns from Arduino programming in computer. NebojsaNikolicet al. also studiedthe weariness of engine component especially crankshaft and said that the main factor of weariness of crankshaft in the majority of internal combustion (IC) engines are the forces between crankshaft journals and high bearings magnitudes [16]. Menget al. has presented the great significant of wear in mechanical systems of engines such in wear phenomenon which developed a methodology which uses force model and pressure field in contact for studying and quantifying it by taking into account geometry and materialproperties of element coupled  [17-19]. Murkas compared two procedures where in first procedure, joint forces and contact pressures are estimated by using the elastic foundation model with hysteresis damping via dynamic analysis and in second procedure, Murkas used finite element method (FEM) to analyse the model[19].

Single cylinder engine crankshafts are the most simple power shafts said by Fonteet al. [20].Crankshafts are made from materials which can be readily shaped, machined, and heat-treated and whichhave desirable mechanical properties such as adequate strength, toughness, hardness, and high fatiguestrengthinvestigated by Bayrakcekenet al. [21-23]. Traditionally, these shafts were forged, which promoted all the necessary properties; but, with theevolution of the nodular cast irons and improvements infoundry techniques, cast crankshaft are now favouredfor moderate loads, and only for heavyduty applications do forged shafts predominate[24, 25]. The dead weightsprovide the static and dynamic balance caused by different ignition sequence during working mentioned by Vogwellet al. [26]. The main bearingsand connecting rod bearings are hardened up to 2–3 mm by means of some surface hardening methods[27].The lubrication of the bearings is provided by lubrication holes drilled in the crankshaft [28-30]. In some cases theinner regions are bored out for light design and reduced inertial forces[31].One of the key element which works under highly variable loading conditions is the crankshaft. This ismore promoted for the single cylinder engines. Several researchers have been studied on the failed crankshafts[32]. Researchers generally states that; mechanical fatigue failures are probably the most common cause ofcrankshaft failures mentioned by Chandler et al. [33, 34]. The sources may include misalignment of the shaft, rotating-bending, vibrationdue to some problem with the main bearings and high stress concentrations caused by a sharp fillet[35]. Silva studiedon the failure of journal bearing of a crankshaft and concluded that the damage of the journals was originatedby the small cracks at the surface of the journals. The small cracks originated by thermal fatigue due tooverheating during the grinding operation[36].Yu and Xu also studied the breakage of a diesel engine crankshaft observing that the failure initiated fromthe fillet region of the crankpin-web. In their observation, the partial absence of the nitrided layer in the filletregion makes the fatigue strength reduce to initiate and propagate fatigue in the weaker region and to lead topremature fatigue fracture[37].

**Figure 1:**Single cylinder crankshaft[38]

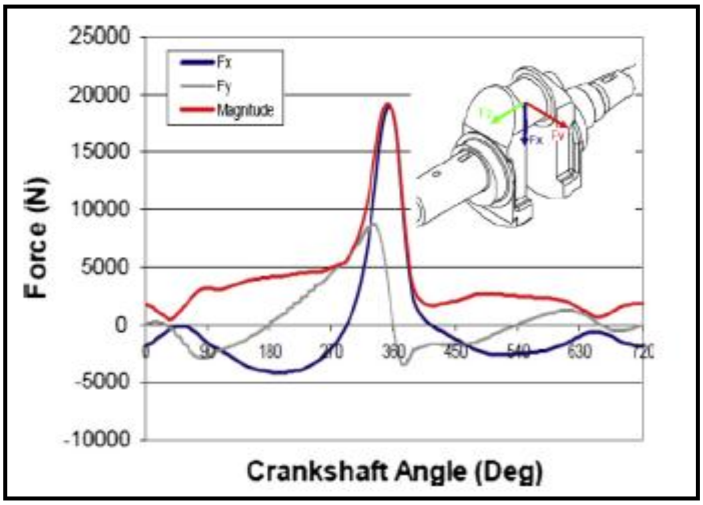


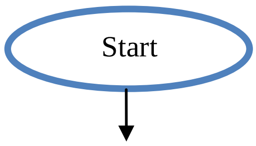

**Figure 2:**Variations of bending and torsion loads and the magnitude of the total forceapplied tothe crankpin as a function of crankshaft angle at 2800 rpm[39]

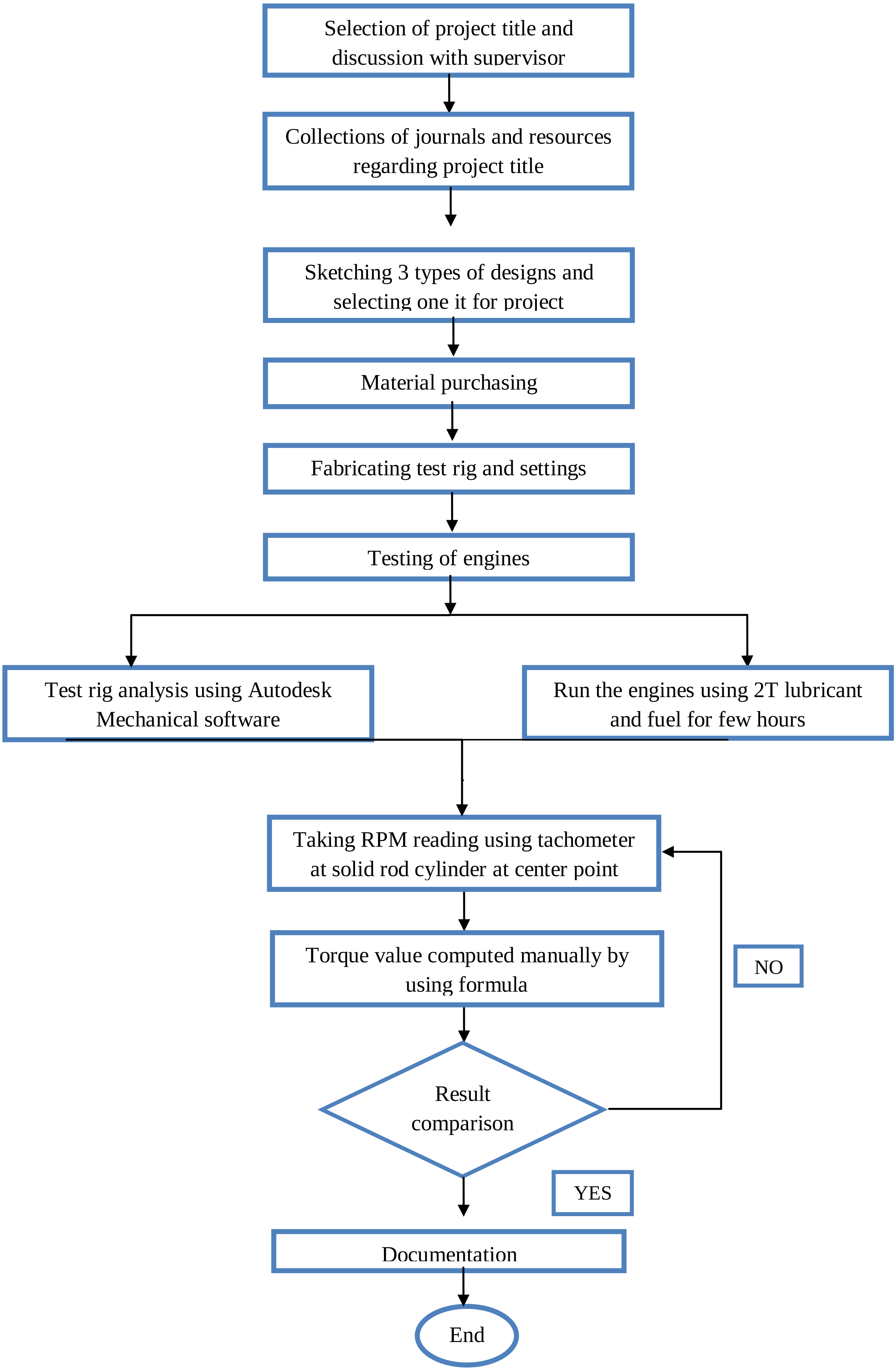
Figure 2 and Figure 3 showssingle cylinder engine crankshaft and the variations of bending (Fx) torsion (Fy), longitudinal force (Fz) directions, and the magnitude of the total forces applied to thecrankshaft as a function of the crankshaft angle.Three forces act on a crankshaft, which are forces due to gas pressure in the cylinder,friction forces and inertia forces. The connecting rod transmits gas pressure from the cylinder to the crankpin as forces whichare decomposed in tangential (torque) and radial (bending) on the crankshaft. The big end of connecting rod, Figure 2, acts onthe crankpin to rotate the crankshaft. It is also drilled to create a lubrication network in order to deliver lubricating oil underpressure to the main journal and crankpin bearings[40]. These oil galleries produces inevitable imbalance of shaft under rotation[41].Counterweights provide the static and dynamic balance during the crankshaft rotation which generally can run between 800and 4000 rpm. Hence, crankshafts should be under static and dynamic equilibrium and free of resonant vibrations[42]. A crankshaftconnects itself to a flywheel in order to reduce the pulsation characteristic of the stroke cycle[43].The crankshaft must be strong enough to take the downward force of the power stroke without excessive bending andmust resist the bending stresses caused by the acting of connecting rod when the piston is at top centre (TDC) and under the effect of maximum gas pressure[44]. The maximum gas pressure acts straight down on the crankpin and tends to bendthe crankshaft between the adjacent main bearings. The crankshaft must also withstand the torsional forces and suddenchange of speed[45]. A crankshaft runs with harmonic torsion combined with cyclic bending stress dueto the radial loads of combustion chamber pressure transmitted from pistons and connecting rods, to which inertia loadsfrom pistons and connecting rods have to be added[46].The maximum gas pressure acts straight down on the crankpin and tends to bend the shaft between the adjacent journalbearings. The crankshaft should also withstand the torsional forces produced by the change of speed. Two main sources areresponsible for the present forces on a moving crankshaft[47]. The load sources cause both bending and torsional loads onthe crankshaft, being only reversed bending on crank throw (pin between webs) and rotating bending combined with steadytorsion on main journals[48, 49]. It should be noted that crankpin has translation movement only and therefore it is underreversed bending without torsion.

## METHODOLOGY

Firstly, the ignition of spark plug and combustion will takes place in the single cylinder, producing energy, as well as the heat and exhaust. The heat and exhaust will start to spread throughout the engine of grass cutterand causes the rising in temperature. From here, Fonte and other authors said that the single cylinder piston plays important role where it will cause the crankshaft move up anddown at the engine components continuously [48]. The lubricant that have been mixed with petrol and duty oil in engine will flow in piston and causes the smooth flow and movement for the crankshaft [48].Eventually, a solid cylinder rod with specified length is inserted externally at shaft connecting part for each engines as load characteristics. According to analysis by NebojsaNikolicet al. said the method forces acting on the crankshaft of engines are usually calculated numerically by using statically determinate methods [16]. According to Fonteet al, the direction of force will act at the centre of crank radius where the combustion is take place at maximum load applied [48]. As the solid cylinder applied to the land mower as, at the time when maximum bending take places, the magnitude of torsional load is zero said by Fonteet al. [48]. Therefore, here all the five engines are treated independently of each other.

## FLOW CHART OF OVERALL PROGRESS




Selection of project title and discussion with supervisor
Collections of journals and resources regarding project title
Sketching 3 types of designs and selecting one it for project
Material purchasing
Fabricating test rig and settings
Testing of engines
Test rig analysis using Autodesk Mechanical software
Run the engines using 2T lubricant and fuel for few hours
Taking RPM reading using tachometer at solid rod cylinder at center point
Torque value computed manually by using formula
NO
Result comparison
YES
Documentation
End

## EXPERIMENTAL SETUP

In this experiment, instead of using real car engine to study the weariness of crankshaft of engine, a land mower or known as grass cutter engine is used as the replacement since the study is more precisely in that small size of engine for the system. The setup consisted of following apparatus and materials:

**Table 1**: List of apparatus and materials used to build test rig.

| Amount (units) | Description |
|---|---|
| 5 | Winas grass cutter machine which used to study the crankshaft, piston and body of engine. |
| 4 | Lock type of roller (size 3 inches of diameter) |
| 2 | Bottle tins of spray for the test rig. |
| 1 | Bottle of machine engine oil (2T). |
| 1 | Plastic bottle to fill in and pour the fuel for the grass cutter. |
| 2 | Stepper motor used to control the throttle turns in terms of specified degree. |
| 1 | Set of Arduino UNO. |
| 1 | Set of breadboard. |
| 2 | Stepper driver. |
| 1 | Motorbike battery as current source. |

The present study aims to associate the correlation of the five parallel engines with a solid cylinder rod is inserted externally at shaft connecting part for each engines as load characteristics. Five of single cylinder engines will be set in parallel line and place them in designed test rig. Only 4 engines were used to run in different timing by using same type of fuel and lubricant oil. The 1 engine is kept constant to use for comparison of engine components of the other 4 engines. The speed of each engines will be modified by Arduino program by controlling their speed of rotating. With the experimental testing, the engine will be tested under same loads in three categories which areat zero rotating of throttle, half rotating speed (throttle) and full rotating speed (throttle). Throughout the experimental data, discussion will be carried out to analysis rate of weariness for crankshaft affected by taking the pictures of wear engine components and compare with the constant engine that has been kept without run it. According to Nikolic, an algorithm construction method of theoretical wear diagram ICengines crankshaft main bearings is used, where it provide a clear visual of load distribution around inner circumference of main bearings [16]. By this method, demonstrated engine crankshaft has been illustrated to compare the crankshaft weariness on each other [16]. Two stepper motor used to control the four of engine throttles movement that has been setup in a circuit complete of Arduino board, easy driver and battery as input source in breadboard. Revolution per minute (RPM) value is taken for four engines at the solid cylinder shaft. Where tachometer is used to measure the value of RPM for each engine. This RPM value indicates the value of engine speed said by Taglialatela[50]. Other than that, Taglialatela have been set some parameters from cylinder pressure curve that represented by engine angular crankshaft peak [6] and its angular location (LPP) [50].

## RESULTS AND DISCUSSION

Based on the experiment conducted, there aretwo categories of result are obtained and discussed.The first part is the building this test rig will be sustainability of the design of loads (engines and shafts) exerted. Basically, the whole design plays the role in order to sustain the apparatus fixed to it. However, strong bottom base is needed at the part where the engines are fixed at the bottom part of rig and the side part of the beam to fix the engine holder with bolts and nuts. Upper part of base is built on the same test rig to place all the throttle of engines and the Arduino – computer setup. For the analysis purpose, all the apparatus used has been measured their mass which would at least give a rough figure of total mass acting on the bar upon the assembly as shown in Figure 5 below.

**Table 2**: List of the apparatus and the contained mass.

| APPARATUS | MASS |
|---|---|
| Winas grass cutter (with the shaft) | 47.5 kg |
| 1mm metal plate on top base of test rig | 1.4 kg |
| TOTAL | 48.9 kg |

Based on the measured mass, it shows that only about 48.9kgof the total mass of the apparatus and materials acting upon the test rig especially the bottom horizontal bar. The strength of material can be computed as shown in Figure 7. The total mass that acting on test rig (horizontal bar) is converted to the force value to be inserted in the finite element analysis method. While the acceleration used is the standard gravity acceleration valued as 10 m/s2.

$$F = ma$$
$$= (48.9kg)\ (10m/s2)$$
$$= 489N$$

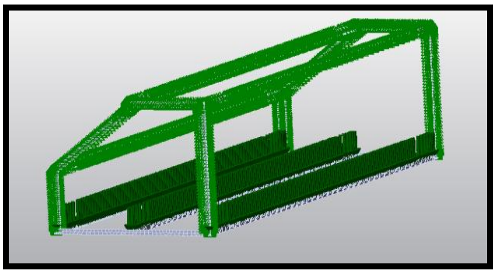
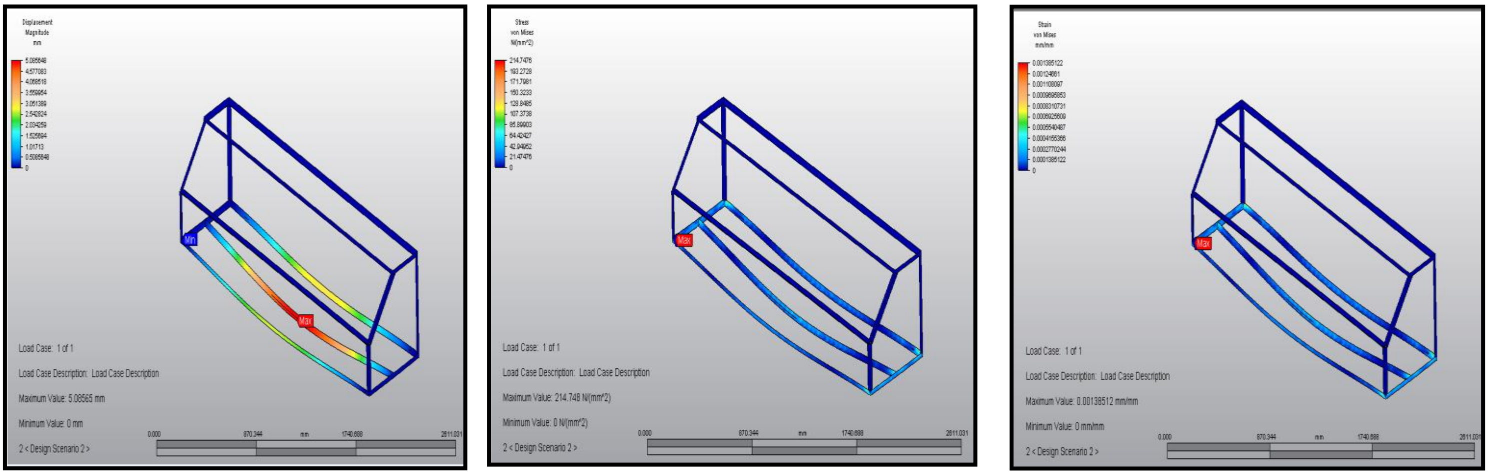


**Figure 3**: The constraint and applied force on the selected beam of test rig.

Based on the Figure 3above, the selected beam is analysed via Finite Element Method. As illustrated, three of the beam that is the horizontal beams are being fixed as the constraints since no any load applied. All the three horizontal beam as shown in figure has been applied with the calculated force of 489N. Other details are as followed:

**Table 3**: Particular details of the AISI 1005 Steel.

| | |
|---|---|
| Material Name | AISI 1005 Steel |
| Mass Density | 7.872e-009 $N.s^2/mm/mm^3$ |
| Modulus of Elasticity | 200000 $N/mm^2$ |
| Poisson's ratio | 0.29 |



(a) (b) (c)

**Figure 4**: The result obtained by using finite element analysis. (a) Displacement, (b) Stress von Mises, (c) Strain von Mises

Based on the result obtained, the colour contour shows that the middle part of the middle beam has the highest displacement magnitude at 5.08565mm. It is obvious that load (machine, shaft and top metal plate) exerted is uniform throughout the beam overly and therefore, the centre or the middle part of the middle beam will have the highest displacement since there is no any support from the bottom as how the four vertical beams at each corners are supporting the horizontal beam at all the ends. This material is sufficient enough to sustain the load exerted based on the value of the safety factor obtained. The other reasons for choosing this AISI 1005 Steel L – shaped hollow square bar as the main body frame for this engine's test rig is that easy to handle these bars in term of cutting, welding, joining and other mechanical process. It is very light weight material which at the end of the day will ease for the mobility of the test rig frame from one place to another. To ensure this beam can support load force without failure, additional force exerted on the beam and being analysed again in finite element analysis. The result shown in Table 4 below.

**Table 4**: Comparison upon the additional force on the horizontal bar beam.

| Force | Stress (N/mm$^2$) | | Strain (N/mm$^2$) | | Displacement | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| 489N | 0 | 214.7476 | 0 | $1.385 \times 10^{-3}$ | 0 | 5.085648 |
| 978N | 0 | 1097.27 | 0 | $7.077 \times 10^{-3}$ | 0 | 12.161300 |

Based on the result obtained, it clearly shows that the beam still could support the load exerted although the force is doubled from the previous analysis.This is entirely done to prove that the beam could sustain the load, and for any amendment or modification cases whereby the grass cutter engines is needed to replace by a bigger size of machine, which would double up the mass, and still can sustained by this engine test rig.

As illustrated in Figure 5, the top part of the test rig, a horizontal metal plate with thickness of 1mm of steel plate placed. This part is used to place the all theunits of engine's throttle with cable wire that already assembled with a hollow solid cylinder like a gripper for it. This top part of test rig also used to place laptop that programmed Arduino coding and the stepper motor with its circuit design for the throttle pulling testing. Then, rear part of horizontal bar beam of test rig have drilled with 10 small holes evenly that used for bracketpurposein order to tighten the*Winas*grass cutter machine body frame with middle part of horizontal part of test rig. This is to avoid the machine from fall down from the test rig due to high vibration created when the engine get starts. Four units of 3 inches roller has been assembled for the test rig mobility purpose. Therefore, the whole design of test rig for this project is simple, precise and easy to handle it for the demonstration purpose.

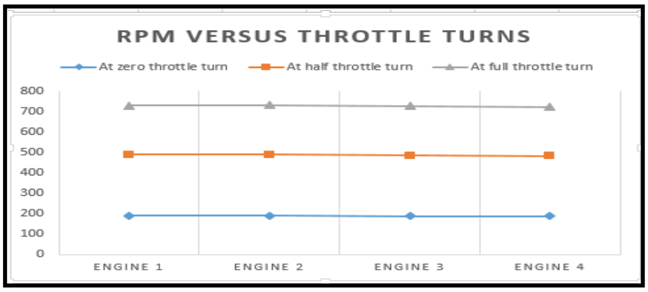
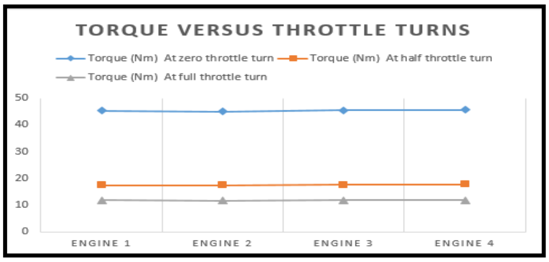



**Figure 5**: The overall fabricated test rig with its apparatus setup

The second part of the result and discussion here is about the RPM and torque calculation for the solid cylinder shaft that welded at centre of grass cutter. Petrol as fuel and 2T machine engine oil as lubricant are used for all the engines to run the machine for few hours. By using tachometer, revolution per minute (RPM) reading were taken for 4 engines only and left one engine for the constant variable where it being used forengine parts comparison purpose with the other 4 engines that have been run. The readings of RPM value is shown in Table 5 below.

**Table 5**: The RPM readings of *Winas* grass cutter engines.

| Engine | At zero throttle turn | At half throttle turn | At full throttle turn |
|---|---|---|---|
| Engine 1 | 188.75 | 488.89 | 728.40 |
| Engine 2 | 189.52 | 490.17 | 730.73 |
| Engine 3 | 187.64 | 484.11 | 726.17 |
| Engine 4 | 186.97 | 482.38 | 723.57 |




**Graph 1**: RPM reading versus throttle turns for four engines.

Based on the readings and graph drawn in Table 5 and Graph 1, engine number 2 is having highest value of the RPM reading among the other engines. This is because, from the observation when the engines are demonstrated to run it, shaft that welded at engine 2 shows very smooth rotational flow which reduces the vibration produce by engine itself as it attached in test rig. Engine number 4 shows the lowest reading of rpm due to the welding defect of solid cylinder rod shaft that not enough in perpendicular position to the metal plate during fabrication. Thus, engine number 4 produces more vibration when the engine is demonstrated to run and causes low in rpm reading even though the throttle turns applied is similar as the others. Further analysis on the RPM reading of the each engine's shaft is done by calculating the torque, τ for all four engines. The calculation is shown as below.

**Sample Calculation of Torque**

Power of lawn mower (Winas 728T) = 1.2 HP
= 0.89484 kW
= 894.84 W

Formula: $P = \tau \times \omega$ where P = Power / Watt
$\tau$ = Torque / Nm
$\omega$ = Omega / $rads^{-1}$

Given: **Engine 1** at zero throttle turn, the revolution per minutes is 188.75rpm

$P = \tau \times \omega$

$P = \tau (2\pi\omega/60)$

$894.84 = \tau [2\pi(188.75)/60]$

$\tau = 45.27$ Nm

**Table 6:** The computed torque values for *Winas* grass cutter engine.

| Engine | Torque (Nm) At zero throttle turn | Torque (Nm) At half throttle turn | Torque (Nm) At full throttle turn |
|---|---|---|---|
| Engine 1 | 45.27 | 17.48 | 11.73 |
| Engine 2 | 45.09 | 17.43 | 11.69 |
| Engine 3 | 45.54 | 17.65 | 11.77 |
| Engine 4 | 45.70 | 17.71 | 11.81 |

Based on the results calculated values and graph drawn in Table 6 and Graph 2, engine 2 shows the lowest torque among the engines at zero throttle turning, half throttle turning and full throttle turning. Lowest torque means that the revolutions will be higher and the shaft can turning more turns and faster but the tendency of force to rotate the load about an axis is lowest. Same explanation to the highest torque at Engine 4. Engine 4 has lowest revolution turns but it has highest of the tendency of force to rotate the load about an axis. It has the high torque to rotate heavier load.

The third part of the result and discussion is about the crankshaft analysis of *Winas* grass cutter engine. The SolidWorks of the crankshaft and the piston – crankshaft are designed as shown in Figure 6.

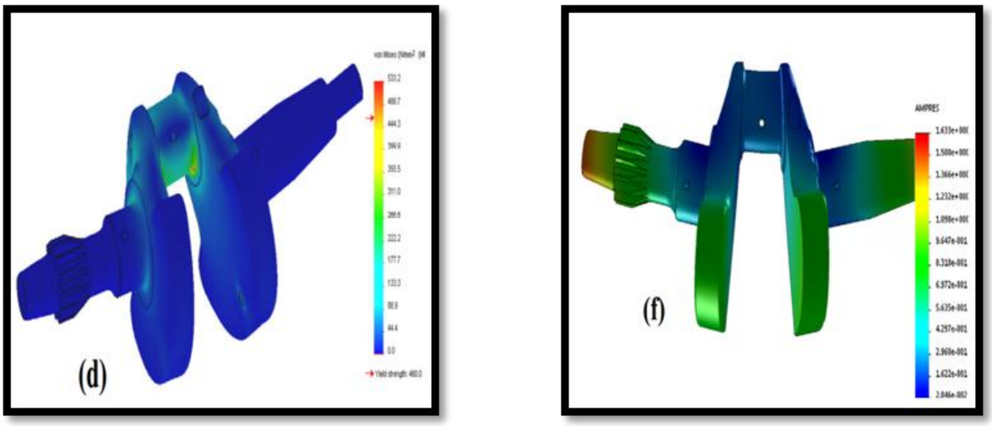



**Figure 6**: (a) von Mises strain and (b) Displacement

According to Fonte et al. usually, the main part of the overall crankshaft failures occurs at crankpin which connects the counterweights through main journal (solid cylinder) which connected with bearing. The Figure 9 and Figure 10 below shows the overall crankshaft and the crankpin failure part that experimented respectively [20].

The diesel single engine with 4 stroke used by Fonte et al. the type of material of crankshaft used was metal alloy SAE 1045 cold drawn, forged and normalized. The author used the engine for 2 years where it house power is 9HP with having 30 N of torque at 3000 rpm. According to him, usually the cracks start on the surface of the crankpin due to rotating bending or torsional when there is some misalignment of main journal or unbalance due to counterweights effects [20]. Instead of using single diesel motor vehicle for our mechanical system design (MSD)
project, we were use single type *Winas* grass cutter engines for MSD project for easy handling and financial purpose. Here the specification of the engine model shown as in Table 7. All the four engines were run for few hours expect engine number 5 which used for constant for comparison purpose. The engine were run for 2 to 3 hours where the petrol and 2T lubricant oil has been mixed in plastic bottle before used it to run engines. To compare the result of two engines with the constant variable engine, all the parts of engine number 3 and engine 5 were disassembled and pictures as taken as shown in Figure 7 and Figure 8.

**Table 7:** The specification of engine

| *Winas* grass cutter engine specification | |
|---|---|
| Power | 1.2 HP |
| Engine Model | 1E36F |
| Engine Displacement | 30.5 CC |
| Engine Type | 2 stroke, single cylinder |
| Carburettor | Float Type |
| Tank Capacity | 1.5 Litre |
| Fuel | 50 : 1 |
| Weight | 11 Kg |

By comparing both the crankshaft based of Figure 7 and Figure 8, there is a very small lines appears on the surface of counterweight of crankshaft due to the friction that faced during the engine experimented for 3 hours. There will be a small crack may produce at the crankpin as referred to Fonte et al. journal if the hours of the engine run is extended more than 24 hours. Therefore from the referred journals and the experimental data collections, the more the hours or days spend to run any engine type of different model, sure there will be a small crack produce mainly at crankpin as it is the main point that connects the a pair of counterweights for a single crankthrow (1 set). Therefore, it can conclude that the type of material used, load applied, torque and friction produces are all the factors affecting the crankshaft failures to occur in engines no matter the type of engine used.

## CONCLUSION

In conclusion, all the objectives set in this engine test rig development has been achieved. By limiting this mobile engine experimental test rig, it can serve for further analysis depends on the type of application needed. The same test rig can be used for a different model of grass cutter engine to study effect of moveable parts of engines using different type of engine oil with fuel. The surrounding factors could affect the moveable parts such as piston and crankshaft failures of the engines. In future, temperature of each engine are taken by using thermocouple instrument tool to study the deviation pf temperature of each engines.

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