Journal of the Nigerian Association of Mathematical Physics
Volume33,(*January, 2016*), pp 387 – 394
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Production of Some Engine Parts for a Single-Cylinder, 0.67hp Petrol Engine Generator Using Reverse Engineering Method

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Abstract

The study was aimed at using the reverse engineering (RE) method to produce engine block, piston and connecting rod, for a single-cylinder, 0.67hp petrol generator internal combustion (IC) engine. The design for the riser size, sprue diameter, runner diameter and gating system were done and used to produce the mould that was used to sand-cast the engine block and piston. The connecting rod was produced by machining a rectangular block of mild steel to dimension. The reverse engineered components were coupled into the generator and the generator was run for 30 minutes under no load condition. Also a load of 400watts was appliedto the generator and was run. Another generator which served as a control engine was also run for 30 minutes under the same conditions as that of the engine with the produced components. The temperatures of both engines were taken at irregular time intervals. The engine speeds of the two engines were also taken. The results showed that there was a progressive rise in temperature for both engines. However, under no-load condition a greater differential was observed between the two engines than when a load of 400watts was put on the two engines. Again the results showed that under no-load condition, the control engine had a speed of 2400rpm compared to 2150 for the engine with cast parts. At a load of 400 watts, the control engine had a speed of 2200 compared to 1900 for the engine with cast parts. The reduction in speed could be attributed to the inability to machine the intricate portions of the engine block and piston to the exact specification of that of the control engine. However, the power output was stable for the engine with cast parts.

Key word: Internal Combustion (IC) Engine, Reverse Engineering (RE), Engine Block, Piston,Connecting Rod.

1.0 Introduction

Nigeria at present generates less than 5000MW of electricity [1]which is grossly inadequate for its population of over 170 million people as against South Africa that generates 36,000MW for it population of about 54 million[2]. This shortage of power generation is perhaps responsible for inadequacies suffered by Nigerians as far the use of electric power is concerned. This has led to most Nigerians providing their power by themselves with the aid of generating set. However, the parts and components of these generating set are on the high side and short supply, becauseof its importation into the country. Also, it is important to develop local capacity to develop internal combustion engines and reduce the over reliance on importation.

The 0.67hp reciprocating internal combustion petrol engine is a type of internal combustion engine designed to operate on petrol and to drive a wide variety of house-hold equipment. Due to the erratic nature of power supplied by the Benin Electricity Distribution Company (BEDC), this type of generator has found a very wide range of application in almost every household and small business outlets where the acquisition of bigger capacity generators is more or less a luxury.This type of generating set popularly called “I-Better-Pass-My-Neighbour, is one of the cheapest source of power supply in Nigeria today. It is the main source of power supply for small scale business operators like artisans and small shop owners.Consequent upon the huge dependence on this type of generating set, it is economically necessary at this time of our country’s history, that theinternal combustion engine and its engine parts should be locally produced, so as to grow the Nigerian manufacturing sector.However there is still dearth in knowledge in designing and development of the internal combustion engine, hencethe use of the reverse engineering technique, which will go a long way in local production and development of the internal

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combustion engine. This will further reduce the scarcity and expenses associated with importation of these generators and their spare parts.

Reverse engineering (RE) is a process whereby an already existing component is reproduced by using locally available materials and technology.Manzoor et al [3] described reverse engineering (RE) as“a process of reproducing the geometry of an available physical object.The method of reverse engineering is either manual or computer aided system.” Abdullahi and Umar [4] simply defined reverse engineering(RE) as the reverse of design-engineering.

The internal combustion (I.C.) engine was defined by Ronney[5] as “a heat engine (a device in which thermal energy is converted into mechanical energy) in which the heat source is a combustible mixture that also serves as the working fluid.”He further stated that “the working fluid in turn is used either to produce shaft work by pushing on a piston or turbine blade that in turn drives a rotating shaft, or to create a high-momentum fluid that is used directly for propulsive force.”Pulkrabek [6]described the internal combustion (I.C.) engine as a heat engine that converts chemical energy in a fuel into mechanical energy that comes out on a rotating output shaft.Fundamentally, there are two types of I.C. ignition engines, the ones that need a spark plug, and others that rely on compression of the fluid [7]. Various Institutions including the University of Benin, University of Lagos and private investors like Innosen Motors and Shell Petroleum Development Company (SPDC) have taken up the challenges of developing the internal combustion engines in Nigeria. Researchers have either carried out studies on the entire I.C. engine or parts of the engine. Ebhojiaye and Ibhadode [8]through reverse engineering technique producedpiston for single-cylinder, four stroke, 8hpdiesel engine. Amalu and Ibhadode [9] produced 3hppetrol engine block by reverse engineering approach. Zhengwuvi [10]undertook the design and manufacture of production mould for casting pistons of 3hpgeneral purpose IC engine.Adibe and Okorie [11] reported on the prospects for design and manufacture of automobile engine crankshafts and connecting rods in Nigeria.

The engine block (cylinder block) is the foundation of the engine. All other engine parts are assembled in or attached to the cylinder block. The piston is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, the purpose of the piston is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. In a pump, the piston function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder.The connecting rod is a major link inside of a combustion engine. It connects the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission.

2.0 Methodology

The research methodology of this study covers the research design, selection of materials, pattern and corebox design and sand mould design.

2.1 Research Design

Two numbers of 0.67hp generator popularly called “I-Better-Pass-My-Neighbour” were bought. One of the generators was disassembled. The engine block, piston and connecting rod were removed. The dimensions of these three engine components were taken and recorded.The recorded dimensions were used to design and produce the corebox and pattern which were used to cast the engine block and the piston. The sand mouldriser, gating systems and the time of solidification of casting were designed and determined. Sand casting process was employed as the production process for the engine block and piston, while the connecting rod was machined out of a block of mild steel.

2.2 Selection of Materials

The selection of materials for this study was tailored towards the materials that were used to produce the components that we are reproducing based reverse engineering principles. The engine block and piston were made of cast iron and aluminium respectively and the connecting rod made of mild steel. Wood was selected for the production of the core-box and pattern, because wood is readily available, easy to handle and cheaper to shape. The core-box accessories which include threaded rods and nuts were made of steel. The core and sand mould were silica sand with clay and some small quantity of bentonite. Sand casting process and machining operation were selected for this study.

2.3 Design Dimensions of the Piston Pattern

(i) Pattern diameter was determined by the following relationship:

Skirt external diameter + Linear shrinkage allowance + Machining allowance + Draft allowance (1)

i.e. 44 + 0.01302 + 1.5+ 1 = 46.51mm

(ii) Pattern height was determined by the following relationship:

Piston height + Linear shrinkage allowance + Machining allowance + Draft allowance (2)

i.e. 50 + 0.01302 +1.5 + 1= 52.51mm

(iii) Piston skirt thickness was determined by the following relationship:

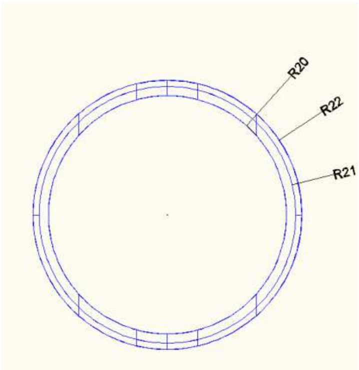
Piston skirt thickness + Linear shrinkage allowance + Machining allowance

+ Draft allowance (3)

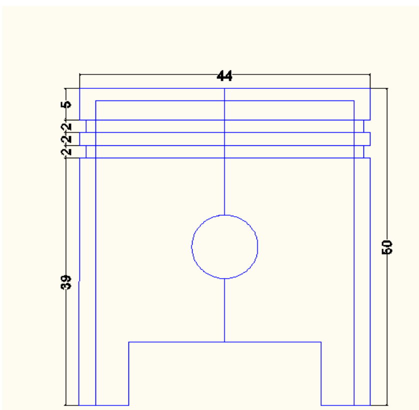
i.e. 2.5 + 0.01302 + 1.5 + 1 = 5.0l mm

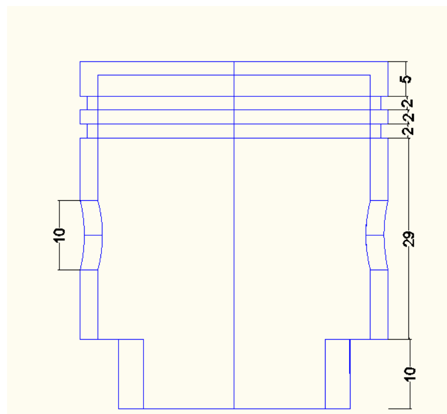
(iv) Crown internal diameter was measured to be 39 mm.

Fig. 1 shows the orthographic drawing of the piston.



(a) Plan View





(b) Front View (c) End View

Fig. 1: Orthographic Presentation of the Piston

2.4 Design Dimensions of the Engine Block Pattern

(i) Pattern diameter was determined using equation (1):

i.e. 100 + 0.01042 + 3 + 1 = 104.01mm

(ii) Pattern height was determined using equation (2):

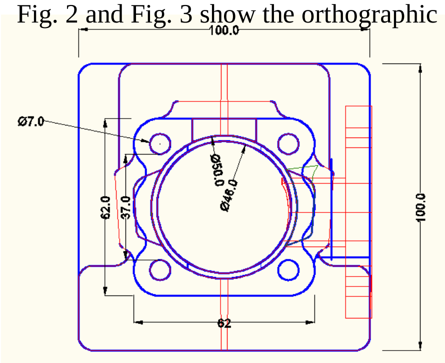
i.e. 85 + 0.01042 + 3 + 1 = 89.01mm

(iii) Skirt thickness was determined using equation (3):

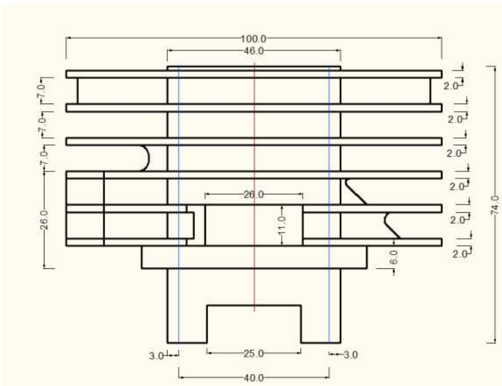
i.e. 3 + 0.01042 + 3 + 1 = 7.01mm

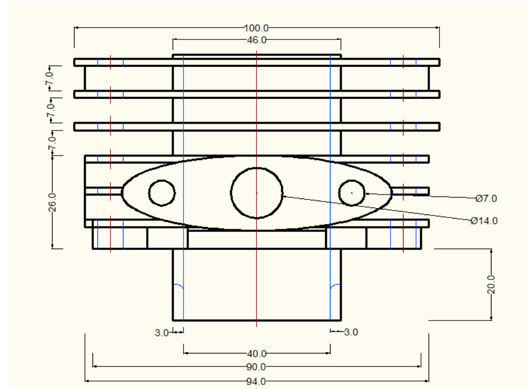
(iv) Cylindrical bore diameter was measured to be 40 mm

Fig. 2 and Fig. 3 show the orthographic and 3-D presentations of the engine block respectively.



(a) Plan view





(b) End View

(b) Front View

Fig. 2: Orthographic Presentation of the Engine Block

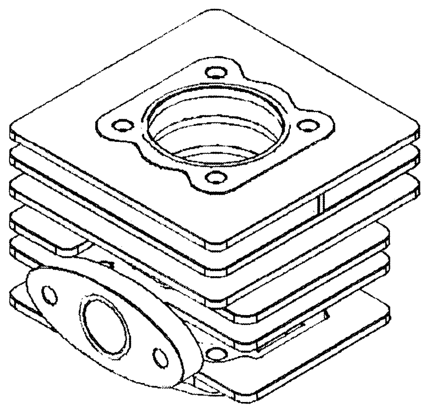


Fig. 3: 3-D Presentation of the Engine Block

2.5 Development of the Corebox

The coreboxes of the engine block and piston were used to produce their sand cores which were designed from the dimensions obtained from the piston and engine block.

2.6 Sand Mould Design

In designing the mould, some design considerations were observed in order to avoid defects and discontinuities which are usually associated with improper casting technique. These mould designs were done for both the engine block and piston, and they include: riser design, mould filling time, pouring velocity, design of feeding system (i.e. sprue, runner, ingate, sprue well, etc.).

2.6.1 Design of Riser for Engine Block and Piston using Ravi's Criterion

For a riser to compensate for solidification shrinkage of the hot spot region in the casting, it must satisfy the Ravi [12] criterion as shown in equation (1):

$$\eta_f V_f = \alpha(V_c + V_f) \quad (4)$$

where, V_f = volume of feeder (riser)

V_c = volume of casting

η_f = efficiency of feeder (riser)

α = volumetric shrinkage of cast metal

2.6.2 Casting Pouring Velocity Casting Engine Block and Piston

The liquid metal pouring velocity, v is given by:

$$v = \sqrt{2gH_s} \quad (5)$$

where, g = acceleration due to gravity (9.8m/s^2)

H_s = mouldmetalostatic height (i.e. cope height + ½ ingate diameter)

2.6.3 Design of Mould Filling Time for Casting Engine Block and Piston

Themould filling time τ_f is expressed as a function of weight of casting W in kg, section thickness t in mm and fluidity length L_f in mm. A generalized equation for filling time [12] can be written as:

$$\tau_f = K_0(K_f L_f/1000)\,(K_s + K_t t\,/20)\,(K_w W)^p \quad (6)$$

where, τ_f = mould filling time

K_0 = overall coefficient

K_f =coefficients for fluidity

K_s = coefficients for size

K_t = coefficients for thickness

L_f= fluidity length

K_w = coefficients for weight

W = weight of the cast

t = section thickness

2.6.4 Determination of MouldSprue Size Diameter

An ideal pouring rate can only be achieved with an appropriate sprue size. The computation usually reduces to determining the area of the narrowest cross section f_n of the sprue, after which the cross-sectional areas of all other elements of the system are obtained.

Mikhailov [13]defined the sprue choke area, f_n as:

$$f_n = \frac{M}{\rho}\tau\mu\sqrt{2gH_s} \quad (7)$$

where, M = mass of all cast in the mould including risers, runnersingates, and sprue well.

ρ = molten metal density

τ = mould filling time

μ = discharge coefficient of the metal, usually $0 < \mu <$ I

g = acceleration due to gravity

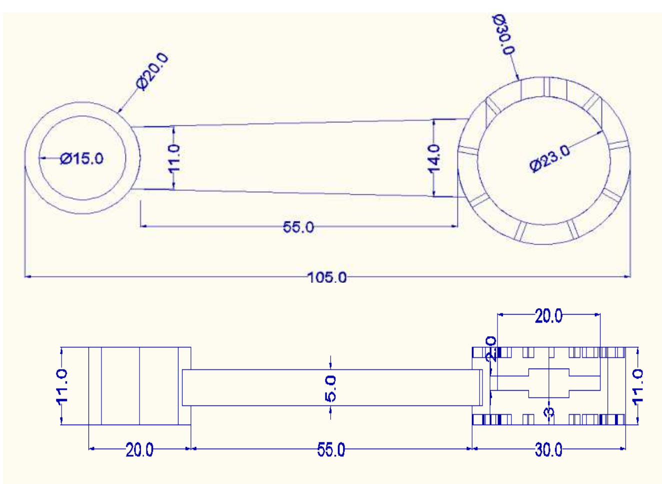
H_s = static vertical distance from the axis of the ingates to the top of the cope flask.

2.6.5 Determination of Mould Runner Size Diameter

The primary function of the runner in a mouldis to slow down the flow of molten metal, which speeds up during its free fall through the sprue.Therefore, the total cross-sectional area of runner(s) must be greater than the sprue area.The Gating Ratio is given by As:Ar:Ag. Where As, Ar and Ag are the cross-sectional areas of sprue exit, runner(s) and ingate(s) respectively. Examples of such gating ratios include: 1:2:1.5 for ferrous and 1:4:4 for nonferrous metals[12].

2.7 The Connecting Rod

The connecting rod was fabricated by machining a bought out rectangular mild steel block with a dimension of 120mm long, 35mm wide and 12mm high, to the desired shape and dimension by using the milling machine and drilling machine. Fig. 4 shows the dimensions of the connecting rod.



(a) Plan View

(b) Front View

Fig. 4: Plan and Front View of the Connecting Rod

3.0 The Manufacturing Processes of the Engine Block, Piston and Connecting Rod

The engine block and piston were produced by casting process and the connecting rod was produced by machining operation. The cast components were further machined to the required shape and dimensions. In carrying out this project work, the following components or materials were either used or produced.

3.1 Piston Manufacture

The piston was cast bypouring the molten metal into the prepared sand mould in the mould box. After pouring, the molten cast was allowed to solidify. After solidification of the cast, the cast piston was removed from the mould by breaking the sand mould. The molten metal in the riser and the sprue well also solidified and was cut off the cast as scrap. The cast piston (Fig. 5) was then checked for defects like porosity, blowhole, crack, slag-entrapment etc. by means of non-destructive testing. The centre lathe was used to carryout finishing operation on the cast piston. The cast piston was weighed to be 0.067kg. That is, 4.69% heavier than the original piston.

Fig. 5: Cast Piston before Machining

3.2 Engine Block Manufacture

The engine block was cast by pouring the molten cast iron into the prepared sand mould in the mould box as was done for the piston. The molten metal in the riser and the sprue well after solidification were also cut off as scrap. The cast engine block was then checked for defects such as porosity, blowhole, crack, slag-entrapment etc. by means of non-destructive testing. The centre lathe was used to carryout finishing operation on the cast engine block. The cast engine block (Fig. 6) was also weighed to be 1.584kg. That is, 9.24% heavier than the original engine block. Fig. 7 showsthe cast engine block after machining and cleaning.

Fig. 6: Cast Engine Block before Machining

Fig. 7: Cast Engine Block after Machining and Cleaning

3.3 Connecting Rod Manufacture

The connecting rod was machined out of a rectangular mild steel block by a milling machine. After which the drilling machine was used to bore the holes required for the gudgeon pin and crankshaft.

3.4 Performance Tests

For this study, performance test was carried out on the three components (i.e. engine block, piston and connecting rod) that were produced by fixing them into an engine and comparing the engine temperature and speed with that of a similar control engine. Also, performance test was carried out on the pattern and core-box of both the engine block and the piston.

3.4.1 Performance Test on Cast Piston, Cast Engine Block and Connecting Rod

The engine which had the cast piston, engine block and the connecting rod was powered on and ran for 30 minutes.

3.4.1.1 Engine Temperature Test

The engine with the cast components (i.e. piston, engine block and connecting rod) was run 30 minutes under no load condition and again under load of 400watts. The temperature of the engine was taken at the top cylinder at irregular interval and was recorded accordingly for the period of 30minutes it ran under no-load and load conditions. This temperature measurement was done with a digital read-out thermocouple. This same temperature test was done for the control engine under the same conditions with that of the engine containing the cast components for easy comparison.

3.4.1.2 Engine Speed Test

The speed of the engine with the cast components (i.e. piston, engine block and connecting rod) was measured using the tachometer and was recorded. The same measurement of speed was done for the control engine and was recorded.

4.0 Results and Discussions

The results obtained from the tests carried out would be presented and discussed in this section.

4.1 Result of thePerformance Test for Cast Engine Block, Piston and Connecting Rod

The cast engine components (i.e. engine block and piston) and the connecting rod produced were interchanged with the original components in the engine. The engine was run for 30 minutes under no-load condition and with a load of 400watts. The engine temperatures were taken at an irregular interval of time and recorded. The speed of the engine was also measured and recorded (Table 1).

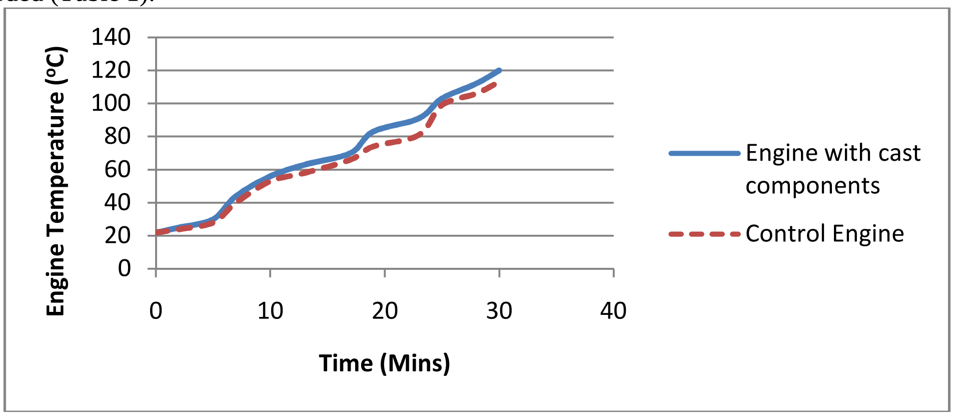


Fig. 8: Engine Temperature against Time under No-load Condition

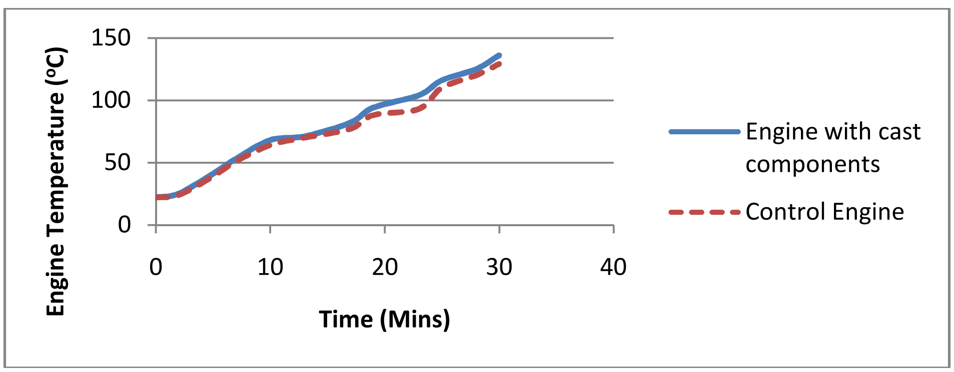


Fig. 9: Engine Temperature against Time under 400watts Load

Fig. 8 and Fig. 9 show the graph of the engine temperatures against time for the two conditions under which the engines were made to operate. These are the ‘under no-load condition’ and ‘under a load of 400watts’respectively.The curves showed that the two engines started at room temperature of 22^{o}C when they were switched on. While the engine temperature with the cast components incresed to 120^{o}C after 30mins the under no-load condition, the control engine temperature increased to 113^{o}C under the same no-load condition after 30mins. However, the temperature of the engine with the cast components increased to 136^{o}C after 30mins when a load of 400watts was put on it, whereas the temperature of the control engine increased to 129^{o}C when the same load of 400watts was put on it for the same period of 30mins. This indicated that there was a progressive rise in temperature for both engines. However, under the no-load condition, the curve of the graph for the engine temperatures with the cast components and that with the control engine (Fig. 8) showed that the two engine temperatures had a greater differential than when a load of 400watts was put on the two engines.

The speed of the engine was measured under the no-load condition and under a load of 400watts acting on it. This was done for both the engine with the cast components and the control engine using the tachometer and the values are shown in (Table 1).

Table 1: Speeds of Engines under No-load Condition and under 400watts Load

Engine Type	**Engine Speeds (rpm)**	
	Under No-load	**Under 400watts Load**
Engine with Cast Components	2150	1900
Control Engine	2400	2200

Under no-load condition, the control engine had a speed of 2400rpm and 2200rpm under a load of 400watts, which represented 8.33% engine speed reduction. The engine with the cast components (i.e. engine block, piston and connecting rod) had a speed of 2150rpm under no-load condition, which represented 10.42% speed reduction when compared to the engine speed of the control engine under no-load. Under a load of 400watts, the engine speed was found to be 1900rpm which represented 20.83% speed reduction when compared to the control engine under no-load condition. The reduction in speed could be attributed to the inability to machine the intricate portions of the engine block and piston to the exact specification of that of the control engine.

5.0 Conclusion

The engine components (i.e. engine block, piston and connecting rod) of a 0.67hp petrol engine generator (a.k.a. I-Better-Pass-My-Neighbour) have been locally produced by reverse engineering technique. Significant knowledge and skills have been gained from this study, which would go a long way in developing theautomobile and power sectors of the Nigeria economy. More importantly, it will advance the production of internal combustion (I.C) engine spare parts in commercial quantities locally. This would reduce the prevailing unemployment rate amongst Nigerian youths.

6.0 References

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