Development And Performance Evaluation Of Screwed Electric Tyre/Tube Patching Vulcanizer

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***Abstract*—This research upgraded the old vulcanizing equipment to save time, investment, man power and to eliminate the problem of gas emission produced by the convectional (gas fired) valcanizer in vulcanization. It also determined the accurate temperature setting and duration of vulcanizing process using a developed electronic vulcanizer. In constructing this vulcanizer, a letter C body configuration made of mild steel with about 805mm long lag bolt with some electronic parts were installed, like temperature gauge, digital timer, led, and heating element. Specifically, the product is divided into different components: the frame, base plate, screw shaft and nut, heating chamber, heating element and temperature regulator. The effectiveness level of the equipment was tested utilizing three different temperatures at a constant and variable time. For tube, the temperature is about 70^{o}C, for vehicle tyre with 1.5 – 3mm thickness is about 70^{o}c, for truck tyre is about 90^{o}C, The rate of energy consumed by the electronic vulcanizer is about Php 0.0757 with an efficiency of 85.22% and for conventional vulcanizer is about Php 1.08 with an efficiency of 43.38%. The study revealed that more tires could be vulcanized in a short period of time, therefore providing greater income over time. It is also environment-friendly since it does not emit carbon dioxide as compared to the conventional vulcanizing. The produced patching equipment is highly cost effective. It reduce its foreign cost by 30%. This will have high cumulative effect under mass production of the equipment.**

Keywords—Electric Tyre/Tube, Development, Performance Evaluation, Screwed, Patching, Vulcanizer

I. INTRODUCTION

Truck, cars, motorcycle and Bicycle owners sometimes face the problem of punctured tyre and this is as a result of bad roads, presence of foreign material (sharp objects) on our roads and sometime the use of inferior tubes. Punctured tube or tyre can be repaired by patching. The tube is removed from tyre to find the leak by inflating the tube and submersing in water, bubble will appear when there is a leak, the spot is marked and the tube deflated and dried.

There are two ways to patch a tube that is either by cold patch or by hot patch. Cold patch method is the process in which the tube is cleaned, dried free from oil and grease. The area around the leak is roughed and covered with vulcanized cement, which is allowed to dry until it is tacky [1]. The patch is pressed into the place and roded from the center out with the edge patch. While hot patch method is the process in which the tube is prepared in the same way as for cold patch. The tools used by the vulcanizing include a piston or a hollow cylindrical object e,g (engine cylinder inner) which is place over the patch, a clamp is then used to hold the piston is placed. If a hollow cylindrical object is used, a little sand is poured on the patched area and paired on the sand [2].When the patch is ignited the heat generated will vulcanize the patch. In a place where the piston is used, the piston is placed on the patched area and held firmly on the patch with the clamp [3].

A combustion material is then placed inside the piston and ignite as the material burns heat is generated and conducted the patch through the piston there by vulcanizing the patch. It is obvious that hot patch method of vulcanizing described above cannot be done in an enclosed area, or inside a workshop because of the carbon monoxide and carbon dioxide gases which are form during combustion of fuel. The tools used is this method of vulcanizing are absolute and it take time to vulcanise a tire tube [4].

In an automobile industry, vulcanizing is the process of cooking or curing the vulcanizing rubber heating it to a temperature of 120 to 150^{0}C but the temperature of 128^{0}C but is considered best a layer of 1-5 mm for vulcanizing requires is to 20 minutes with 5 additional minutes for each additional 1-5 mm layer. The vulcanizing can be heated by electrical power, gas gasoline or steam. Most vulcanizing process carried out across the country today is still using the absolute tools and equipment and this involves the burring of fuel to generate heat required. This method, apart from being time consuming it consists a health hazard such as hyocardial is chemia (along disease) accompanied by angina to the person carrying out the vulcanizing process and people within the vicinity where the vulcanizing is being done. It can also lead to fire hazard on the fuel is highly inflammable [5].

In view of the above problems, there is need for electric vulcanizing machine to be developed, the electricity energy is converted to heat energy which requires for the heating of the patch on the tyre. The vulcanizing temperature produce by the heating element will be conducted to the plate (housing), to the heating element and the temperature will be with, the aid of thermostat regulated.

1.1 Vulcanizing

In the automobile industry, vulcanizing is the process by which the physical properties of natural or synthesis rubber are improved; finished rubber has strength and is resistance to swelling and elastic over a greater range of temperature. In its simplest form, heating rubber with suphur bring about vulcanization, in the modern practice a temperature of 140^{o}C to 180^{o}c is develop and in addition to Sulphur accelerating, carbon, black oxides is usually added, not merely as an extender, but to improve further the qualities of the rubber [6]. Vulcanizing gum which is classified as ready to heat rubber, is now utilized to repaire worn out interior/ exterior rubber tires with the help of vulcanizing equipment certain problems such as inaccuracy of the product are evident in third – world countries, as the first – worlds never use some [7].

The discovery of vulcanization was through Good year that rubber could be improved by processing it with other substances, as Good year was displaying a mixture of rubber and sulphur, the piece slipped from his hand into five, when he looked it out he found to his amazement that the mass has charred without meeting. Good year named this process of combining rubber with sulphur by heat vulganization. Later he discovered that the addition of line, magnesium and lead compounds speed up the vulcanization process. [8] and [9]. In the process of vulcanization, sulphur atom cross links between the chain molecule of rubber, tying then firmly together. The vulganization process causes some striking changes in the property of rubber. Its strengths is increased and it can be stretched to greater length than before. It will no longer dissolve in gasoline or benzene, through it will swell up if it is soaked in them. [9].

1.2 Class of Vulcanizing

Newly discovered rubber classes such as vulcanizing gum are now utilized for repairing worm out rubber, such as an automobile tire.
Vulcanizing gum is classified according to its texture, binding temperature and the content of accelerators. The three classes of gum were as follows:

a) Class A usually bonds on the rubber 30 – 70^{0}C and is smooth.
b) Class B usually bonds on the rubber 35 - 80^{0}C and is moderately rough
c) Class C usually bonds on the rubber 45 – 90^{0}C [10].

Actually there are new vulcanizing equipment in the market plus the internet ads, there are some vulcanizes that are electrically operated but they don’t have timer nor temperature control.
Commercial vulcanized (electric and manual) if not properly used the vulcanize gum may be burnt even with the tire; this hold true with manually operated machine, compared to the manually operated vulcanizing equipment, this electronic operated vulcanize saves time, labor money, and man power in the vulcanizing shop operation. The flow chart of the study is shown in figure.1.

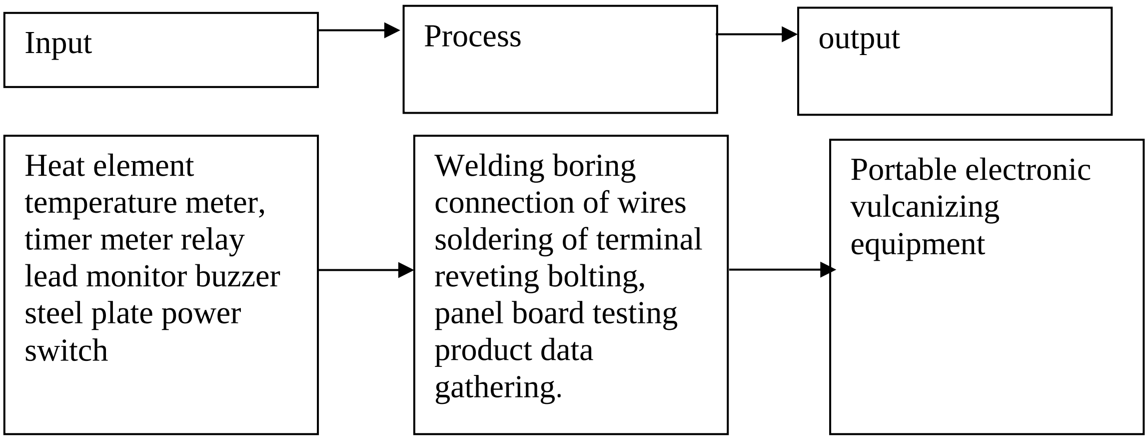


Fig. 1.1: Flow chart for portable electronic vulcanizing equipment (Liming *et al.*, 2018).

Other types of vulcanize is convectional types which make use of gas emission by burning diesel which produce a lot of carbon monoxide. Also we have solar vulcanizer which uses sun power foe vulcanization the solar power operated vulcanize is an environmentally friendly equipment. Its design is considered for greening the world to be lived from generation to generation [11]. The modernization of this gadded is introduced for the benefit of mankind, renewable energy dramatically lowers pollution emission, reduces environmental health risks and slow the deflation of finite natural resources [12]. Renewable energy is derived from the sun, wind, water or earth core. It can also be derived from biomass. And all this energy varies. It can not be available at all time, compare with the use of standard generator powered to produce current to functionalized the device.[13].

1.3 Vulcanization Method

A variety of method exist for vulcanization economically most important method (vulcanization of tires) uses high pressure and temperature. A typical vulcanization temperature for a passenger tire is 10 minutes at 170^{0}C [14]. Vulcanization is the chemical process by which the physical properties of synthetic rubber are improved; finished rubber has higher strength and resistance to swelling and abrasion and elastic over a range of temperature. In a simplest form, heating rubber with sulfur brings about vulcanization. Data on table 1 and 2 shows that the three vulcanizes has the best temperature of 60^{o}c which given when bonded exactly to the rubber tire. For convectional vulcanize; the rate of energy consumption at php 1.08 and efficiency of 43.38%, while the class B gum the rate of energy consumption of php 1.52 and with an efficiency of 78.08%. for an electronic vulcanize: the rate of energy consumption at php o.15 and with an efficiency of 85.22%. for solar vulcanize: the rate energy consumption of 0.0033 and efficiency of 85.22%, while the class B gum, the efficiency of 85.22 [15].

Table 1: Time, temperature, power, fuel consumption of solar power, electronic and convectional vulcanization.

Table of vulcanizer	Time in minutes		Temperature in 0^{o}C		Power/fuel consumption	
	A	B	A	B	A	B
Solar	1	2	60	60	0.005kW/h	0.10kW/h
Electronic	1	2	60	60	0.005kW/h	0.10kW/h
Convectional	5	10	60	60	200ml	30ml

[16].

Table 2: Efficiency and rate of energy consumed (php) of solar power Electronic /convectional vulcanize

Types of vulcanize	Cost in kw/hr Gas ml		Rate of energy consumption		Results		Efficiency (%)	
Class								
	A	B	A	B	A	B	A	B
Solar	Php 0.0067		Php 0.0033	Php 0.067	Best Bonding		85.22%	
Electronic	Php 0.0067		Php0.0757	Php 0.15	Best Bonding		85.22%	
Convectional	Php 0.0067		Php 1.08	Php 1.52	Good Bonding		43.30%/78.08%	

[16].

TRMG made the following recommendations; Tires that are manufactured with puncture sealing capabilities require specialized repair techniques. The tire and or sealant manufactures should be Contacted for recommendations. It may be necessary to repeat the pre-cleaning process) to ensure that the repair area is free of contaminants [17].

1.4 Key Repair Terminology (From Buff Contour to Buffing Template)

Whether attempting a minor rubber repair, the only time a repair can be made in the bead area, puncture nail hole repair or section repair, one of the key step involves buffing.

Buffing terms and meaning:

a) Buff contour; the specified shape of a buffed area.
b) Buffing: removal of the previously vulcanized rubber surface.
c) Buff line: the dividing line in the cross section of tire between the buffed surface of the original tire and the new treaded rubber.
d) Buff radius: a measurement of the buffed surface curvature from shoulder to shoulder.
e) Buff surface: a specially repaired surface of a tire casing or repair area to provide proper texture to help promote adhesion to the new rubber.
f) Buffed texture: that surface produced by buffing rasping or cutting as standard by the rubber manufacturer association.
g) Buffer: a machine use to rasp the old tread from the casing. A powered rotary rasp provides a clean/ even surface for adhesion of the new tread rubber.
h) Buffer template: a machine device of a specified shape used to obtain the required buffed tire radius. [18].

The tread rubber and Tire Repair materials Manufacturing Group (TRMG) has released additional recommended practices (RPs) for retreading and repairing through the Tire Retread and Repair Information Bureau (TRIB) website. The RPs are free to view on TRIBs website. www.retread.org. [18].

TRMG advices selecting the appropriate repair unit either a one or two piece repair, based on repair material manufacturer recommendation. “for inquries with an angle greater than 25 degrees, depending on repair manufacturer use a two- piece unit system [19].

1.5 Puncture Repairs

The big different between light truck tires below Load range E and LT tires Load Rang E and above is the size of the permissible puncture repair. Both repairs should be limited to the treaded area only, but light truck radial fabric body ply tire. Puncture repairs should not exceed ¼ inch (6.0 mm) in diameter after preparation (Jiada *et al.*, 2019; Lifeng *at el.*, 2020; Javier et al., 2019). They went further and said for light truck radial steel body ply tires, the puncture repair should not exceed ¼ inch (6.00 mm) in diameter after preparation

1.6 Cleaning Tips

TRMG recommend removing all contaminants from around the injury. However, this has become more problematic with the increased popularity of puncture sealants. Whether they are purchased in the aftermarket or come with vehicles without spares, they also need to be removed.

II. MATERIAL AND METHOD

The patcher/sealing equipment was developed to solely handle the patching process of an injured tyre or tyre tubes. The stages of research work involved; design conceptualization, design of the equipment, fabrication of the designed equipment and testing of the machine to evaluate its performance.

2.1 Design Conceptualization

In order to effectively develop the tyre patching equipment and its components, various factors were considered which directly deal with the function of the equipment and its components, material selection, environmental usage, the end users and the interest of the designer. Some of factors considered for the equipment's development are:
Cost, Strength, Varieties of tyres/tubes, Tyre damage, Durability of the equipment, Ease of component production, Ease of assembly, Integrity and High efficiency. Some design parameters were selected based on data obtained from related literatures on tyre patching and such parameters are listed; (a) Heating element power and (b) Heating time as per thickness of tyres/tubes.

2.2 Machine Description

The patching equipment comprises three major units:
(i) The frame unit
(ii) The screw shaft unit
(iii) The heating chamber and the base of the equipment.
The frame is like letter "C" turned backward in standing on the bottom plate by welding method. The screw shaft unit which comprises the shaft wheel for pressure loading and release on the tyre to be repaired. The heating chamber which comprise the heating element and the base plate on which the tyre or tube are placed during patching process, the base plate is the one that carries all the load and positioned them for stability, also timer is used to check the time when the patching is done.

2.3 Design Analysis of the Vulcanizer Machine

The components of the equipment are: The frame, Base plate, Screw shaft and nuts, Heating chamber, and Temperature regulator.

(i) Design analysis of the frame

The material used is column angle iron of mild steel, the frame was designed to hold firm the order machine component for an effective operation. It is of 850mm in height, 450mm base length.

2.3.1 Determination of the centroidal axes (I_{XC} , I_{yc} , r_u and r_y).

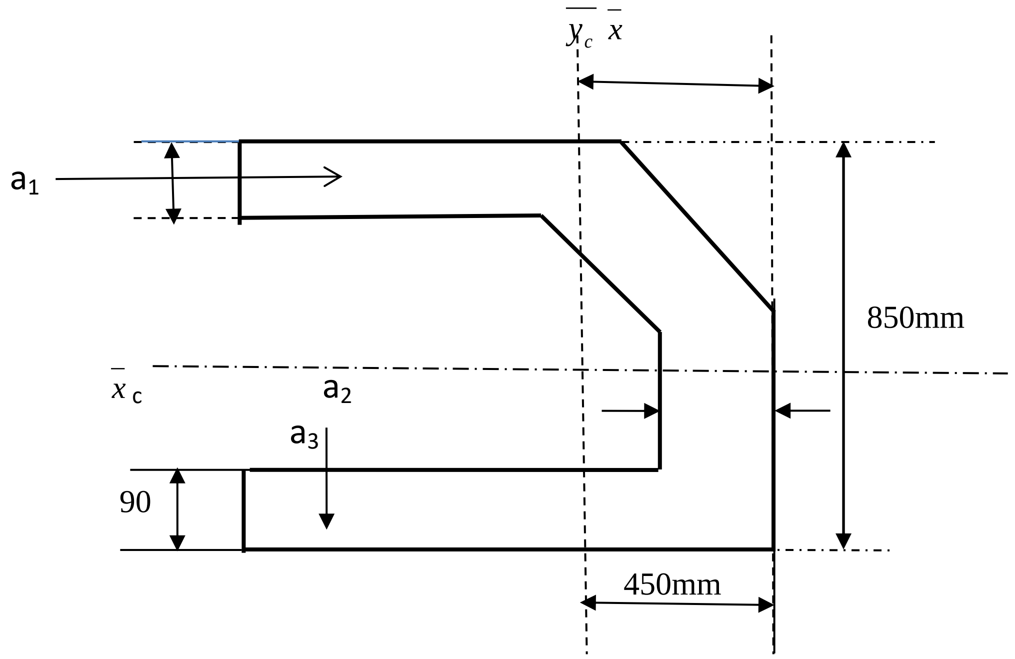


Fig. 2.1: Determination of the centroidal axes (I_{XC} , I_{yc} , r_u and r_y).

The 'X' centroidal axis lie at one half the height. The location of the 'Y' centroidal axis must be determined. The channel was broken into three areas as a_1 , a_2 , and a_3 respectively.

I_x is the moment of inertial of each component part with respect to the 'X' centroidal axis of each part.

D_y is the transfer distance of each component part measured from the 'x' centroidal axis of each part to the 'x_c' axis. The total moment of inertial is then;

$$I_{XC} = I_X + Ad^2_y \quad --- \quad (2.1)$$

While

$$I_{yc} = I_Y + Ad^2_x \quad --- \quad (3.2)$$

Table 2.1: Computation table

S/N	Shape	Area (mm^2)	X (mm)	Ax (mm)	I_x (mm^4)	d_y (mm)	Ad^2y (mm^4)	I_y (mm)	d_x (mm)	Ad^2_x (mm^4)
1.	a_1 (450)(90)	40,500	225	$9.11x10^6$	$27.34x10^6$	450	$6.64x10^9$	$68.34 x10^6$	40,329	$6.558 x10^{13}$
2.	a_2(625)(90)	56,250	312.5	$17.58x10^6$	$37.97x10^6$	0	0	$27.34 x10^6$	55,989	$1.763 x10^{14}$
3.	a_3 (450)(90)	40,500	225	$9.11x10^6$	$27.34x10^6$	405	$6.64x10^9$	$68.34 x10^7$	40,239	$6.558 x10^{13}$
Total		137,250	260.84	$35.80x10^6$	$92.65x10^6$		$13.28x10^9$	$13.94 x10^8$		$3.075 x10^{14}$

I_{X1}=1/12bh^3 =1/12x450x90^3 =1/12(328,050,000) =27,337,500 = 27.34x10^6

I_{x2} = 1/12bh^3 = 1/12x625x90^3 =1/12(455,626,000) = 37,968,750 =37.97x10^6

$$\overline{x} = \frac{35.80 \text{ x } 10^6}{137,250} = 260.84\text{mm}$$

$$Iy_1 = \frac{1}{12}(bh^3) = 68.34 \times 10^7 mm^4$$

$$Iy_2 = \frac{1}{12}(bh^3) = 27.34 \times 10^6 mm^4$$

$$dy_1 = dy_3 = 405,\ dx_1 = dx_3 = x_1 - \bar{x} = 40{,}500 - 260.84 = 40{,}239.16$$

$$dx_2 = x_2 - \bar{x} - 56{,}250 - 260.84 = 55{,}989.16$$

From Table 2.1 $a_1 = Ad^2mm^4 = 6.558 \text{ x} 10^{13}$

$$a^2 = Ad^2mm^4 = 1.763x10^{14}$$

$$a^3 = Ad^2mm^4 = 6.558 \text{ x} 10^{13}$$

$$\text{Total } \sum_x Ad^2 = 3.075 \text{ x} 10^{14}$$

$$I_{XC} = I_x + Ad_y^2$$

$= 13.373x10^9$ mm^4

$$I_{yC} = I_y + Ad_x^2$$

$= 3.075 \text{ x}10^{14}$mm^4

$$\tau_x^o = \sqrt{\frac{I_{XC}}{A}}$$

$= 9.870x10^3$

$$\tau_y^o = \sqrt{\frac{I_{yC}}{A}}$$

τ_y^o= 1.497x10^6

τ_x^o= 9.870x10^3

(ii) Design Analysis of the Screw shaft

Determination of the required torque the following data were collected from data table for the design of the required torque:

ISO meteric threads

Pitch = 1.75mm (single-thread)

Outside diameter = 12mm

Root diameter = 9.853mm

Root area = 76.25mm^2

Coefficient of thread friction = 0.12(=f)

Coefficient of collar friction = 0.25 (fc)

Mean collar radius = 6mm

Load required W = 4000N

Operator can comfortably exert a force of 80N at the end of the turning wheel

The torque Required "T"

$$T = W\left[r_m^o\left(\frac{\tan\alpha + \text{f}/\cos\theta\text{n}}{1 - \text{f } \tan\alpha/\cos\theta\text{n}}\right) + \text{f}_c \text{ r}_c\right]x \quad ---$$

(3.3)

Where $r_m = \frac{1}{4}(12 + 9.853) = 5.46$mm

$$\text{`} \tan\alpha = \frac{\text{Lead}}{2\pi r_m} = \frac{1.75}{2\pi(5.46)} = 0.0508$$

Note from data $\theta n = \theta = 30$ since the index angle is so small.

Then

$$T = 4000\left[0.00546\left(\frac{0.0509 + 12/0.866}{1 - (0.12)(0.0509)/0.866}\right) + (0.25(0.00\right.$$

Screw torque + collar torque = 4.16 + 6 = 10.16Nm

The section A-A above the nut, is subjected to torques and bending. Also the section B-B below the nut is subjected to torque and direct compressive load. It will be necessary to check both sections for maximum shear stress $S_3 = \frac{T_r}{J}$

--- (3.4)

$$= \frac{(10.16)(0.00493)}{0.924 \text{ x} 10^{-9}} = 54.3\text{MN/M}^2$$

Where T = 10.16 Nm (from above)

$$r = r_t = \frac{9.85}{2}\text{ mm},\ j = \tfrac{1}{2}\bar{\wedge} r_c^4 = 0.924x10^{-9} m_4$$

Bending stress, $S_t = \frac{M_{bc}}{I}$ (3.5)

$$= \frac{(12)(0.00493)}{0.462x10^{-9}} = 128MN/m^2$$

Where

$M_6 = (80)(0.15) = 12$ Nm, $C = r_t = 4.93$mm

and $I = \frac{1}{4}\pi r_t^4 = 0462 \text{ x}10^{-9} \text{ m}^4$

Maximum share stress $\tau_{max} = \sqrt{\left(\frac{1}{2}\frac{S}{t}\right)2 + S_s^2}$ ---

(3.6)

$$= 83.9MN/m^2$$

The direct compressive stress $r\,S_c = \frac{W}{A}$ ---

(3.7)

$$= \frac{8400}{\pi(0.00985)^2/4} = 52.5 \text{ MN/m}^2$$

Hence the maximum shear stress r^s

$$\tau(\max) = \sqrt{(52.5/2)^2 + (32)^2} = 41.4\text{MN/m}^2$$

It is hereby concluded that the maximum shear stress ours at section A – A is 83.9MN/m^2

The bearing pressure on the thread 'P'

$$P = \frac{W}{2\pi_n r_m h} =$$

$$n = \frac{\text{nut length}}{\text{pitch}},\ h = r_0 - r_0$$

$$h = \frac{12 - 9.853}{2} = 1.07\text{mm}$$

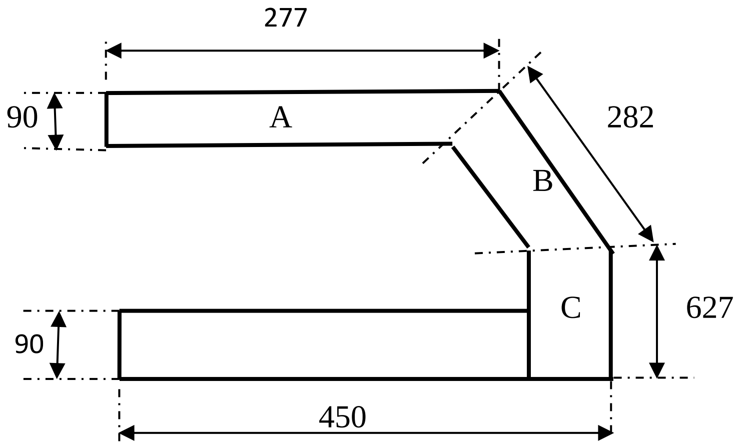
$$r_m = \tfrac{1}{4} = 0.25$$

$$P = \frac{4000}{\tfrac{2}{3}142x14.3x0.25x1.07}\ \text{mm}\quad P = 1{,}132\text{N/mm}^2$$

(iii) Screw press Efficiency Determination E_f

$$E_f = \frac{\text{Output work per turn}}{\text{input work per turn}} = \frac{0.054\text{W}}{(0.00348\text{N})^{2\pi}} \quad \text{- - -} \quad (3.9)$$

Note 7.95X10^{-6} (selected from data available)



Assuming all shapes are rectangular

Area of a_1= 90

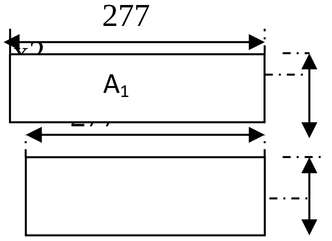


Fig. 2.2: Determination of the weight of the equipment

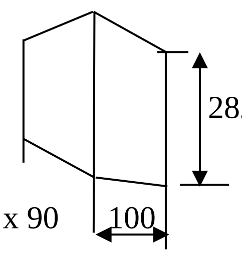
a_2 = 100 x 2

A_1 = 2(277x90) + A_2= 2(277x100)

A_1 = 40,860mm^2 +45,400

A_1 = a_1 + a_2 = 86,260mm^2

Area B 90



b_1 = 282 x 100 + b_2 = 282 x 90

B_{Area} = b1 + b2

= 28,200 + 25380

B_{Area} = 53,580mm^3

Area C = C_1 + C_2

=450x90+ 450x100

=40,500 + 45,000

$$E_f = \left[\tfrac{\theta}{I}\right]\%$$

$$= \frac{0.004(4000)}{0.00000795\ (4000)\ \text{x}\ 2\pi} = \frac{16}{0.19993}\ 80\%$$

(iv) Determination of the weight of the equipment

The total weight is the weight of the; frame + screws shaft + screw wheel + heating chamber cover and regulator switch which are negligible. This can also be added by weighing them and add their weight to the first three weights

(a) Area of the frame (thickness of plate used 3mm)

85,000mm^2

Total Area of frame : A + B + C + D

= (86,260 + 53,580 + 85,000)mm^2 - - (3.10)

=224,840 mm^2

Since the thickness of plate used is 3mm.

Therefore volume = Area x Thickness

Volume = T_A X t - - - (3.11)

= 224,840 x 3

= 674,520mm^3

Convert to m^3 = 0.00067452m^3

Density of the mild steel = 7858kg/m^3

Since Density = $\frac{mass}{volume}$ - - - (3.12)

Mass of the frame = Density x Volume

M= DV

M = 7858kg/m^3 x 0.00067452m^3

M = 5.300378kg

Weight of the frame; W = mg --- (3.13)

W = 5.300378kg x 9.81

= 51.996N $\approx$ 52N

Weight of the screw shaft

wheel = 143, shaft = 607, width of the shaft = 30mm

Area of the wheel; $A = \pi r^2$

Length of the wheel = circumference = $2\pi r$

Volume of the wheel = $\pi r^2 \times 2\pi R$ --- (3.14)

$V = \pi r^2 \times 2\pi R = 3.142\,(1.5)^2 \times 2(3.142)\,\frac{143}{2}$

= 3,176.37m^3

Mass = DV

= 7858 x 0.00000317637m^3

Mass of the screw shaft = 0.02495991546kg

Volume = $\pi r^2 l$ --- (3.15)

= 3.142 (1.5)^2 x 607

= 4,291.1865mm^3

= 0.0000042911865m^3

Mass = DV

= 7858kg/m^3 x 0.0000042911865m^3

= 0.033720143517kg

Total mass of the screw shaft

T_{ss} = weight of the wheel + weight of the screw shaft

= (0.02495991546 + 0.033720143517)kg

= 0.058680058977kg

Weight of the shaft W. = mg

= (0.058680058977 x 9.81)N

= 0.57565137kg $\approx$ 0.58N

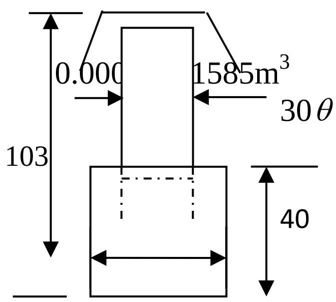
The mass of the lower shaft for lower plate

Volume = $\pi r^2 L$

= 3.142 x (15)^2 x103

= 72,815.85mm^3 = 0.0001585m^3

30θ the shaft housing



Volume = $(\pi r^2 L - \pi r^2)L$

=(3.142 30^2 – 3.142 x 15^2) 40

= 84,834mm^3

= 0.000084834m^3

Total volume of the lower shaft and housing

T_v = 0.00007281585 + 0.000084834

= 0.00015764985m^3

Mass = Density x Volume

M = DV

= 7858kg/m^3 x 0.00015764985m^3

M = 1.239x 10^{10}kg

W = 12.153N

Total weight of the vulganizer machine

T_{wv} = weight of the frame + weight of upper screw shaft + weight of the lower plate shaft + weight of the lower base shaft housing

T_{wv} = (52+ 0.58 + 12.153)N

=65.11N

(v) Design of the heating chamber

This was done base on the available data. From the data the following data were selected since this unit were not fabricated they are bought out good and required value are available aready. Therefore for the production of this vulcanizer patch equipment the following component and value were selected;

power of the heating element = 500w

voltage = 220v

vulcanizer temperature =30 – 90^{0}c

vulcanizer time less than 7minutes

2.4 Summary of the designed parameter of the vulcanizer

Frame centroid in the x- axis (I_{xc}) = 13.373 x 10^{9}mm^4

Frame centroid in the Y- axis (I_{yc}) = 3.075 x 10^{14}mm^4

Screwshaft pitch = 1.75mm

Shaft outside diameter = 30mm

Root diameter

=28.853mm

Root area =76.25mm^2

Coefficient of thread friction =0.12 (=f)

Coefficient of collar radius =0.25 (=fe)

Mean collar radius =6mm

Design load =4000N

Torque =10.16NM

Bending stress

=128MN/M^2

Maximum shear stress

=83.9MN/M^2

Operator force to exerted =80N

Bearing pressure

=1,132N/mm^2

Efficiency of screw press	=80%
Total weight of vulcanizer	=65.11N
Power of the heating element	=500N
Voltage	=220V
Vulcanizer temperature	=30 – 90^{o}c
Vulcanizer time	=less than

7minutes

2.5 Patching Procedure

The patching procedure covers both tyre and tubes

a. Tyre procedure

The following steps are taken in repairing tyres;

i. Note and mark the affected area with white materials or chalk
ii. Widen the tyre in use a wood to hold the tyre from returning back to its original width
iii. Clean the surface affected area with , also clean the punch emery cloth ole with a round file.
iv. Apply a glue on the affected surface and the hole.
v. Use a small rubber to fill the hole depending on the thickness of the tyre
vi. Place patching pad on the inner surface of the affected area
vii. Place a paper across the surface of the patching pad
viii. Then take the tyre to the machine by placing the affected area between the heating chamber and thighting it down to create pressure on the punctured side
ix. Plug to electrical circuit and observe the sealing process according to the stated temperature above but depending on the thickness.
x. Screw it up after which the temperature have reach
xi. Use water to poured on the surface gently rob the paper away from the patch area.

b. Tube procedure;

The process involves:

i. Cleaning the affected surface
ii. Applying glue
iii. Place the patching pad on the affected area
iv. Place a paper across the surface of the patching pad
v. Then take the tube to the machine by placing the affected area between the heating chamber and thighting it down to create pressure on the punctured side
vi. Plug to electrical circuit and observe the sealing process according to the stated temperature above but depending on the thickness.
vii. Screw it up after which the temperature have reach
viii. Use water to poured on the surface gently rob the paper away from the patch area.

III. RESULTS AND DISCUSSION

3.1 Results

The results generated from this research covers the designed values of the patching equipment (vulcanizer), the experiment results collected from the use of the vulcanizer in order to evaluate its performance. The designed analysis results for the vulcanizer are:

Frame centroid in the x- axis (I_{xc}) = 13.373 x 10^{9}mm^{4}, Frame centroid in the Y- axis (I_{yc}) = 3.075 x 10^{14}mm^{4}, Screw shaft pitch 1.75mm, Shaft outside diameter 30mm, Root diameter 28.853mm, Root area 76.25mm^{2}, Coefficient of thread friction 0.12 (=f), Coefficient of collar radius 0.25 (=fe), Mean collar radius 6mm, Design load 4000N, Torque 10.16NM,Bending stress 128MN/M^{2}, Maximum shear stress 83.9MN/M^{2}, Operator force to exerted 80N, Bearing pressure 1,132N/mm^{2}, Efficiency of screw press 80%, Total weight of vulcanizer 65.11N, Power of the heating element 500N, Voltage 220V, Vulcanizer temperature 30 – 90^{o}c, Vulcanizer time less than 7minutes.

Table 3.1.Experimental results

Sample	Thickness(mm)	Temperature (O^oc)	Vulganizer time (mint)
Standard value(tube)	1	30-70	7
Car/buses T_A	0.8	50	4
T_B	0.5	55	3
T_C	0.6	60	4
T_D	0.7	60	5
TAV	0.65	56.3	4
Standard value(tube) Truck/tractor	3.42	30-80	7
T_A	2.51	65	6
T_B	2.56	70	5
T_C	3.01	75	6
T_D	2.90	68	5
T_{AV}	2.75	70	5.5
Standard value(tyre) Car/buses	6.5	50-90	7
T_{yA}	5.5	75	6
T_{YB}	5.7	80	5
T_{yC}	6.0	85	5.5
T_yD	5.9	87	6
T_{Yav}	5.8	82	5.6
Standard value(tyre) Truck/tractor	200	100-120	7
T_{yA}	150	100	6.5
T_{yB}	130	95	5.5
T_{yC}	145	90	6.0
T_{yD}	180	100	6.5
T_{yAV}	151.25	96.3	6.1

Table 3.2 Shows average of the data collected from the sample which will describe how the graph should be.

Table 3.2: Average data collected from the samples

Sample	**Thickness mm**	**Temperature (O^oc)**	**Vulganizer time (minit)**
Tube. (Car/buses)	0.65	56.3	4
Tube. (Truck/tractor)	2.75	68	5
Tyre. (Car/buses)	5.8	82	5.6
Tyre. (Tractor/truck)	151.25	93.3	6.1

3.3 Cost Analysis

The production cost of the patching equipment is as shown in table 3.3.

Table 3.3: Production cost of the patching equipment

S/N	MATERIALS	PRICE (₦)
1.	Rectangular body frame using 2" by 2" thick angle iron	14,000
2.	Lead screws	15,000
3.	Heating chamber	15,000
4.	Heating elements	3,000
5.	Temperature controller with sensor	6,000
6.	Base plate	2,000
7.	Electrical equipment installations	3,500
8.	Miscellaneous expenses	30,000
	Total	88500

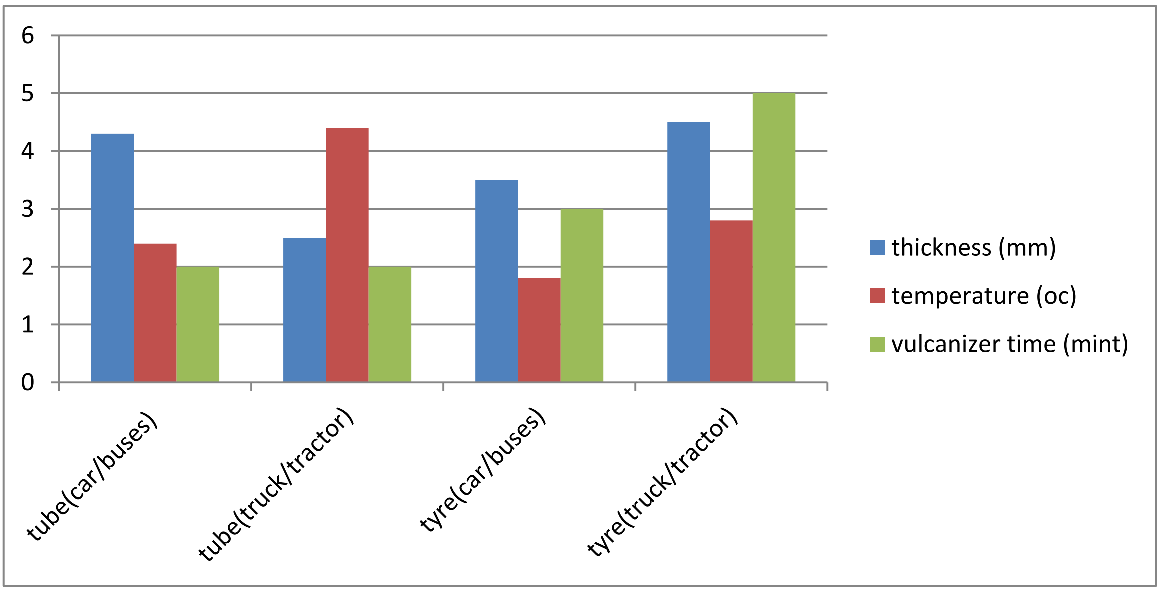


Figure 3.1: Production cost of the patching equipment

3.4 Discussion

The vulcanizer has been well designed with the specification listed under results. This specification made it producible and reproducible anywhere in the world and still follow the same performance. While two types of different manufacturer, (Michelin and Goodyear) are used.

a. car and buses tyres: the thickness were between 5.8-6.5mm based on the wear level of each tyre. Their average patching time is 5.6minutes which is 1.4mins less than the maximum time of 7minutes at 30-80^{o}c.
b. truck and tractor tyre: their thickness varies between 147.5-200mm due to their wear level. Their average patching time is

6.1minutes which is 0.9 less than maximum time of 7minutes.

The performance on the vulcanizing tubes of 1mm and that of patching temperature of the tube is between 30-70^{o}C with time spent of 4minutes from the average of set of sizes used, compared with maximum time of 7minutes. It saves 3minutes.

IV. CONCLUSION

4.1 Conclusion

The aim of this research has been achieved by it the development of the patching equipment and its performance was evaluated. It has been designed, fabricated and tested to know its level of performance.

Details of its good performance, made the equipment fit for commercialization as it met the required engineering and economic values.

V. ACKNOWLEDGMENT

The authors appreciate the Technologists, Technicians and other staff of Industrial/Production Engineering department, Federal University Technology Akure, Nigeria; who had in one way or the other contributed to this research.

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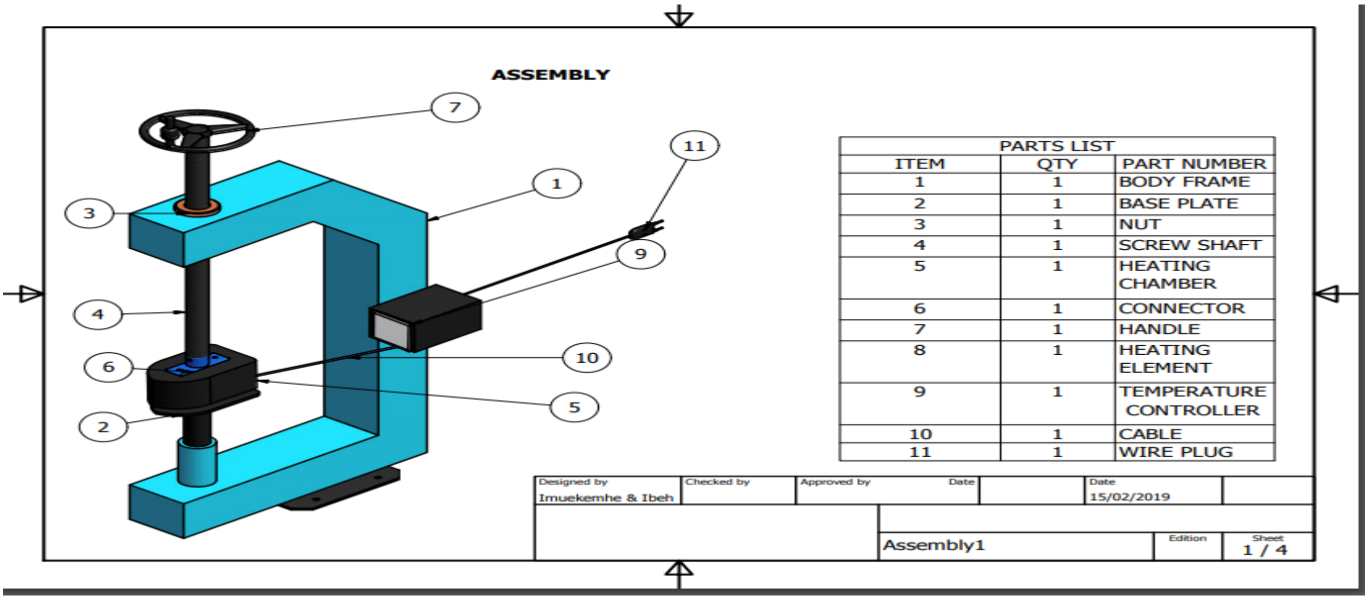
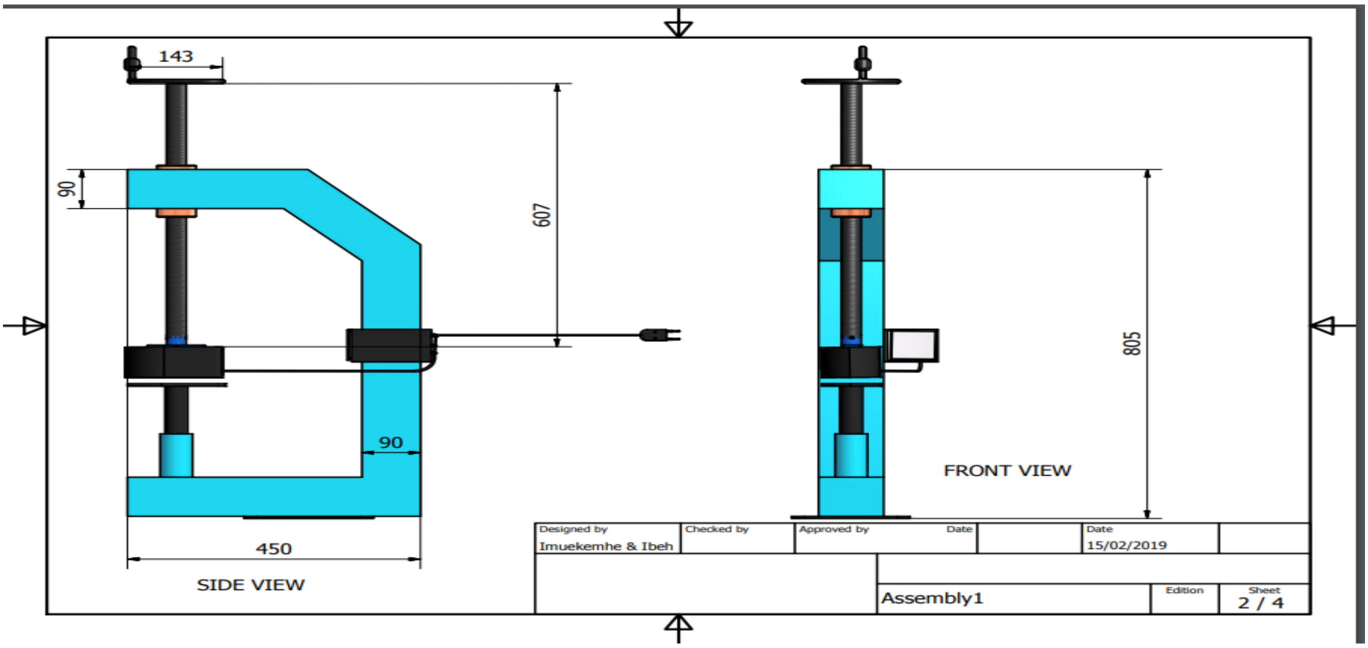
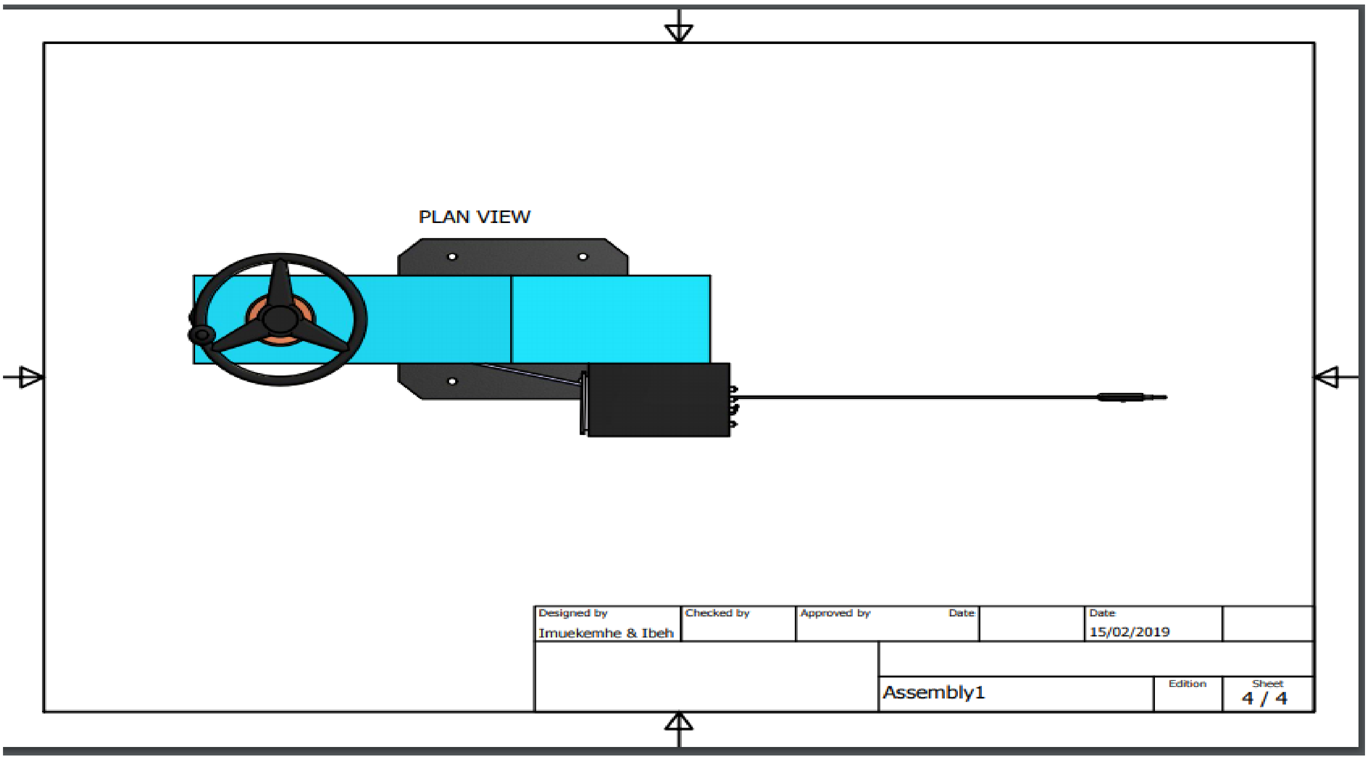
Appendices I: Isometric drawing of the vulcanizer machine



Appendices II: side and front view of the vulcanizer machine



Appendices III: plan(top) view of the vulcanizing machine



Appendices iv: othogragphy drawing of the vulganizing machines