DEVELOPMENT OF A PEDAL POWERED WASHING MACHINE

BY

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MEE/11/0417

A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING, FACULTY OF ENGINEERING, FEDERAL UNIVERSITY OF OYE-EKITI EKITI STATE, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.Eng.) MECHANICAL ENGINEERING

SEPTEMBER 2016

DECLARATION

I SALIU, ADETAYO EMMANUEL with matriculation number MEE/11/0417 hereby declare that this research project titled "DEVELOPMENT OF A PEDAL POWERED WASHING MACHINE" is a product of my research and is original. Other authors whose works were used in the project have been duly acknowledged.

MEE/11/0417

SALIU, ADETAYO EMMANUEL ______________________________

MATRIC NO. AND NAME **SIGNATURE AND DATE**

CERTIFICATION

I certify that this project work was carried out by SALIU, ADETAYO EMMANUEL with matriculation number MEE/11/0417 a student of Mechanical Engineering, Faculty of Engineering, Federal University of Oye-Ekiti, Ekiti State under my supervision.

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APPROVAL

This project has fulfilled the partial requirement for the award of degree of bachelor of Engineering in the department of Mechanical Engineering of Federal University of Oye-Ekiti, Ekiti State and is hereby approved.

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DEDICATION

This project is dedicated to God Almighty for His mercy, grace and guidance over me. It is also dedicated to my late mother. I pray her soul would continue to rest in perfect peace.

ACKNOWLEDGEMENT

With Sincerity, I acknowledge God Almighty for seeing me through my period of study in FUOYE. It has been by his grace and mercy.

I am deeply grateful to Engr. F.O Ajayi, my supervisor for his assistance and fatherly advice towards the success of this project.

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To all my well-wishers and course mates, especially Mr. Damisa Rasaq, Mr. Ogbebor Alex and Mr. Adejumo Idris. You people have been wonderful.

ABSTRACT

The PEDAL POWERED WASHING MACHINE is a project, which is undertaken to solve the problem of electric supply to people in rural areas. To run a washing machine, the source of power is electricity. In Nigeria most of the villages are suffering from shortage of electricity. So to overcome above problem we select the washing machine, which is operated manually. It requires no electric power supply or diesel supply. This project is low weight & portable can be easily transported. We use simple cycling mechanism to run the washing machine shaft.

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CHAPTER ONE

1.0 INTRODUCTION

In the developing world, washing laundry is a difficult, time-consuming task that falls solely on women. Mothers and daughters typical spend 8 hours each week scribing each piece of their family's clothing and wringing out the harsh washing solution by hand. Powered washing machine exists, but they are impractical in rural areas reasons because running water and electricity are expensive or unavailable. Several groups already tried to build a machine for the regions but they have been unsuccessful. Their machines were either to build and repair because they improved parts or they do not wash effectively. The project is a low cost, pedal power washing machine that designed around readily available parts. Its innovation is its simple design and its use inexpensive parts and bicycle components. The parts are available locally, so we can be manufactured and repaired in the community without depending on imported goods.

A **washing machine, clothes washer**, or simply **washer**, is a machine designed to wash laundry, such as clothing, towels and sheets. The term is mostly applied only to machines that use water as the cleaning solution, as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or even ultrasonic cleaners.

Pedal Powered Washing Machine is a low cost washing machine made up of easily and readily available scrap parts in daily life. It is a machine which generates power through human pedaling and with the drive mechanism, converts the pedaling motion into required rotary motion of the drum. Its innovation lies in its simple design, use of inexpensive parts, very low repairing and maintenance cost, affordability to each member of the society and it does not affect the environment.

Pedal Powered Washing Machine is a completely new concept, which in its one laundry cycle does washing, rinsing and drying of clothes similar to that of an electric washing machine available in the market.

The **PEDAL POWERED WASHING MACHINE** is innovative and it requires skill to manufacture. Its subcomponent price is also less.

1.1.0 JUSTIFICATION OF STUDY

- **Efficient:** It is much more efficient to wash clothes using the Pedal washing machine than hand washing. The Pedal washing machine washes and dries many clothes concurrently whereas when washing with hand, each item must be washed individually in the wash tank or bucket. The Pedal washing machine also requires less energy when compared to washing by hand. The horizontal axis of rotation in the Pedal washing machine uses less power because it rotates continuously without changing directions. The operator does not need to combat the momentum and drag forces of a barrel full of water.

- **Comfortability:** The Pedal washing machine is also more comfortable to than hand washing. The operator does not need to lean over the washing tank or buckets and submerge his or her hands in the soapy water. Instead, the operator sits and pedals most of the time. The operator only needs getup to load the machine, change the water and unload the machine. This leaves him or her hands free to work on making crafts and keeps them out of the harmful detergent.

- **Affordable:** With a pedal powered washing machine, an individual family will not need spend a large sum of money for a home washing machine.

  Those who would not normally be able to afford such a device would be able to use one for a small fee. A Pedal washing machine is also inexpensive to operate because the user does not need to pay for power. This is especially important in rural areas, where electricity is extremely expensive and not constant.

- **Easy to Build and Maintain**: Unlike any of the other alternatives, the Pedal washing machine uses locally available materials or recycled bicycle parts. It can be produced in any area that has prevalent bicycle technology. Since the parts are widely available, the Pedal washing machine can serve as a basis for local entrepreneurs to start micro-enterprises which would stimulate the local economy.

  Another advantage of using locally available parts is that the Pedal washing machine is easy to repair. It is mechanically simple enough that any bicycle repair shop would be able to service the pedal-drive.

1.2.0 STATEMENT OF PROBLEM

- One of the main challenges faced with washing in rural area is constant electricity and water supply.

- Another problem is the cost of this electric washing machines, even an average person in urban area might not be able to afford it.
- Cost of maintenance of electric washing machines is also high.

1.3.0 OBJECTIVES OF THE STUDY

The objective of this project is to design and construct a pedal powered washing machine with readily available parts to solve the problem of electricity and washing stress in rural areas.

To design must meet the following requirements;

- Cleaning: machine-washed clothes must be as clean as those hand-washed for 5 minutes.
- Gentleness: must wear clothes at slower rate than hand-washing (hole/tear growth).
- Capacity: minimum 3kg of clothes/load –should be easy to re-size.
- Water: effective washing must occur in soft and hard water at temperatures from 70-120F.
- Water usage: maximum 20L water/1kg clothes.
- Active pedaling time for effective washing: maximum 20 minutes each for wash and rinse cycles.
- Total operating time: maximum 3 hours, including fetching water, filling, washing, draining, and cleaning.
- Power: maximum 100W (comfortable level of human-power output).
- Lifetime of structure: 5 years, assuming daily use.
- Cost: maximum $150
- Materials: local (wood, weldable metals, oil drum, bicycle parts, etc.).
- Dimensions: less than combined size of a bicycle and commercial washing machine.

1.4.0 LIMITATION OF STUDY

Putting low cost in mind, one cannot work with expensive materials but with only scraps or readily available parts which may fail over time.

One of the main challenges faced in introducing the pedal-powered washing machine is cost. The machine must be inexpensive and easy to build if it will be adopted into the target community. So the machine must be designed from the start with low cost in mind. The machine will only contain parts that are readily available in Nigeria. This eliminates the need to order or import components just for the washing machine.

Another challenge that may be faced is acceptance into the community. The pedal-powered washing machine is quite different from the community's current method of washing clothes; the community may be reluctant to try the new machine.

CHAPTER TWO

2.0 LITERATURE REVIEW.

2.1.0 THE EVOLUTION OF WASHING TECHNOLOGY

- **STICKS AND STONES**

Ancient peoples cleaned their clothes by pounding them on rocks or rubbing them with abrasive sands; and washing the dirt away in local streams. Evidence of ancient washing soap was found at Sapo Hill in Rome, where the ashes containing the fat of sacrificial animals was used as a soap.

- **SCRUB BOARD**

The first example of man-made technology being used to assist in the washing of clothes is seen in the creation of the scrub board in 1797, although over a century earlier a patent application covering a washing and wringing machine had been filed, but never built.

- **THE ROTARY DRUM**

The concept of using a rotating drum to clean dirty laundry was patented by an English inventor in 1782.

James King, an America, patented the first washing machine to use a drum in 1851. The drum made King's machine resemble a modern machine, albeit it was still hand powered.

Later, in 1858, Hamilton Smith patented the rotary washing machine.

- DOMESTIC WASHING MACHINE

William Blackstone of Indiana built a birthday present for his wife in 1874. It was a washing machine intended for domestic use which removed and washed away dirt from clothes. The Blackstone washing machine is often cited as the first washer designed for home use.

The first drum washing machine was invented in 1851 by James King. It had a drum design, and was hand powered.

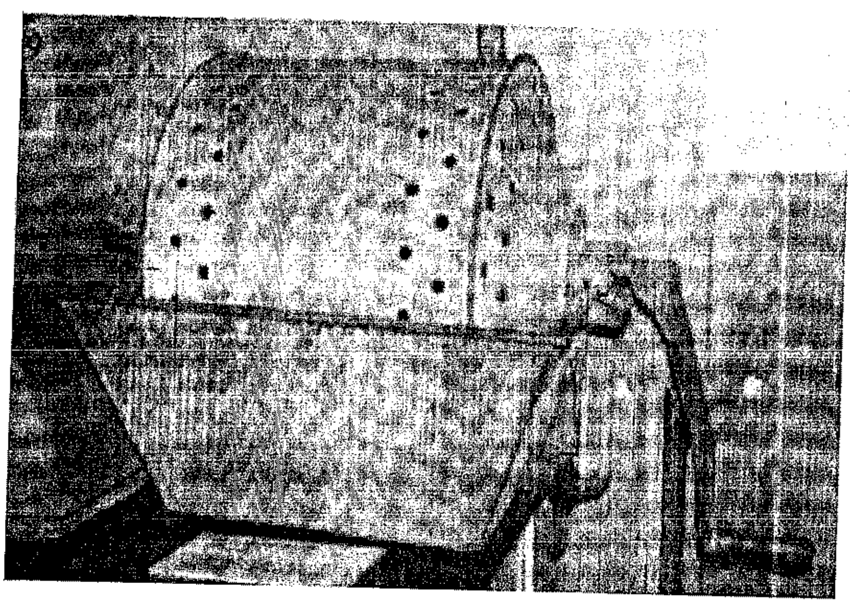

FIG 2.1: The first drum washing machine invented in 1851.

- THE ROTARY SQUEEZE SCRUBBER

The rotary squeeze scrubber represented the next step in the evolution of washing, mechanically removing water from the textiles. It also introduced a mechanism that resulted in crushed fingers and limbs as they were caught up in the rollers in the process of squeezing out the water in the fabric. This is the first converged washing machine, combining a washing device and a wringing device.

- FROM MANUAL TO ELECTRIC

The arrival of electric power meant that hand-operated washing devices could be augmented with motors. There is some debate as to who can lay claim to being the official inventor of the electric washing machine, but it is widely believed to be attributable to Louis Goldenberg.

However, a washing machine called the Thor, which was invented by Alva J. Fisher and manufactured by the Hurley Machine Company in 1908, is often cited as the first drum-based electric washing machine. The Thor was a drum type washing machine with a galvanized tub and an electric motor. A patent for this machine was issued on August 9th 1910.

- THE AGITATOR

Electric powered washing devices underwent several design changes in order to obtain the mechanical action similar to the "scrub board" motion required to break the bond between the soil and the textiles. Various paddle type and corrugated rotors were manufactured in the early 1900's in an attempt to increase the wash effectiveness without damaging the linens. Today's paddle type agitator in top loaders and corrugated drum style in front loaders are very similar to the designs of the 1920's.

- THE MOVE TO MANUFACTURING, MAYTAG AND WHIRLPOOL

By the 1920s, large numbers of washing machines were being manufactured in the developed world, but economic pressures meant that this luxury item did not continue to see the same level of adoption during the 1930s. Early machines were also fitted manually and temporarily to water supplies, often via a rubber hose attached to a standard kitchen tap, with plumbed-in machines only becoming commonplace at a later stage.

The Maytag Corporation began in 1893 when F.L. Maytag began manufacturing farm implements in Newton, Iowa. Business was slow in winter, so to add to his line of products he introduced a wooden-tub washing machine in 1907. Maytag soon devoted himself full-time to the washing machine business.

The Whirlpool Corporation started in 1911 as the Upton Machine Co., founded in St. Joseph, Michigan, to produce electric motor-driven wringer washers.

2.2.0 PRIOR ART

There are existing solutions to the clothes washing problem, but no existing technology is both practical and affordable for people in our target community. Existing solutions are either designed for industrialized nations with running water and electricity, or they are not practical for rural setting where replacement parts are difficult to find.

Commercial washing machines have existed for many years, but they are expensive and require electricity to operate. Sometimes, they are available in urban settings, but the average family cannot afford to purchase one. In rural areas, commercial washing machines are not an option because electricity may be unavailable or extremely expensive.

A number of groups have modified commercial washing machines to power them with human power. They attached a pedal-drive mechanism to the washing machine drum and attached a suspension system. This technique is not feasible in rural areas of developing nations because washing machines and their old components are usually difficult to find.

Commercial hand-cranked washing machines do exist, but they are not intended for continuous use; they are designed for traveling or camping trips. The "**Wonderwash**" produced by ***The* Laundry Alternative, Inc.** only washes 5lb of clothes and is not designed to hold up to the rigors of constant use. Priced at about US $50 in the US, it is likely to arrive in rural areas at a much higher price, and its use will be limited by the lack of replacement parts.

In the past, Maya Pedal attempted to make a pedal-powered washing machine from locally available materials, but it was unsuccessful. They built a prototype with a vertical axis agitator, but it did not wash clothes well, it did not have spin dry capability and it consumed a great deal of water. Although Maya Pedal recognizes the demand for pedal-powered washing machine, it does not have the resources or time to design, prototyping and refine a new device.

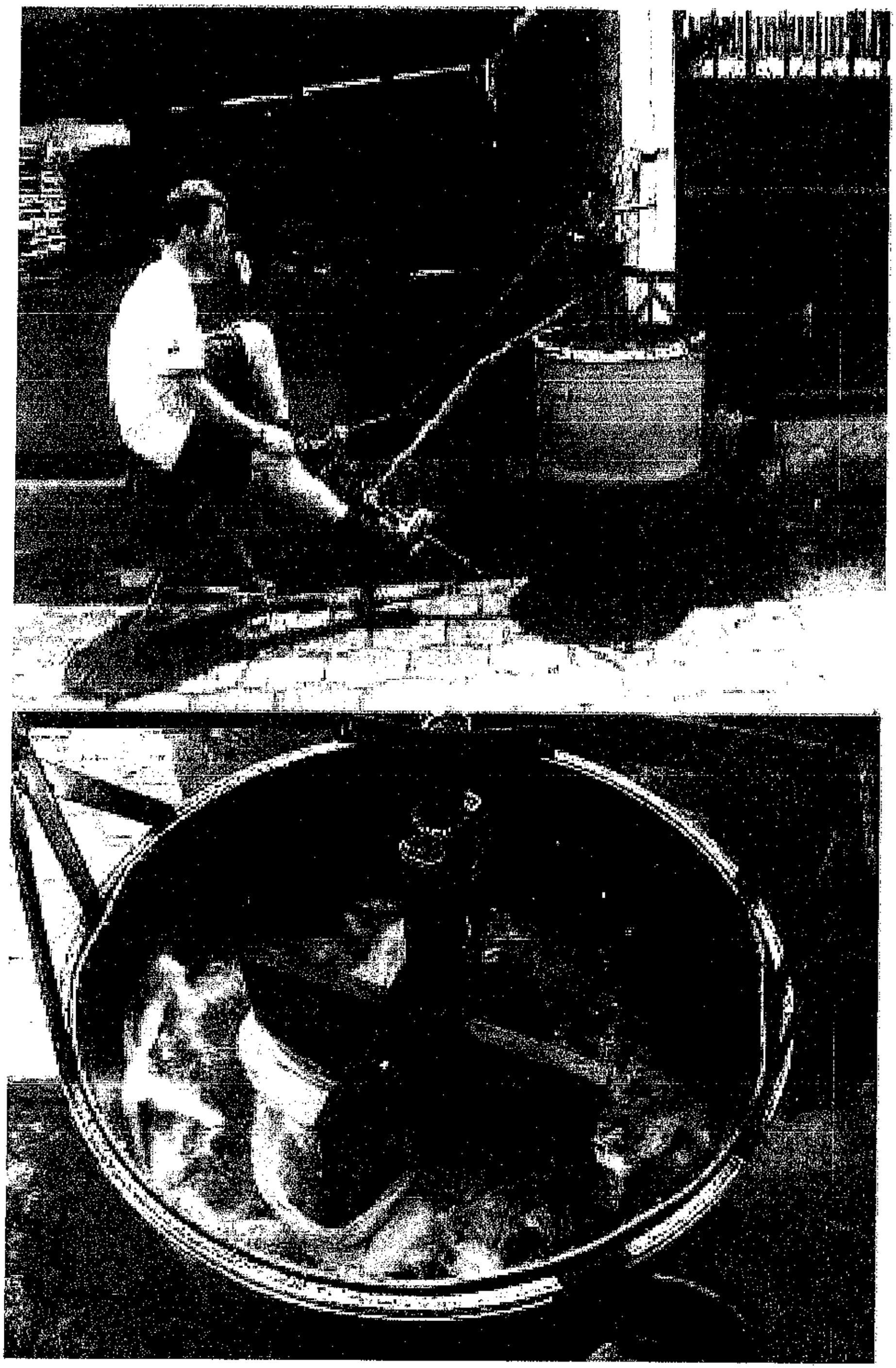

FIG 2.2: MayaPedal's prototype washing machine shows that demand exists, but it is difficult to use and it damages clothing.

CHAPTER THREE

3.0 DESIGN PROCEDURES AND CONSTRUCTION DETAILS

3.1.0 GENERAL DESIGN SPECIFICATIONS

The most important aspect in the design of the machine is its ability to perform as a device that eases the task of washing clothes. In order to be a viable solution in rural areas, the machine should be able to deliver the same quality of washing without adding excessive overheads (in terms of water use, clothing wear, effort required to operate, etc.). Thus the design and operation of the machine was firmly grounded in the physics of clothes washing, with a special emphasis on the mechanical aspects (since water temperature and detergent composition are likely to vary). Also a number of secondary goals were identified with varying degrees of importance that could help make the machine more useful and thus more successful. The ability to spin-dry clothes would increase water economy by requiring fewer wash cycles, and could relieve the strenuous task of manually wringing the clothes before they are hung to dry. The layout of the machine allows users to perform manual work (handcraft, food preparation, etc.) while pedaling, thus, further reducing the amount of time consumed by washing. The machine was also made portable, which would allow it to be shared among families, transported close to a water source for operation, or used in households where space is limited. Safety of the machine which is an important part in Engineering was also put into consideration.

3.2 THE DESIGN CONSIDERATIONS

3.2.1 INITIAL IDEAS

I evaluated a number of mechanisms that could serve as the basis for the washing machine. Initial concepts were developed starting from the mechanical requirements of laundry washing.

- VERTICAL AXIS AGITATOR: The usual washing machine found in American homes consists of two vertical-axis concentric tubs. The inner tube, which holds the clothes, has densely-spaced perforations which allow the water to run in and out easily. Soap and water are kept inside the outer tub during the cycle. A central agitator alternating directions induces friction between the clothes to mechanically remove dirt and stains. For the spin cycle, water is emptied from the outer drum and the inner drum is spun to centrifugally extract water from the clothes. I didn't go with this design because it was expensive and considering the target community, the washing machine must not be too expensive.

- VERTICAL-AXIS TUMBLER: Commonly used in European homes, this washer also uses two concentric tubs however their revolution axis is horizontal. Instead of using an agitator, the horizontal washer utilizes fins along the inner barrel that lift the clothes on the side of the drum, and let them fall back in the water on top of other clothes. Cycling the clothes through the water in this fashion eliminates the need for rapid changes in the direction of rotation of the agitator, which results in lower energy requirements. Since the drum is only filled up to one third with water, the machine realizes a sizeable water economy.

- CRANK-SHAFT PISTON: Using rotational motion to agitate the clothes, we used crack-shaft to convert the rotation of the pedals to horizontal translation of a piston. There are several possibilities for the shaft design. The clothes can be held in a container with holes that is plunged into and out of the water. The shafts can also be a solid block pushing the clothes underneath it through the water. Two plates with holes could hold clothes between them as they plunge in and out of the water. I did not select this design because it seemed inefficient to convert the rotation of the pedals into vertical motion since commercial washers operate on rotational motion already.

- TILTED-AXIS TUMBLER: A tub spinning at an inclined axis using a helical fin would perform the same kind of action, in a fashion similar to a cement mixer. The tilted design would allow for easier addition of water and clothes. No known commercial washers use this mechanism. Manufacturing of the helical fin proved to be problematic, and the other construction benefits I was hoping for in the tilted axis design did not end up materializing themselves.

- USING A SCRAP ELECTRIC WASHING MACHINE: I also considered connecting the bicycle to a scrap washing machine with aid of a belt. The belt will run from the back rim of the bicycle (large pulley; driving) to the pulley of the washing machine (small pulley; driven). This design was the easiest but unavailability of scrap washing machine at my residential location led to the design not materializing.

3.2.2 FINAL DESIGN CHOICE

The final design resembles a commercially available horizontal axis washer. A bicycle pedal was welded to a shaft connected to an inner drum that is densely-perforated. The inner drum is in a cuboidal housing (washing chamber). So once the operator peddles the perforated inner drum rotates and washes the clothes while the cuboidal box houses the water and detergent for the washing cycle. The washing chamber has a cover that can be opened and closed when clothes are to be loaded and removed from the machine. The box also has two openings; one permits water inlet while the other is used for removing the water.

The inner drum is perforated, so that spinning the drum will extract water from the garments. Rotational force produced by the pedal turns the inner drum with the aid of a shaft.

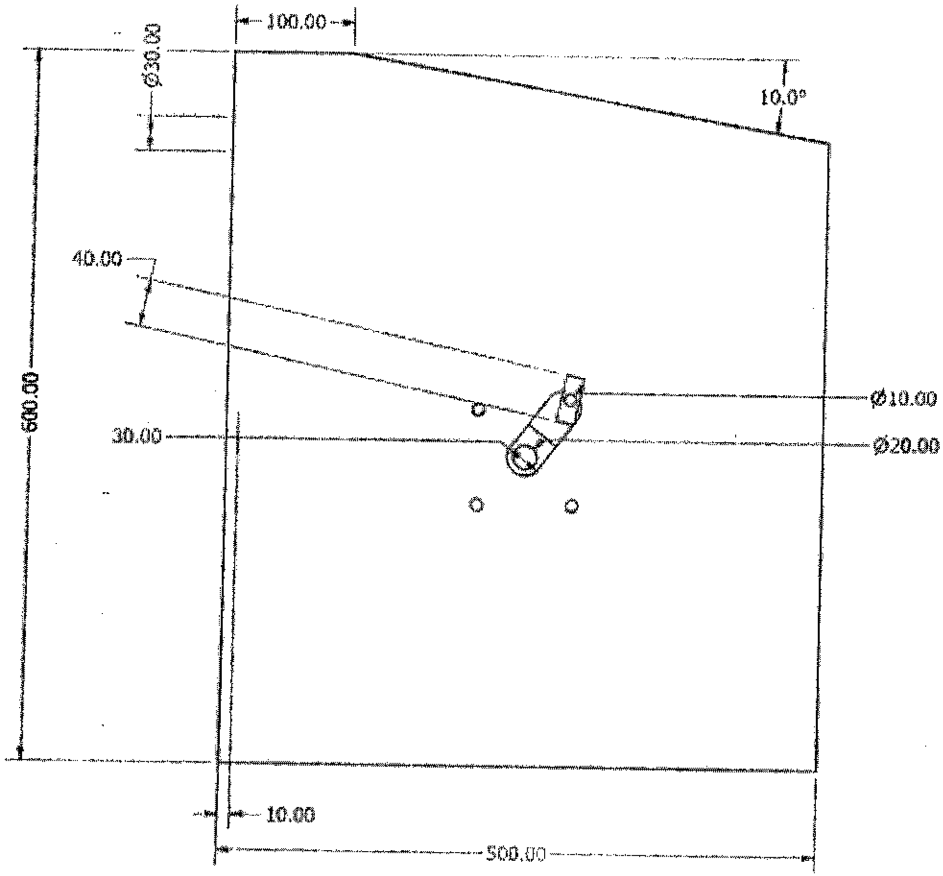

FIG 3.1: side view of the project.

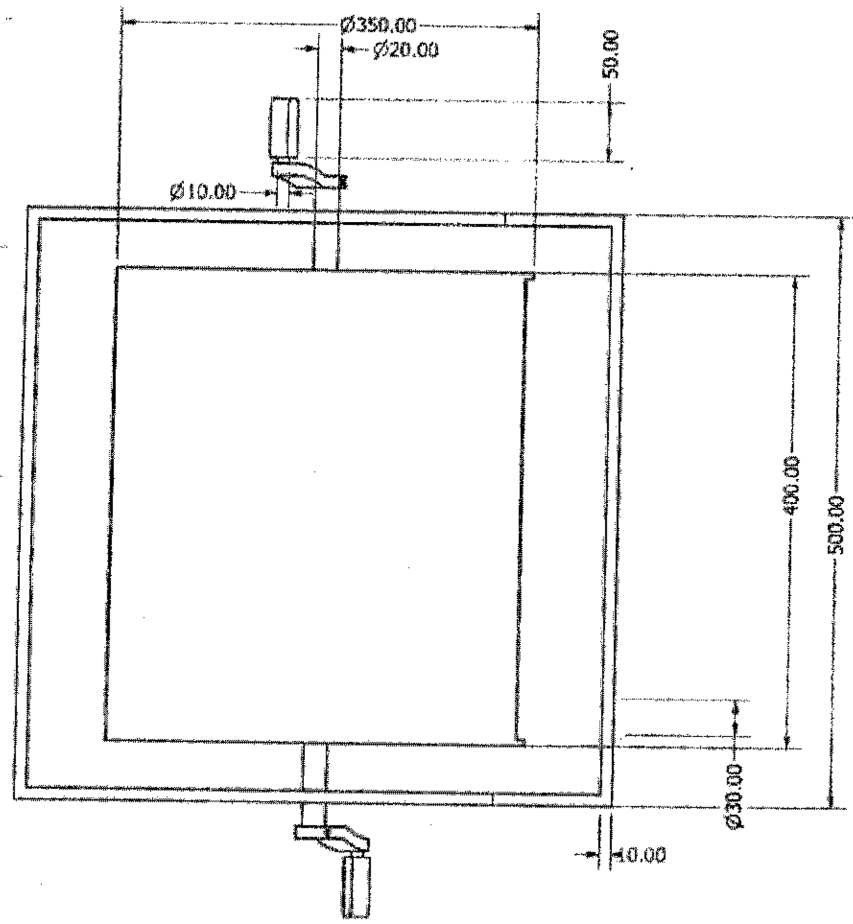

FIG 3.2: Area view of the project.

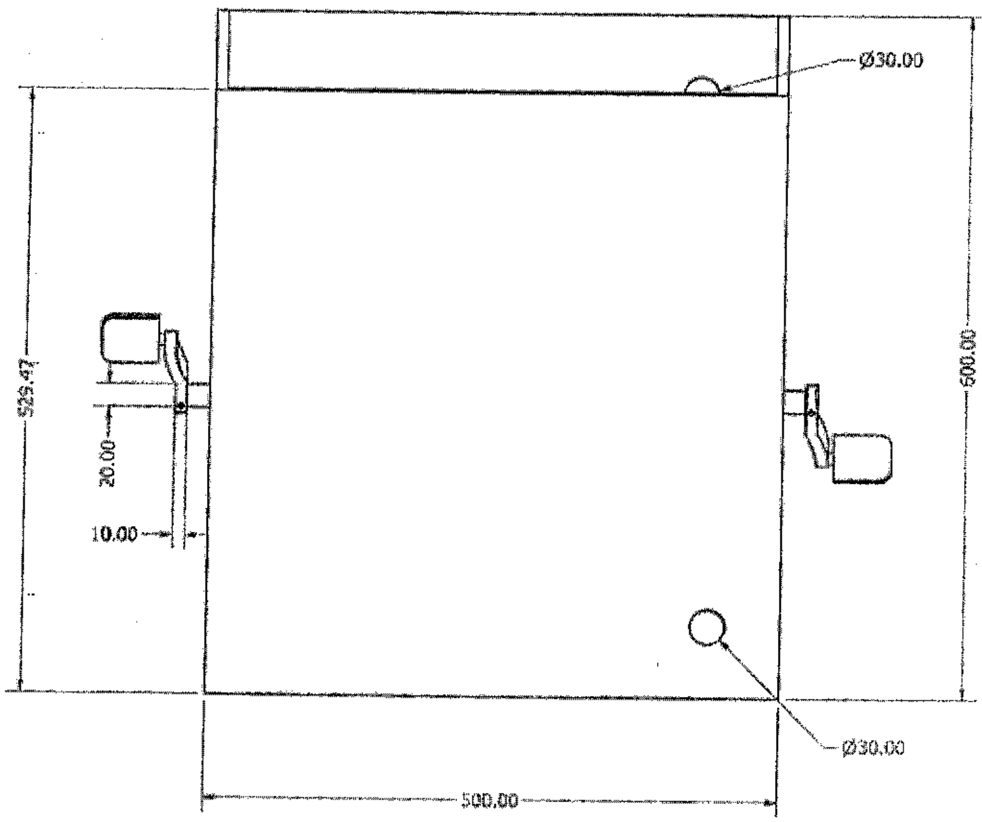

FIG 3.3: Front view of the project

The major parts of the project set-up includes;

INNER DRUM

This is where the clothes would be housed while washing. It is perforated to allow the clothes to mix with detergent and water.

WASHING CHAMBER

It cuboidal in shape, this is where the water and detergent are housed while washing.it also holds or support the inner drum. Also attached to it are the pedals on both sides and the cover at the top.

BASE SUPPORT

It supports the washing chamber. The chamber rests its whole weight on the support.

BICYCLE PEDAL

Used to rotate the shaft which in turn rotates the inner drum, hence, clothes are washed.

COVER OF WASHING CHMABER

Used to cover the box while washing to prevent dirt's from entering the clothes been washed.

SHAFT

Shaft is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them. Drive shafts are carriers of torque: they are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia. To allow for variations in the alignment and distance between the driving and the driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splined or prismatic joint.

BEARINGS

A bearing is a machine element that constraints relative motion between moving parts to only the desired motion. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of the normal forces that bear on the moving parts. Bearings are classified broadly according to the type of operation, the motors allowed, or so the directions of the loads (forces) applied to the parts.

The term "bearing" is derived from the verb "to bear". A bearing being a machine element that allows one part to bear (i.e....to support) another. The simplest bearings are bearing surfaces, cut or formed into a part with varying degrees of control over the form size, roughness and location of the surface. Other bearings are separate devices installed into a machine or machine part. The most sophisticated bearings for the most demanding applications are very precise devices: their manufacture requires some of the highest standards of current technology.

3.3.0 MANUFACTURING PROCESSES USED IN THE PROJECT

WELDING

It is the process of joining two similar or dissimilar metals by fusion with or without the aid of a filler material. Welding was used to join the shafts to both sides of the inner drum. It was also used to join the enclosed parts of the inner drum. It was also used to join the box together.

CUTTING

Cutting is the process of reducing a material to a desired length or contour. A saw is used for this process. During the course of fabrication of the project, the shaft was cut into appropriate sizes and dimensions.

MACHINING

Machining processes includes: milling, drilling, chamfering, boring, grooving etc., for this project, the machining process used was drilling. Holes were drilled at appropriate dimensions to allow fasteners to pass through and also to allow the shaft easy passage from outside the box to inside the box.

3.4.0 ASSUMPTIONS AND CALCULATIONS

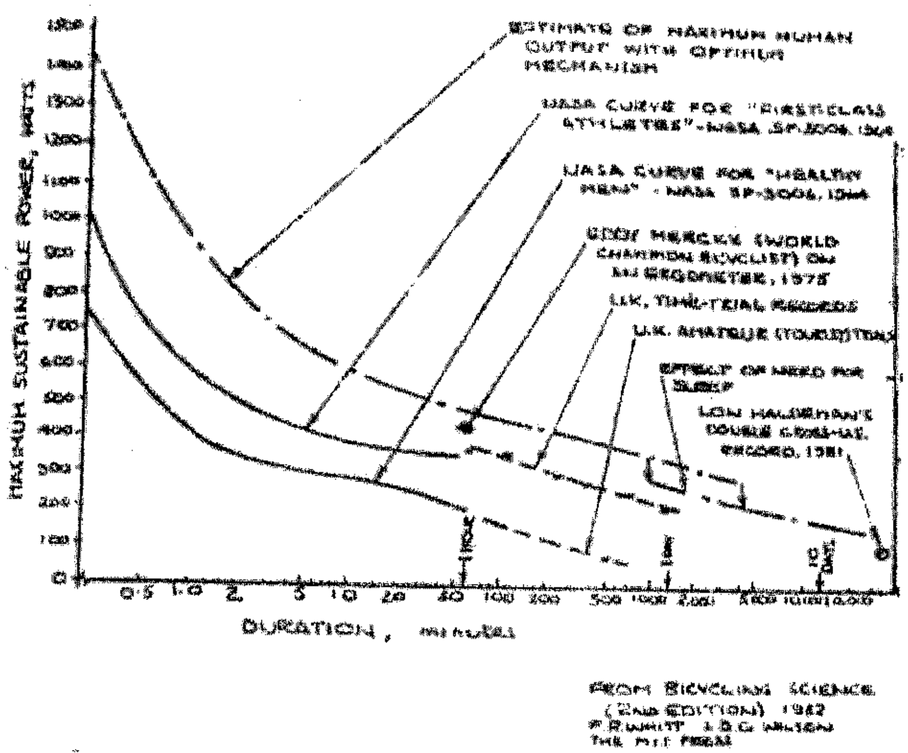

FIG 3.4: Human Power Output Pedaling.

*Source: INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 3, ISSUE 11, NOVEMBER 2014.ISSN 2277-8616

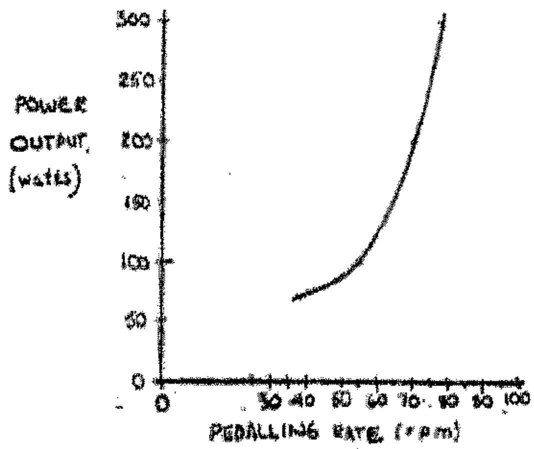

FIG 3.5: How Optimum Pedaling Rate Varies With Desired Power Output.

*Source: INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH VOLUME 3, ISSUE 11, NOVEMBER 2014. ISSN 2277-8616

According to the figures above, "healthy men" can produce a power of over 200 Watts for over an hour. This, of course, means extremely hard exercise and may not be convenient for example when commuting in a human powered machine. However, the figure gives the extreme values to give an idea about the order of magnitude of maximum human power available.

Athletes can produce higher power levels. The peak values are over 1200 W, but the level goes rapidly down along with time. For them, power over 300 W is possible for several hours.

The Belgian bicycle racer Eddy Merckx (born 1945), called the greatest and most successful cyclist of all time, is stated having been able to sustain the power of 440 W for an hour (http://www.gutwin.org/mt/snow/archives/2005/04/from_earth_to_e_1.html).

Mr. Joe Bosworth has measured the power output levels needed by a bicycle racer. The results are presented on the Internet at (http://forums.autosport.com/lofiversion/index.php/t91874.html).

His results are as follows:

Table 3.1: Power levels needed to ride a bicycle at different speeds.

km/h	W
48	450
40	313
30	176
20	78

Highest power output he has been able to reach (450 W) is very close to the value stated for Eddy Merckx for one hour (440 W). Of course it has to be kept in mind that these are values achieved with a racing bicycle that has as low road load (driving resistance) as possible. An ordinary bike would probably need slightly higher power levels to maintain the speeds mentioned above.

However, we learn here that a power output of over 400 Watts is possible to reach also for other cyclists besides Eddy Merckx. A cyclist who can reach this power level is in a very good physical condition, and if he not a trained athlete, he is probably capable of producing this amount of power only for a very short while.

Considering all this,

- I assumed that 150W of power was generated over an hour.
- Power output = 150W
- From table 3.1, we find the speed generated at 150W by interpolating between 176W and 78W.

$$\frac{176-150}{176-78}=\frac{30-x}{30-2}$$

x = 27.4 km/h.

- The speed at 150W is 27.4 km/h.

SUMMARY OF DATA FOR SELECTED BEARING

Bearing number P203, single roll, deep groove ball bearing.

Bore number (Internal diameter) d= 0.3mm.

(Outside diameter) D= 62mm.

Width B = 17mm.

Maximum fillet radius = 0.039 inch

Basic dynamic rating C = 13496.3N

3.4.0 MATERIAL SELECTION

Before any machine or system is designed and constructed, it must be ensured that the best materials are chosen for it. Factors considered for the selection of the materials include;

1. The environmental conditions in which the material will function.
2. Physical and mechanical properties.

PHYSICAL PROPERTIES

It comprises the density, coefficient of thermal expansion, thermal conductivity.

MECHANICAL PROPERTIES

This includes tensile strength, shear strength, density, and roughness, fatigue and creep resistance.

3. Cost constraint.
4. Durability of material.
5. Manufacturing requirements, which includes ease of joining by welding, ease of forming and ease of machining.
6. Availability of the materials.

The following materials were recommended.

Table 3.3: Showing Machine Parts and Material Selection.

MACHINE PARTS	MATERIAL SELECTION	REASONS
Bolts and nuts	Mild steel	• Can withstand shear and bending forces.
Shaft	Mild steel	• Can withstand shear and bending forces. • High strength and rigidity. • Easily machined.
Cuboidal housing	Sheet metal	• Can withstand shear and bending forces. • High strength and rigidity.
Inner drum	Mild steel	• Can withstand shear and bending forces. • High strength and rigidity.
Cover of washing chamber	Mild steel	• Easily to build.
Bearing (P203)	CI	• Offers reliable support to the shaft.
Washing chamber support	Sheet metal	• High strength and rigidity

CHAPTER FOUR

4.0 RESULT AND DISCUSSION

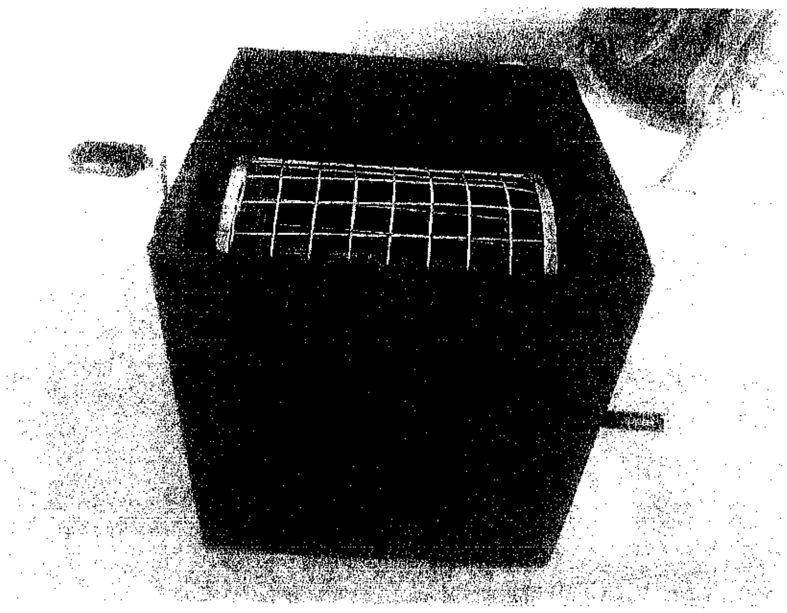

FIG 4.1: The project

4.1.0 PERFORMANCE TEST AND RESULT

There are several methods of testing for the efficiency of machines but with respect to this pedal powered washing machine, three sets of about 2kg clothes were washed.

A – 2kg of light clothes (i.e. clothes that can tear easily).

B – 2kg of thick clothes (i.e. clothes that are difficult to scrub).

C – 2kg of normal clothes (i.e. clothes that are neither too thick nor too light).

The efficiency of the constructed machines were examined as follows:

(i) Clothes A, B, and C were washed using hands.

(ii) Clothes A, B, and C were washed using hand-powered rotary drum.

(iii) Clothes A, B, and C were washed using the constructed pedal powered washing machine.

For process i, ii, iii, the following were recorded;

- How clean it washes clothes.
- How comfortable it is.
- Wear/ tear rate.

4.2.0 RESULTS

The following results were obtained;

For process (i) – hand washing

Table 4.1: showing the recorded results for hand washed clothes.

Clothes	How clean it washes (0-5)	How comfortable it is. (0-5)	Tear rate (0-5)
Clothes A	3	3	4
Clothes B	3	2	3
Clothes C	1	1	1

For process (ii) – washing with a rotary drum

Table 4.2: showing the recorded results for clothes washed by a rotary drum.

Clothes	How clean it washes (0-5)	How comfortable it is. (0-5)	Tear rate (0-5)
Clothes A	4	3	1
Clothes B	3	3	1
Clothes C	2	1	1

For process (iii)- washing with the pedal powered washing machine.

Table 4.3: showing the recorded results for clothes washed by the pedal powered washing machine.

Clothes	How clean it washes (0-5)	How comfortable it is. (0-5)	Tear rate (0-5)
Clothes A	5	4	1
Clothes B	4	3	1
Clothes C	3	2	1

Where,

1 – Very low.

2 – Low.

3 – Average.

4 – High.

4 – Very High.

4.3.0 DISCUSSIONS

Process i

From the table 4.1 we can see that for

Clothes A

- Wear rate: hand washing wears/ tears these type clothes at high rate has the operator has to still needs to scrub hard to remove stains.
- Comfortability: it is slightly comfortable as the person washing does not bend for too long before the clothes get cleaned.
- How clean it washes: hand washing washes these type of clothes to the satisfactorily.

Clothes B

- Wear rate: hand washing wears/ tears clothes at a normal rate because they are quite thicker than clothes A.
- Comfortability: not so comfortable as the person washing needs to bend down for a long period of time.
- How clean it washes: hand washing washes the clothes slightly well.

Clothes C

- Wear rate: the rate of wear or tear is slow because the clothes are thick and the forces applied by both hands wouldn't be enough to wear or tear the clothes easily. Washing gradually reduces the materials quality though.
- Comfortability: it's not comfortable at all, because the person washing has to bend his or her back for a long period of time, which is quite exhausting.
- How clean it washes: this clothes are not really washed well by hands

PROCESS ii

From table 4.2,

Clothes A

- Wear rate: the hand operated rotating drum's tear rate on light clothes is very less than that of hand washing since there is no need to scrub clothes.
- Comfortability: it is slightly comfortable as the operator just has to stand and rotate the drum continuously for a short while until the clothes are neat.
- How clean it washes: it washes light clothes almost like hand washed clothes.

Clothes B

- Wear rate: the hand operated rotating drum's tear rate on light clothes is very less than that of hand washing as there is no need for scrubbing clothes.
- Comfortability: it is slightly comfortable as the operator just has to stand and rotate the drum continuously for a short while until the clothes are neat.

- How clean it washes: it washes this type of clothes better than washing with hands.

Clothes C

- Wear rate: the hand operated rotating drum's tear rate on light clothes is very less than that of hand washing has there is no need for scrubbing clothes.
- Comfortability: it is not very comfortable as the operator has to stand and rotate the drum continuously until the clothes are neat. Which might take a while.
- How clean it washes: it washes this type of clothes better than washing with hands.

PROCESS iii

From table 4.3,

For clothes A

- Wear rate: the pedal operated washing machine's tear rate on this type clothes is very less than that of hand washing as there is no need to scrub the clothes.
- Comfortability: it quite comfortable as the operator sits and continually pedals until the clothes are neat. Which takes no time at all.
- How clean it washes: it washes this type of clothes better than hand washed clothes and clothes washed with the rotating drum.

Clothes B

- Wear rate: the pedal operated washing machine's tear rate on this type clothes is very less than that of hand washing as there is no need to scrub the clothes.
- Comfortability: it quite comfortable as the operator sits and continually pedals until the clothes are neat. Which takes relatively less time when compared to the two processes above.
- How clean it washes: it washes this type of clothes better than hand washed clothes and clothes washed with the rotating drum.

Clothes C

- Wear rate: : the pedal operated washing machine's tear rate on this type clothes is very less than that of hand washing as there is no need to scrub the clothes.
- Comfortability: it slightly comfortable as the operator sits and continually pedals until the clothes are neat. Which takes relatively less time when compared to the two processes above.
- How clean it washes: it washes this type of clothes better than hand washed clothes and clothes washed with the rotating drum.

The pedal powered washing machine and the hand operated rotary drum are better than hand washed clothes. The reason why the pedal washing machine is more efficient than the rotary drum is because a person can generate four times more power (1/4 horsepower (hp)) by pedaling than by hand cranking. At the rate of 1/4 hp, continuous pedaling can be done for only short time, of about 10 minutes. However pedaling motion at half of this power (1/8 hp)can be sustained for around 60 minutes Maximum power produced with legs is generally limited by adaptations within the oxygen transportation system. On the contrary the capacity for arm exercise is dependent upon the amounts of muscle mass engaged and that is why a person can generate more power by pedaling than hand cranking (Tiwari P.S., 2011).

Pedal power enables a person to drive device at same rate as achieved by hand cranking but with less efforts and fatigue. There are many people who live day to day life without reliable power to complete daily work. Often these people are living in situations where manual labor allows to sustain themselves, but some of the mechanical devices can offer one way to ease the manual labor.

4.4.0 GENERAL OBSERVATION

1. The time taken by this machine is far less than the other two methods employed.
2. Washing by hand has the highest disadvantage as it takes the most time, has a high tear rate and does not wash well.
3. Since time is money, and less energy is expended, we can conclude that the use of this machine is justified for its cost.
4. The machine was easy to operate even though it makes much noise.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

An alternative for washing machine in this power crisis situation was introduced. Here, we are having a low cost washing machine which can be used as an exercise equipment. It is also, economical and to some extent energy saving.

From the above project, it can be concluded that the "pedal powered washing machine" is a very simple yet very powerful design of washing cloth which if brought into application in the rural areas of the developing countries can aid a lot of plight and the suffering of the poor peoples who find it very difficult to wash cloth by means of hand. Thus it is used as an application keeping in mind the social welfare of the peoples of the rural areas. Also it is safe in working condition and hence it does not require any safety guards during operation. The cost of maintenance is a low and it has a long life.

5.2 LIMITATIONS

- The current financial situation of the country made me use for mild steel for the cuboidal housing as the price of stainless steel was too expensive.
- Travelling also took a huge chunk out of the project budget.
- I started late too due to confusion over which design fits my objective very well.

5.3 RECOMMENDATION

- A pulley can be connected to the cuboidal housing or washing chamber and this pulley, would be driven by a bicycle. This way work input would be reduced and output would be maximized.
- A flywheel can also be introduced to store power and reduce human effort.
- The government of Nigeria can improve this design and make it available in rural areas.

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APPENDIX A

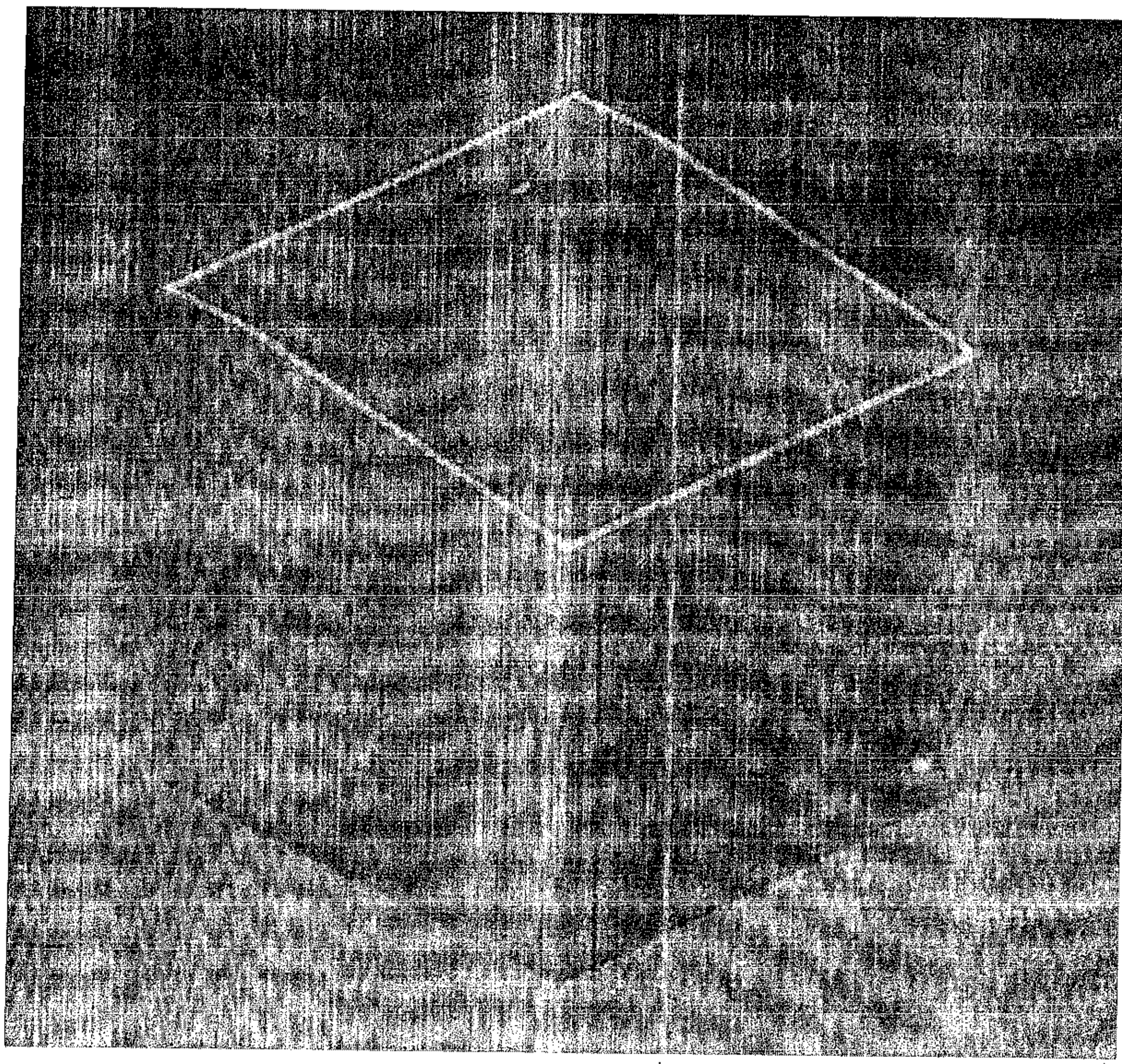
BILL OF ENGINEERING MATERIALS.

S/N	MATERIALS	SPECIFICATIONS	QUANTITY	COST
1.	Sheet metal	1500mm×1800mm	1	₦ 8000
2.	Bearing	P203	2	₦ 2000
3.	Pipes	30mm	2	₦ 1000
4.	Low carbon steel with grid	500mm×500mm	1	₦ 2000
5.	Shaft (mild steel)	20mm diameter	1	₦ 2000
6	Miscellaneous			₦ 8000

Total cost = ₦ 23,000

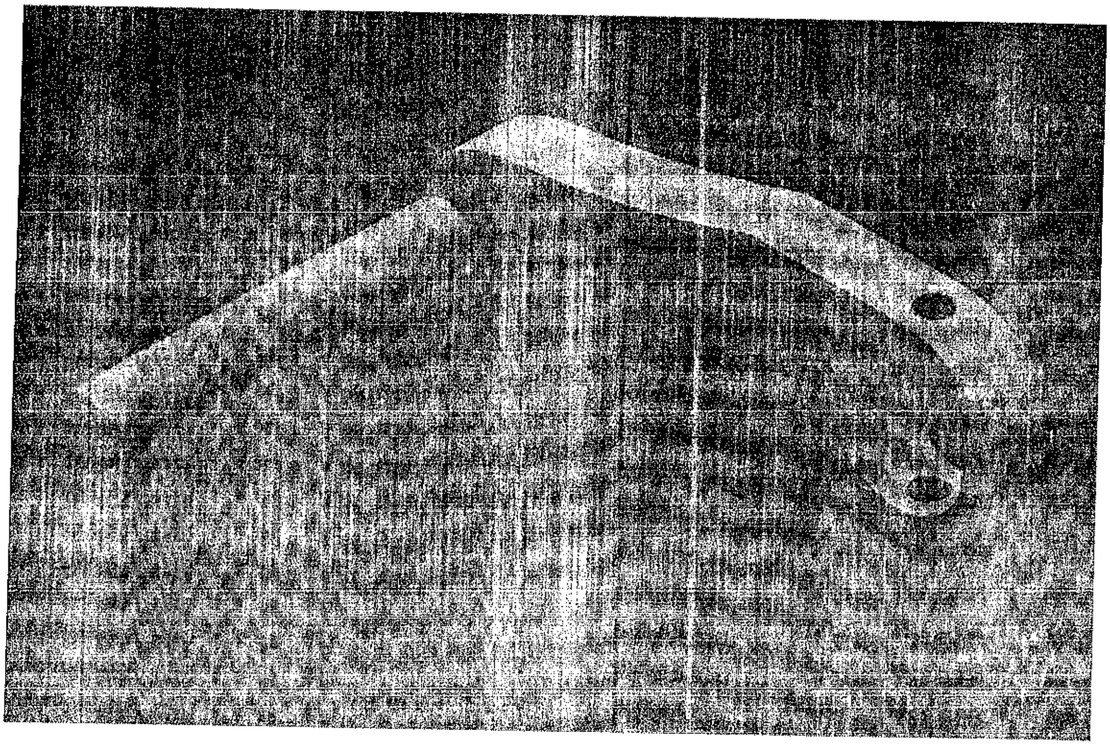
APPENDIX B

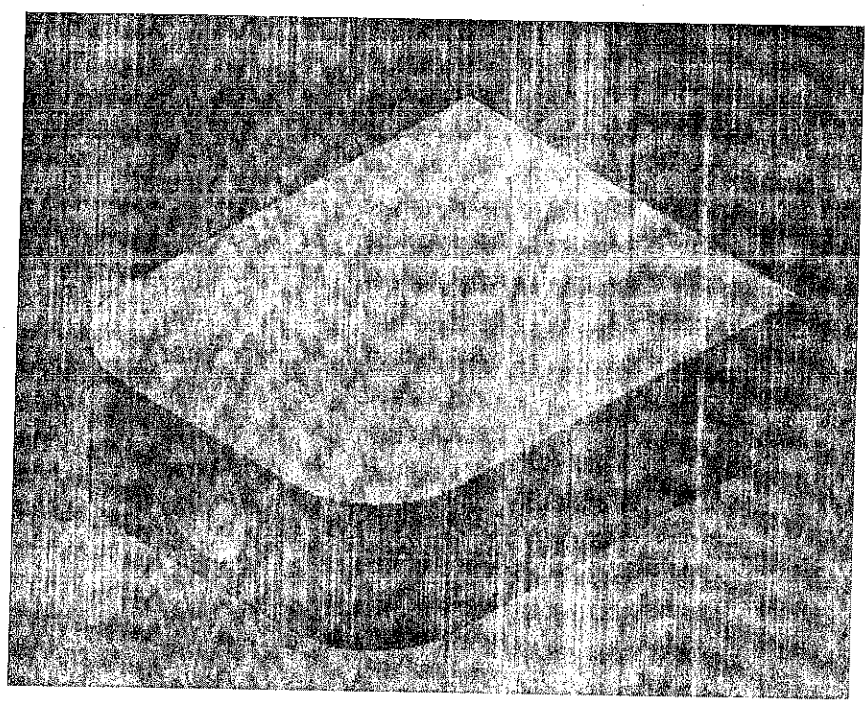
THE WASHING CHAMBER ON INVENTOR FUSION 2015



APPENDIX C

THE PEDAL ON INVENTOR FUSION 2015.





APPENDIX D

DRAWING OF THE DRUM BEFORE LOADING ON INVENTOR FUSION 2015