DESIGN AND FABRICATION OF A SOLAR POWERED WATER PUMPING MACHINE

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A PROJECT PRESENTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING, FACULTY OF ENGINERING, UNIVERSITY OF BENIN. BENIN CITY,EDO STATE IN PARTIAL FUILFUILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING(B.ENG.) IN MECHANICAL ENGINEERING

SEPTEMBER, 2023

CERTIFICATION

This is to certify that this project, THE DESIGN AND FABRICATION OF A SOLAR POWERED WATER PUMPING MACHINE, was carried out by

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in the department of Mechanical Engineering, Faculty of engineering, University of Benin, Benin City, Edo State, Nigeria. In partial fulfillment of the requirement for the award of Bachelor of engineering, (B.Eng.) in Mechanical Engineering.

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(HEAD OF DEPARTMENT)

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Engr. Dr. I. B. Owunna Date
(Project Cordinator)

DEDICATION

This project is dedicated to the Almighty God who made everything possible.

ACKNOWLEDGEMENT

First and foremost, we want to give thanks to God Almighty for the strength and wisdom to carry out this project. We also express our gratitude to Prof. G.O. Ariave, Head of Department, Mechanical Engineering, University of Benin.To our amiable and erudite supervisor, Engr. Godspower A. Ojariafe, thanks for your support, effort and encouragement despite your schedule to ensure that this work was carried out successfully. Also, we appreciate your broad knowledge of expertise and how you scaled us through during this course of carrying out this project. Our special thanks to Engr. P.O. Ollagbegi, Engr. Dr.E.G. Sadjere and other outstanding staff of Mechanical Engineering for the knowledge you all imbedded in me during the course of our study. Also, we want to extend much gratitude to our families yet again for their non-stop love and financial support throughout this project.

ABSTRACT

This paper gives an analysis of the reciprocating pump, a positive displacement pump. The reciprocating pump is a positive displacement pump that suctions and elevates liquid by displacing it with a piston or plunger while performing the reciprocating action in a tightly fitting cylinder. The project offers a portable positive displacement pump to show how fluids travel in a lab setting. The part consists of a scotch yoke mechanism driven by an electric motor, a piston, suction pipe, delivery pipe, suction valve, and a transparent plastic cylinder assembly.

This fabrication will show how a positive displacement pump operates throughout the suction and delivery strokes of each cycle of the pumping mechanism and gives a visual grasp of how it works. The pump was created with a high-precision aim for fluid movement by closely adhering to international standards throughout design and construction. The pump's working designed speed is 15 rpm, and the piston's stroke is 0.18 m long. Half of the pump plunger's stroke length was represented by the crank radius. The height of the centre of the cylinder above the liquid surface is 0.5 m, and the height to which the liquid is raised above the centre of the cylinder Is 1 m. The practical operations were performed, and data was collected. The reciprocating pump principles were applied for the pressure head analysis during the suction and delivery strokes. The values generated were used in the computation analysis for the discharge, work done and the power required to drive the pump. The resulting analysis gave the discharge head of 3.6891m work done of 1.117727Nm/sec, and the power required to drive the motor of 60 W.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Access to clean and reliable water sources is essential for various industrial, agricultural, and domestic applications. Traditional water pumping systems, such as those driven by electric motors or diesel engines, have been widely used. However, these conventional systems often face limitations in terms of cost-effectiveness, and environmental impact. As a result, alternative methods for water pumping have gained significant attention in recent years.

A pump is a mechanical device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps. Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes from microscopic or use in medical applications to large industrial pumps.

Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering aeration in the car industry for water cooling and fuel injection in the energy industry for pumping oil and natural gas or for operating cooling towers. In the medical industry pumps are used for biochemical processes in developing and manufacturing medicine and as artificial replacements for body parts, in particular the artificial heart and penile prosthesis.

Water pumping is a crucial process in various industries and applications, from agriculture and irrigation to domestic water supply and industrial processes. Traditional water pumps often rely on electrical or fuel-powered mechanisms, which can be expensive to operate and maintain, especially in remote or offgrid areas.

Solar based reciprocating pump is a pump running on electricity generated by solar cell gotten from collected sunlight instead of using grid electricity or diesel run water pump,. Reciprocating pump is a positive displacement pump where certain volume of liquid is collected in enclosed volume and is discharged using pressure. It operates by using a piston or plunger to create a to and fro reciprocating motion within a cylinder.

Reciprocating pumps are typically used for high-viscosity fluids and low flow rates, and are often used in applications such as oil and gas production, food processing, and pharmaceutical manufacturing.

In this project, the scotch yoke mechanism acts as the driving mechanism responsible for converting rotational motion into reciprocating motion. It consists of a rotating shaft, yoke, piston, cylinder, control valves and bearings. Its simplicity is the main feature as it efficiently converts rotary motion into reciprocating motion.

1.2 Statement of the Problem

In rural communities where there is lack of reliable access to electricity and consistent water sources, there is a critical need for sustainable water solution. In the earlier days, the use of buckets and calabash is employed in fetching water for homes, agricultural and domestic's uses. Later, hand pumps were developed to reduce the stress and the inconveniences and other forms of contaminations which arise due to direct contact of the body to the available water for consumption. Besides, only a small quantity of water can be made available due to physical factors such as tiredness, distance and climatic factors like dry season. Conventional electric pumps are expensive to install and maintain while hand

pumps require substantial physical effort. Owing to these, the present work aims to develop a solar powered reciprocating pumping machine utilizing the scotch yoke mechanism to provide a cost effective and efficient water supply solution for remote and rural areas, with focus on improving agricultural productivity and enhancing the overall quality
of life.

1.3 Aim and Objectives

The aim of this project is the design and fabrication of a solar powered reciprocating water pumping machine . Other objectives of the project are:

1. To design and fabricate a solar powered reciprocating water pumping machine utilizing the scotch yoke mechanism.
2. Integration of a solar electrical aided source that can provide a consistent and reliable power supply
3. Test the fabricated machine.

1.4 Significance of the Study

The project design has its importance in various fields as better access to clean water for drinking can be gotten from the design. Using solar power, the design has better reliability and can be used in villages where there is little or no electricity, reducing the reliance on fossil fuels and decreasing greenhouse emissions. It also aims at improving human life by removing older means of fetching water using buckets and storing in clay pots. Replacing the human effort with a reciprocating pump which is faster and less tedious and better storage tanks which are bigger and contaminate water less.

1.5 Scope of the Study

The scope of the study which involves the design and modeling of the pneumatic water pumping machine, is primarily focused on the design, development and implementation of a solar powered reciprocating water pumping machine utilizing the scotch yoke mechanism. The primary energy source will be solar panels and emphasis will be placed on use of locally sourced materials. It will include considerations related to safety such as ensuring the machine is properly grounded.

1.6 methodology

The following methods will be adopted to achieve the aim and objectives of the work:

i. literature review of work. Ii, feasibility study of work.

iii. Conceptual design

v. Detailed design.

vi. Fabrication of prototype.

vii. Testing and performance evaluation of the fabricated prototype machine. viii. Conclusion and recommendation.

CHAPTER TWO

LITERATURE REVIEW

2.1 History of Water Pumps

A pump is a mechanical device that is used to transfer different fluids (gases or liquids) from one location to another by applying mechanical action. Pumps have been used for thousands of years to lift water from one place to another. The earliest known water lifting device was the shadoof, which was used in ancient Egypt around 2000 BCE (Hassan, 2007). This device consisted of a long pole with a bucket on one end and a counterweight on the other. By pulling down on the bucket, the counterweight would lift the water out of the well and into a canal or irrigation ditch.

Over time, the shadoof was replaced by other water lifting devices, such as the Archimedes screw, which was invented in ancient Greece around 250 BCE (Lewis, 1997). This device consisted of a spiral tube wrapped around a cylinder. When the cylinder was turned, water would be lifted up the tube and out of the well.

In the middle Ages, the water wheel was developed as a way to lift water from rivers and streams (Gies, 1994). This device consisted of a large wheel with buckets attached to its rim. As the wheel turned, the buckets would scoop up water and lift it to a higher level.

During the Industrial Revolution, steam engines were developed that could power pumps to lift water from deep wells (McNeil, 1990). These pumps were much more efficient than earlier water lifting devices and could lift water from much greater depths. In the 20th century, electric pumps became the most common type of water lifting device (Karassik, Messina, Cooper and Heald, 2008). These pumps are powered by electricity and can be used to lift water from wells, rivers, and other sources. They are much more efficient than earlier pumps and can lift water to much greater heights.

In recent years, new technologies have been developed that are changing the way we think about water lifting. One of these technologies is solar-powered pumps, which use photovoltaic cells to convert sunlight into electricity (Khatib and El-Ali, 2016). These pumps are particularly useful in remote areas where there is no access to electricity. Another new technology is the use of wind power to lift water. Windmills have been used for centuries to grind grain, but they can also be used to power pumps (Sorensen, 1978). This technology is particularly useful in areas with high winds, such as coastal regions. In addition to these new technologies, there is also a renewed interest in traditional water lifting devices, such as the water wheel and the Archimedes screw. These devices are being adapted for modern use and are being used in a variety of applications, from irrigation to hydroelectric power generation (Koutsoyiannis and Mamassis, 2010).

Despite these advances, there are still challenges facing the development of water lifting devices. One of the biggest challenges is the need for energy-efficient pumps that can operate in remote areas without access to electricity (Smout and Norman, 2014). Another challenge is the need for pumps that can handle a wide range of water sources, from shallow wells to deep aquifers. To address these challenges, researchers are developing new materials and designs for pumps that are more efficient and can handle a wider range of water sources. For example, researchers are developing pumps made from lightweight materials that can be easily transported to remote areas (Zhang and Wang, 2019).

They are also developing pumps that can operate using renewable energy sources, such as solar and wind power (Eltawil, Zhao and Yuan, 2012).

Pumps have evolved significantly over time, from the shadoof and Archimedes screw to modern electric and solarpowered pumps. New technologies are being developed that are changing the way we think about water lifting, and there is a renewed interest in traditional water lifting devices. In the modern era, water lifting devices have become more sophisticated and efficient. Electric pumps are now the most common type of water lifting device, but they can be expensive to operate and maintain, especially in remote areas without access to electricity. To address this challenge, researchers are developing new technologies that are more energy-efficient, reliable, and sustainable. Solar-powered pumps, windmills, and lightweight materials are some of the technologies that are being developed to address these challenges (Eltawil, Zhao and Yuan, 2012)

In addition to developing new technologies, researchers are also looking to adapt traditional water lifting devices to modernday needs. For example, the traditional water wheel can be adapted to use renewable energy sources, such as solar and wind power, to lift water. This provides a sustainable solution to meeting the water needs of rural agricultural development.

The history of water lifting devices is a long and fascinating one, spanning thousands of years and many different civilizations. From simple buckets and bags to sophisticated aqueducts and electric pumps, water lifting devices have played a crucial role in meeting the water needs of people, animals, and crops. As we face new challenges in the 21st century, researchers are developing new technologies and adapting traditional devices to meet the water needs of a growing population in a sustainable and efficient way.

2.3 Water Pumps History across various dynasties

Water pumps have been used for thousands of years to meet the water needs of people, animals, and crops. The history of water pumps can be traced back to ancient civilizations, such as the Egyptians, Greeks, and Romans, who developed a variety of devices for lifting

water. This session will explore the history of water pumps, including their development across various
dynasties and civilizations.

Ancient Egypt

The ancient Egyptians were one of the first civilizations to develop water pumps (Smout and Norman, 2014). They used simple devices, such as buckets or bags attached to ropes or chains, to lift water from wells or rivers. These devices were powered by human or animal labor and were not very efficient. Later, more sophisticated devices were developed, such as the shadoof, which was a long pole with a bucket on one end and a counterweight on the other. The shadoof was used in ancient Egypt and other parts of the world to lift water from wells and canals.

The Egyptians also developed the sakia, which was a type of water wheel powered by human or animal labor. The sakia was used to lift water from wells and canals and was particularly useful for irrigation. The Egyptians also developed the nilometer, which was a device used to measure the height of the Nile River during floods. This was important for predicting the annual flooding of the Nile, which was essential for agriculture.

Fig. 2.1: Shaduf/Shadoof used for irrigation in Egypt

Ancient Greece

In ancient Greece, several water lifting devices were developed, including the Archimedes screw, which was a spiral tube wrapped around a cylinder, which was turned by a handle (Eltawil, Zhao and Yuan, 2012).

As the screw turned, water was lifted up the tube and out of the top. The Archimedes screw was used to lift water from rivers and canals and was particularly useful for irrigation. Another device developed in ancient Greece was the hydraulic organ, which was a type of water pump that used air pressure to lift water. The hydraulic organ was used in ancient Greece and Rome for a variety of purposes, including irrigation and entertainment.

Ancient Rome

In ancient Rome, several water lifting devices were developed, including the saqiya, which was a type of water wheel powered by human or animal labor (Eltawil, Zhao and Yuan, 2012). The saqiya was used to lift water from wells and canals and was particularly useful for irrigation. The Romans also developed aqueducts, which were large channels used to transport water from one place to another. Aqueducts were used to supply water to cities and towns and were an important part of Roman engineering. The aqueducts were built with a slight slope to allow the water to flow downhill, and they were often built on arches to cross valleys and other obstacles.

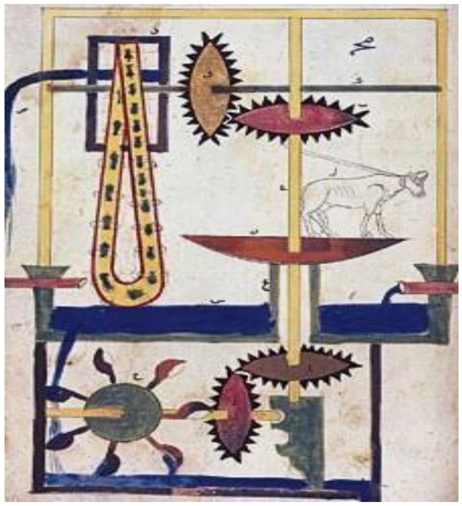


Fig. 2.2: Al-Jazari's hydropowered saqiya chain pump device (https://www.alamy.com, 2023).

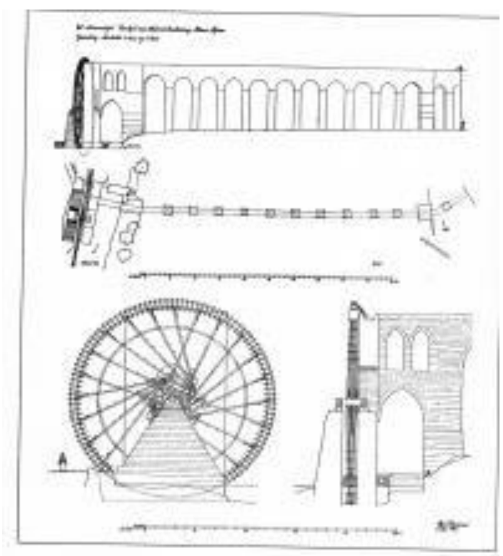


Fig. 2.3: Roman Aqueducts (romanaqueducts.info/24panels/waterlifting.htm, 2023)

Middle Ages

During the middle Ages, water lifting devices continued to be developed, including the noria, which was a type of water wheel powered by the flow of water in a river or canal

(Sorensen, 1978). The noria was used to lift water from wells and canals and was particularly useful for irrigation. The middle Ages also saw the development of the water mill, which was a type of water wheel used to grind grain. Water mills were used throughout Europe and were an important part of the medieval economy.

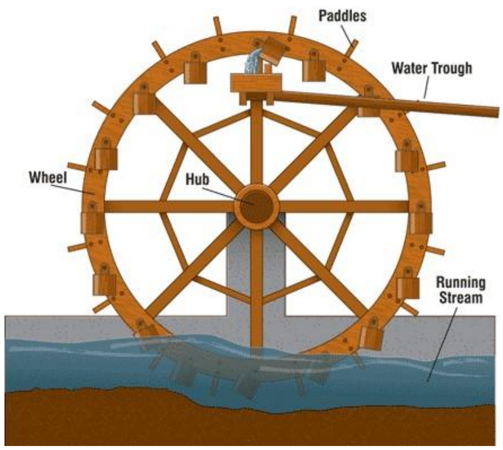


Fig. 2.3: Noria machinery (Wikipedia.com, 2023)

The Renaissance

During the Renaissance, water pumps became more sophisticated and efficient. The Italian engineer Giovanni Branca developed a steam-powered water pump in the early 17th century, which was one of the first steam engines (Khatib and El-Ali, 2016). The pump used the pressure of steam to lift water from a well or other source. The steam engine was later developed by other engineers, such as Thomas Savery and James Watt, and became an important part of the Industrial Revolution.

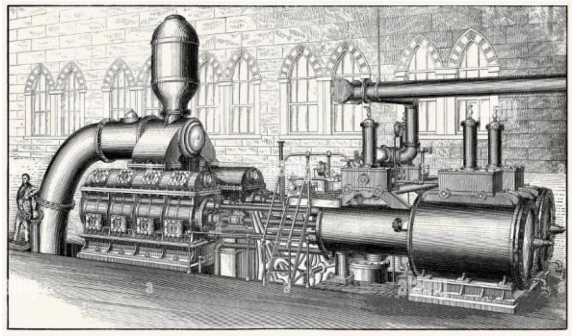


Fig. 2.4: Water pumping steam engines (https://www.alamy.com, 2023)

Modern Era

In the modern era, water pumps have become more sophisticated and efficient. Electric pumps are now the most common type of water lifting device (Khatib and El-Ali, 2016), but they can be expensive to operate and maintain, especially in remote areas without access to electricity. To address this challenge, researchers are developing new technologies that are more energy-efficient, reliable, and sustainable. Solar-powered pumps, windmills, and lightweight materials are some of the technologies that are being developed to address these challenges (Khatib and El-Ali, 2016).

In addition to developing new technologies, researchers are also looking to adapt traditional water lifting devices to modern-day needs. For example, the traditional water wheel can be adapted to use renewable energy sources, such as solar and wind power, to lift water. This provides a sustainable solution to meeting the water needs of rural agricultural development (Sorensen, 1978). In conclusion, water pumps have played a crucial role in meeting the water needs of people, animals, and crops throughout history. From simple devices powered by human or animal labor to sophisticated electric pumps, water pumps have evolved over time to meet the changing needs of society. As we face new challenges in the 21st century, researchers are developing new technologies and adapting traditional devices to meet the water needs of a growing population in a sustainable way.

2.5 Modernization of Water Pumps

Water pumps have come a long way since their inception, and modernization has played a significant role in their evolution. Today, there are several types of water pumps available, each with its own unique features and benefits. In this write-up, we will discuss the modernization of water pumps and the different kinds of water pumps available today.

One of the most significant advancements in water pump technology has been the development of electric pumps. Electric pumps are widely used today and are known for their efficiency and reliability. They are powered by electricity and can be used to lift water from wells, rivers, and other sources. Electric pumps are available in different sizes and capacities, making them suitable for a wide range of applications.

Another type of water pump that has gained popularity in recent years is the solar-powered pump. Solar-powered pumps are powered by solar panels and are ideal for remote areas where access to electricity is limited. They are energy-efficient and environmentally friendly, making them a popular choice for sustainable water management.

Wind-powered pumps are another type of water pump that has been in use for centuries. They are powered by wind turbines and are ideal for areas with high wind speeds. Wind-powered pumps are energy-efficient and can be used to lift water from wells, rivers, and other sources.

Hydraulic pumps are another type of water pump that is widely used today. They are powered by hydraulic pressure and are ideal for applications that require high pressure and flow rates. Hydraulic pumps are commonly used in industrial applications, such as mining and construction.

In addition to these types of water pumps, there are several other types of pumps available today, including centrifugal pumps, submersible pumps, and positive displacement pumps. Each type of pump has its own unique features and benefits, making it suitable for different applications.

The modernization of water pumps has led to the development of several types of pumps that are efficient, reliable, and sustainable. Electric pumps, solar-powered pumps, wind-powered pumps, hydraulic pumps, and other types of pumps are available today, each with its own unique features and benefits. As we face new challenges in the 21st century, researchers and engineers are developing new technologies to meet the water needs of a growing population in a sustainable way.

2.6 Positive Displacement Pump

A positive displacement pump delivers a fixed volume of liquid for each cycle of pump operation. This volume remains constant regardless of the system's resistance to flow, as long as the capacity of the power unit driving the pump or the pump component strength limits are not exceeded. Although a pump with many chambers may have overlapping delivery among specific chambers, which minimises this effect, the positive displacement pump delivers liquid in discrete quantities with no delivery in between. Positive displacement pumps differ from centrifugal pumps in that they provide a continuous flow regardless of pump speed or discharge resistance.

Positive displacement pumps are classified into three types based on their design and operation. There are three types of pumps: reciprocating pumps, rotary pumps, and diaphragm pumps.

Positive displacement pumps all work on the same fundamental concept. Consider a reciprocating positive displacement pump with a single reciprocating piston in a cylinder with a single suction port and a single discharge port, as shown in Figure 2.6. Check valves in the suction and discharge ports allow flow in only one direction.

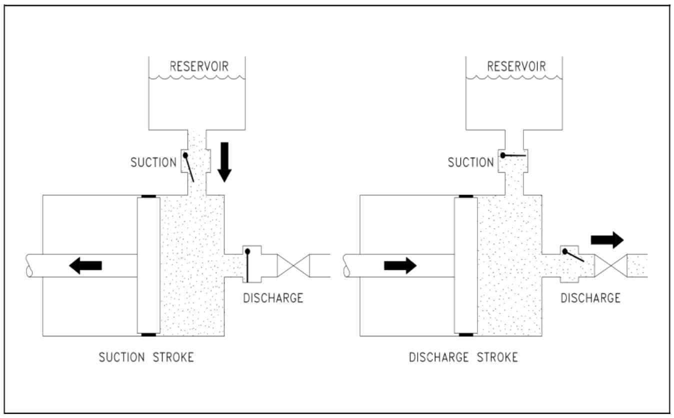


Fig. 2.7: Reciprocating Positive Displacement Pump Operation

The piston advances to the left during the suction stroke, allowing the check valve in the suction line between the reservoir and the pump cylinder to open and admit water from the reservoir. The piston advances to the right during the discharge stroke, seating the check valve in the suction line and opening the check valve in the discharge line. The volume of liquid pushed by the pump in one cycle (one suction stroke and one discharge stroke) is equal to the change in the cylinder's liquid volume as the piston moves from its farthest left to farthest right position.

Positive displacement pumps, on the other hand, work by trapping a fixed amount of fluid and then forcing it through the pump's discharge pipe. This is achieved through the use of a reciprocating piston, diaphragm, or rotary mechanism. Positive displacement pumps are typically used for high-viscosity fluids and low flow rates, and are often used in applications such as oil and gas production, food processing, and pharmaceutical manufacturing.

The following pumps are classified as positive displacement pumps

i. Reciprocating piston pump

ii. Gear-type rotary pump

iii. Lobe-type rotary pump

iv. Screw-type rotary pump

V. Moving vane pump

2.7 types and applications of reciprocating pumps

Reciprocating pumps can be categorized into three types which is, according to mechanism, according to air vessel and according to number of cylinders.

According to mechanism

i. single-acting

ii. double-acting

According to air vessel

i. pump with air vessel

ii. Pump without air vessel

According to number of cylinders

i. single cylinder

ii. Double cylinder

iii. Triple cylinder pump

The application of reciprocating pump systems along pipelines, aircraft engines and the simulation of pulsatile arterial blood flow and other design parameters in fluid flow measurement and control, the works by Han and Qing (2011), Yang (2009), Joffe (1988), Dudenhoeffer (1994), Akarte (2022), Sahoo (2006), Wu and Yuan (2012), Burton and Short (1999), Vetter and Friedrich (1987), Johnston (1991), Ekong et al. (2012), Ekong et al. (2013a), Rodulf et al. (2005), Menkara et al. (2022), respectively.

CHAPTER THREE

MATERIALS AND METHOD

3.1 DESIGN CONCEPTS

In order to produce a sustainable design for the solar powered reciprocating water pump which will be meet and satisfy the most of water pump needs.

3.1.1. Design concept one: solar powered Reciprocating Pump Single-Acting

This idea uses a Scotch yoke mechanism to power a singleacting reciprocating pump. Water is drawn into the cylinder by the pump during one stroke, and it is ejected during the other. Suitable for uses requiring a moderate amount of water pumping, such small-scale irrigation.

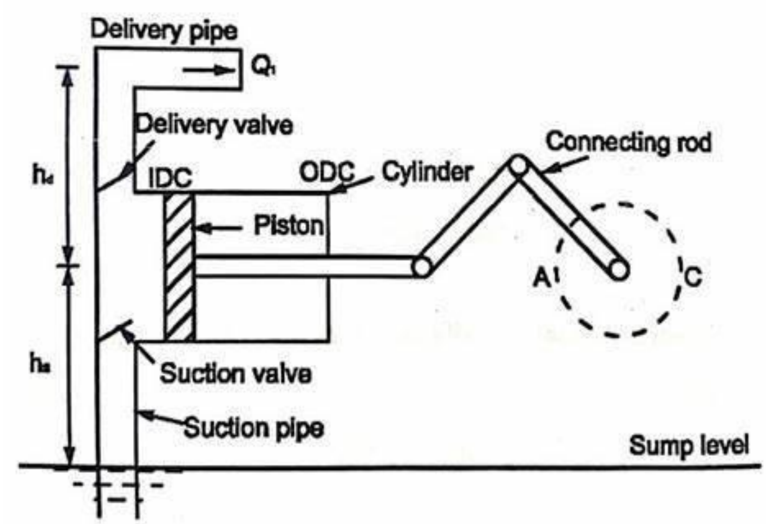


Figure 3.1 concept 1

Solar powered single acting reciprocating pump

Benefits of concept 1

i. Ease of operation and design.

ii. affordable due to decreasing water use.

iii. Very little upkeep is necessary.

Limitations of concept 1

i. Limited ability to pump large volumes of water.

ii. Not necessarily appropriate for bigger community water supplies.

3.1 2. Design concept 2: Double-Acting Reciprocating Pump

In this idea, a Scotch yoke mechanism is used to drive a double-acting reciprocating pump. The pump's efficiency is increased by drawing water into the cylinder during both strokes. Suitable for uses requiring more water pumping, including community water supply.

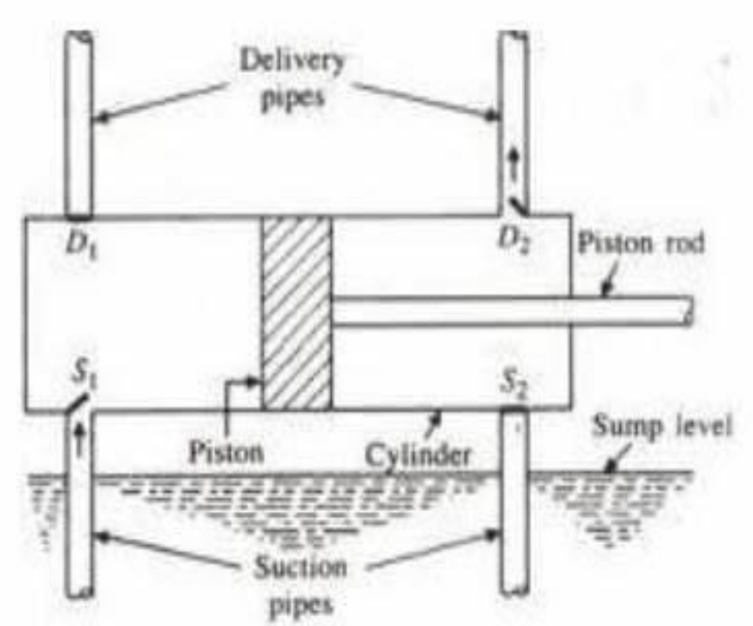


Figure 3.2 concept 2 double acting reciprocating pump source

Advantages of concept 2

i. Greater capacity for pumping water than single-acting pumps ii. Effective for satisfying the needs of larger communities.

iii. Reliable and robust design.

Disadvantages of concept 2

i. Slightly more expensive and difficult at first. ii. Possibly need more upkeep than simpler design.

3.1.3 Design concept 3: Pump with Variable Stroke Length

This idea uses a Scotch yoke mechanism to power a reciprocating pump with a variable stroke length. Depending on the amount of water needed, the stroke length can be altered dynamically to optimize energy use.

Suitable for regions with changing water needs.

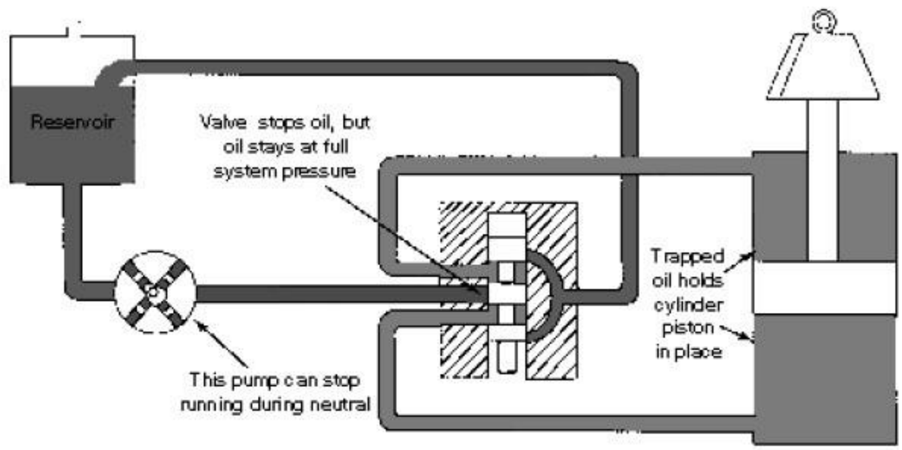


Figure 3.3 concept 3 pump with variable stroke length

Advantages

i. Energy-efficient with adjustable stroke length.

Ii.suitable for regions with a wide range of water needs iii.. Possibility of energy savings during times of low demand.

Disadvantages

i. Increased mechanical complexity and control system needs are drawbacks. ii. A higher initial cost arising from the adjustable mechanism.

3.2 selection of concept: use of decision matrix

A decision matrix was used to help select the most viable concept for production among the three. The evaluation was done based on 5 major criteria, with each criteria assigned with a weight ranging from 1 to 5 with

1 being the least important and 5 being the most important.

i. capacity

ii. Safety

iii. Sustainability i

iv. Reliability

v. cost

3.3 DESIGN FACTORS AND CONSIDERATIONS

During the process of design concept development, several factors were carefully considered. They are:

1. Capacity: the pumping devices capacity is the maximum amount of water it can deliver, and it is commonly expressed in liters per minute (LPM), gallons per minute (GPM), or some other suitable unit. This criterion evaluates each concepts' ability to effectively address the unique water supply requirements of the intended application. In this case, agricultural sector in rural areas. So the capacity was considered.
2. Safety: in order to ensure that the device will be safe to use, several steps were taken; all wires, circuit and electric conductors were properly insulated. All unwanted sharp

edges and rough surface were polished and blunted. Materials and seatings used to reduce vibration were used.

3. Sustainability: This is the ability for a material, device or machine to sustain for an indefinite period of time without damaging the environment. Due to the use of material which can last long and be recycled, it can be said that this project is sustainable.

4. Reliability: this assesses the possibility that each concept will operate in different climate conditions, availability of electricity and so on. A reliable design is one that can consistently do its intended purpose regardless of these conditions.

5. Cost: cost refers to the financial implications as regarding all three concepts taking into consideration the upfront expenses required for installation, ongoing operational and maintenance cost.

Table 3.1 Decision matrix table

criteria	Weight	Concept 1		Concept 2		Concept 3	
		Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
sustainability	5	5	25	3	15	2	10
safety	4	4	16	3	12	3	12
reliability	3	5	12	3	9	3	9
cost	2	2	8	2	4	2	4
capacity	1	2	4	3	3	5	5
Total			65		43		40

From the design matrix table, the significant criteria favored concept 1 with a weighted average of 65 compared to the concept 2 of 43 and concept 3 of 40.

3.3 Scotch yoke mechanism

The Scotch Yoke could be a device that converts a slider's linear motion into motility motion or vice versa. A sliding yoke with a slot that engages a pin on the spinning half is directly connected to the piston or alternative reciprocator half. Given a constant motility speed, the piston's motion might eventually take the form of a pure wave.

Link 1 is fixed in fig. When the link 2 (which corresponds to the crank) spins about the center, b, the link 4 (which corresponds to the frame) reciprocates in this mechanism. The guiding fixed link 1 to the frame. We are utilizing this method for these reasons. The action of the crank is transformed into slippery motion using a Scotch yoke mechanism. The link's horizontal part reciprocates or slides within the fixed link as the crank turns.

Scotch yoke mechanisms have less moving parts and smoother operation than slider crank mechanisms, which is an advantage. The most typical application of this system is in high pressure oil and gas pipelines. Today, it is also utilized in a variety of internal combustion engines, including the Bourke and SyTech engines, as well as other hot air and steam engines.

3.3.1 working principle of scotch yoke mechanism

It is a straightforward mechanism that converts the pin's rotating motion into linear motion. As soon as the DC motor's ability is connected, the shaft begins to rotate, at which point the crank begins to move forward and rotate the pin slider inside the yoke component. When the yoke experiences a forward displacement moment, the crank rotates clockwise. The crank's length determines the yoke's maximum displacement. The yoke is sliding fully emotional in advance as the crank completes the dextrorotary rotation. The crank will eventually rotate continuously until it returns to its initial position of rotation if this location takes longer to begin the return stroke. The Yoke then reverses course and returns to its starting place. As a result, the crank must complete one full rotation before the yoke may complete sliding motions in both directions. The yoke will slide through an equivalent distance as the crank's twofold length with the help of a full crank rotation. The crank length can be changed to adjust the yoke displacement.

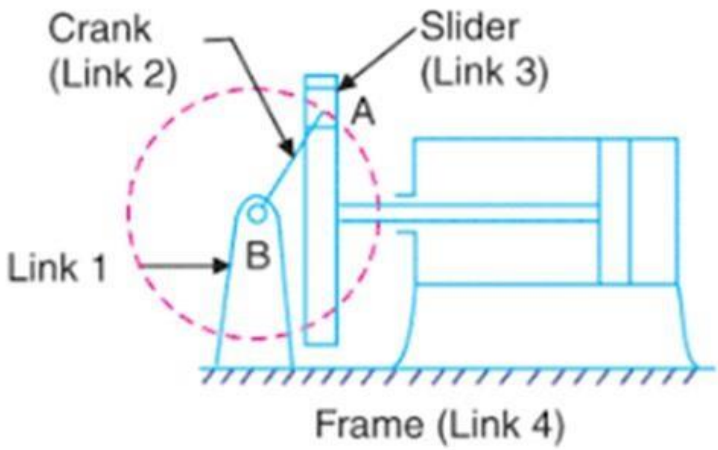


Figure 3.4 scotch yoke mechanism

3.4 DESIGN SPECIFICATION

The detailed design of solar powered reciprocating water pump is based on some already existing water pump specification

Hydraulic component

a. Hydraulic cylinder of diameter 1.5in(38.1mm), 180mm length, 2mm thick

b. Hydraulic piston rod of 12mm diameter, 100mm length and hard cold steel

c. Suction pipe of 1inch diameter

d. Outlet pipe of 1inch diameter

e. Solar panel of 18v 50w

f. Battery

Scotch yoke mechanism component

a. slider of length 180mm, diameter 16mm

b. disk of diameter 190mm

c. bearing of diameter 16mm

3.5 Design calculation

3.5.1 Calculation for Hydraulic Cylinder

Calculation for Forward stroke

Force (F) = Relative pressure(Pr) x Effective Area of piston (A)

$F = P \times \pi R^2$ - - - Source: Khurmi and Gupta (2005) 3.1

F= 30 x 3.142 x 1^2

F= 94.26N

Calculation for backward stroke

Force (F) = Relative pressure (Pr) x Effective Area of piston (A)

$F = P \times (R^2 - r^2)$ - - - *Source:Khurmi and Gupta (2005)* *3.2*

F = 30 x 3.142 x (1^2–0.6^2)

F = 60.3264N

Diameter of hydraulic cylinder (D)= 3.81cm

Radius of hydraulic cylinder (R)= 1.905cm

Stroke length = 180mm = 8cm

Piston rod diameter = 2cm

Area of the hydraulic cylinder = πR^2

= 3.142 x $(1.905)^2$ = 11.4024cm^2

Forward stroke pressure = <u>Forward stroke force</u>

Area of the hydraulic cylinder

Forward stroke pressure = 94.36 ÷ 11.4024 = 8.2666 N/cm^2

Backward stroke pressure = <u>Backward stroke force</u>

Area of the hydraulic cylinder

Backward stroke pressure = 60.3264 ÷ 11.4024 = 5.296 N/cm^2

3.5.2 Velocity of Water Flow from Hydraulic Cylinder

$V^2 = U^2 + 2aL$ - *Source: Bansal (2010)* *3.3*

\- - - -

A = acceleration

U = initial velocity = 0m/s

L= stroke = 180mm = 18cm

R = radius of outgoing pipe/hose = ½inch = 1.27cm = 0.0127m

M = mass of piston = 0.3kg

Due to frictional force between the piston and cylinder the:

Actual force (Fa) = (Forward stroke pressure x Area of outgoing pipe)–

10%x(Forward stroke pressure x

Area of Outgoing pipe)

$F_a = (P_F \times A_o) - 10\% \times (P_F \times A_o)$ - *Source: Bansal (2010)* *3.4*

- - - - -

$F = (8.2666 \times 10^4) \times \pi \times (0.0127)^2$

F = 41.8874N

Fa= (41.8874) – (0.1x 41.8874)

Fa= 33.51N

Mass = 3.351kg

Total mass = mass + mass of piston

Total mass = 3.351 + 0.3

Total mass = 3.651kg

Acceleration = Actual force ÷ total mass

Acceleration = 33.51 – 3.651

Acceleration = $9.1783 m/s^2$

Velocity of water from the hydraulic cylinder

From Eqn. 3.3 above

$V^2 = 0 + 2 \times 9.1783 \times 0.08$

$V = \sqrt{(1.3662)}$

V= 1.2118m/s

3.5.3 Calculation of Weight of Suctioned Water

Backward stroke pressure = 5.296 N/cm²

Weight (W) = (Backward stroke pressure x Area of suction pipe)

$W = (P_b \times A)$ - - - - - - - - 3.5

Source: Bansal (2010)

W= $(5.296 \times 10^4) \times \pi \times (0.0127)^2$

W= 26.8082N

Actual weight (Wa) = (26.8082)–(0.1 x 26.8082)

Wa = 21.4465N

Mass of suctioned water = 2.1446kg

3.5.4 Calculation for Head of Water Raised (H)

$P_f = \rho g h$ - - *Source: Bansal (2010*- - - - 3.6
-

ρ = density of water = 1000kg/m³ Forward

Pressure (P_f) = 8.2666N/cm² g = 9.81m/s²

H = P ÷ (ρ x g)

H = 82666÷(1000 x 9.81)

H = 8.247m

3.5.5 Discharge of Water from Hydraulic Cylinder

Radius of hydraulic cylinder = 1.905cm= 0.01905m

Velocity (v) = stroke (L) x number of stroke per minute (N)

$N = \frac{v}{(L \times 10^{-3})}$- *Source: Bansal (2010)* - - - - - - - 3.7

N=1.2118÷0.08

N= 15.1475 stroke/sec

N= 908.85 stroke/minute

$W.D = \rho g \times (N \div 60) \times (H_s + H_d)$ *Source: Khurmi and Gupta (2005)* *3.8*- - - -

Hd = discharge head = 8.247m

E = density of water = 1000kg/m³

A = πr²

R = radius of hydraulic cylinder = 0.01905m

(N÷60) = 15.1475stroke/sec

G = 9.81m/s²

Workdone = 1000 x 9.81 x π x 0.01905² x 0.08 x 15.1475 x (0 + 8.247)

Workdone = 111.7727watt

3.5.6 Calculation for the Power Required

Power required (P) =$\boldsymbol{workdone\ per\ second}$/1000

P=WD/1000 - -- *Source: Khurmi and Gupta (2005)* *3.9*

Power required (P)=111.7727/1000

Power required (P)= 0.111.7727KW

When power by a 0.05KW or 50W

Discharge head;

$50 = 1000 \times 9.81 \times \pi \times 0.01905^2 \times 0.08 \times 15.1475 \times (0 + hd)$

Hd= 50÷13.55313

Hd= 3.6891m

3.5.7 scotch yoke mechanism calculations

a. Stroke Length of the Piston Radius of the crank,

r = 180mm = 0.18m L = 2r = 2*0.1 L = 0.36m

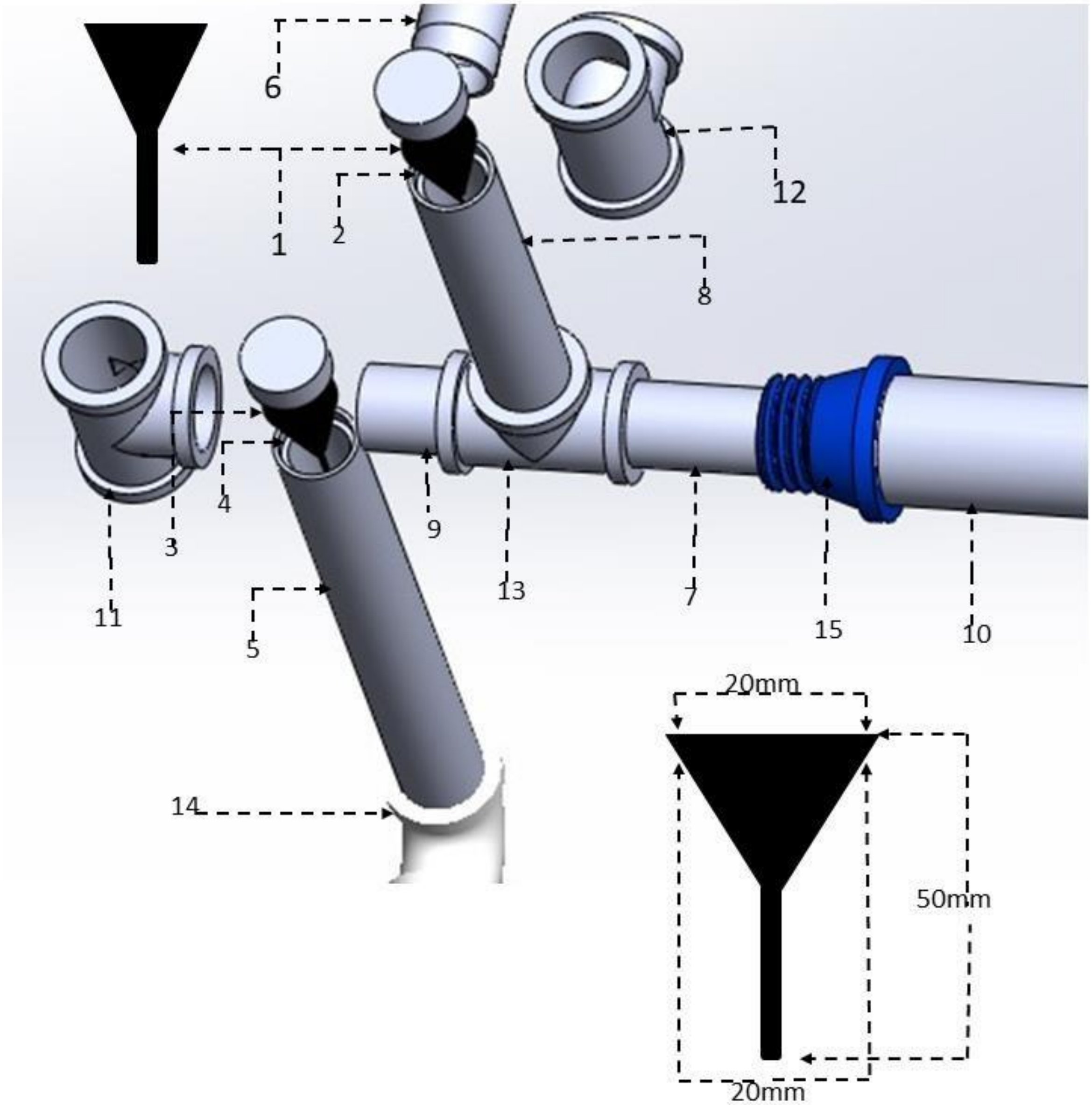
b. Angular Velocity of the Crank

VOLT(V) = 12v(max)

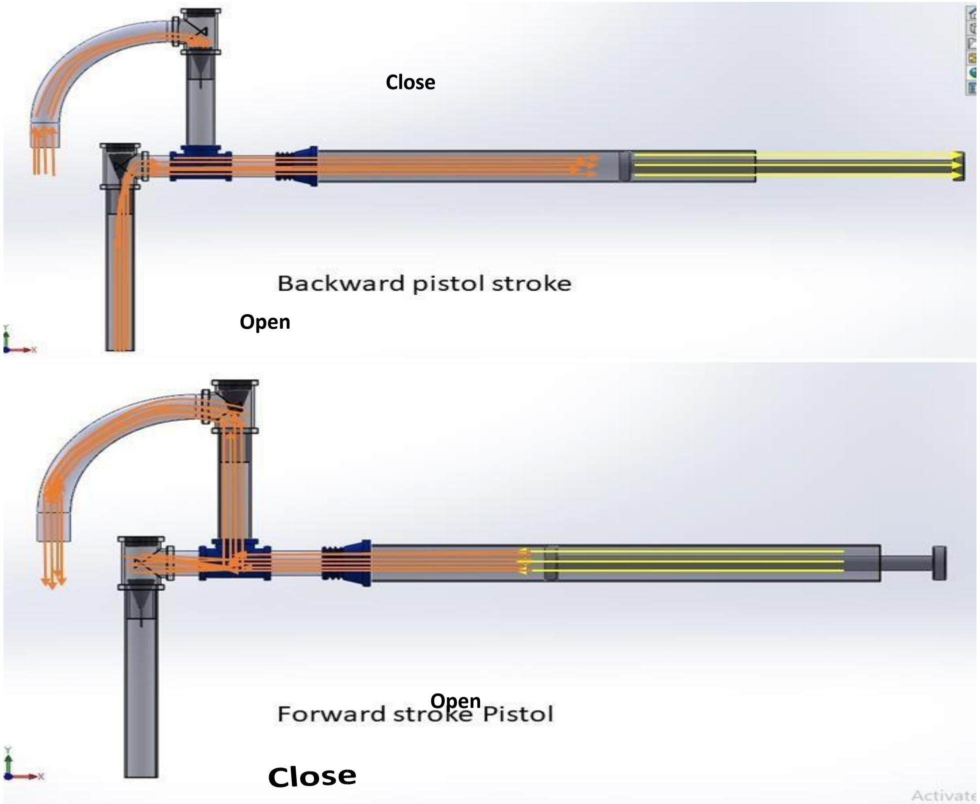
SPEED(rpm) = 492

, N = 492rpm $\omega = 2\pi rN/60 = (2\pi*0.1*492)/60$ $\omega = 5.152$rad/sec

Detailed design/drawing of pressure gates(check valves)



S/N	NAME
1	Delivering pressure lock
2	Delivering pressure gate
3	Suctioning pressure lock
4	Suctioning pressure gate
5,6,7,8,9	1 Inch Pipe
10	1.5 inch pipe
11,12,13,14,15	Pipe fitting



3.6 PROTOTYPE FABRICATION

The fabrication of the various parts and the final assembly of the solar powered water pumping device require the usage of particular manufacturing techniques. The following manufacturing processes and production steps were utilized to create the machine:

i. Measuring the dimensions to determine the machine's proper size

ii. Cutting: This involved using a handsaw and a motorized cutting stone to cut several machine parts, including the structural frame, strings, plates, and so forth.

iii. Welding, which entailed combining several metal components of the machine, such as the structural frame, hydraulic cylinder, scotch yoke component, using electric arc welding.

iv. Drilling: Holes were drilled in various machine parts using a hand and machine drill.

v. pieces assembly, which required joining the various pieces of the machine together using screws, bolts, and nuts as well as welding and rivets.

FINAL DESIGN

3.7 MATERIAL SELECTION

The material used were selected to meet the qualities and quantities of the needed to produce the desired function, work and features of a water pumping machine

COMPONENT	MATERIAL
Frame	Steel pan, Galvanize steel, Aluminum
Hydraulic component	Polyvinyl Chloride (PVC) pipe

Pressure gates	Polyvinyl Chloride (PVC)
Solar panel	Silicon solar cell, Aluminum, glass sheet
Tank	Plastic

3.7.1 Bill of engineering materials and evaluation

S/N	COMPONENT	MATERIAL	QUANTITY	UNIT	TOTAL COST
1	1.5inch by 1/2inch square pipe (9ft)	Cast iron	1	2500	2500
2	check valve			4000	8000
3	Bolt and Nuts	Mild steel	20	100	2000
4	1inch pipe (9ft)	Polyvinyl Chloride (PVC)	1	2600	2600
5	1/2-inch pipe(9ft)	Polyvinyl Chloride (PVC)	1	3200	3200
6	Pipe filling	Polyvinyl Chloride (PVC)	7	100	700
7	Battery		1	7000	7000
8	Motor		1	5000	5000

9	Cylinder		1	18000	18000
10	Cutting stone		1	2000	2000
11	Solar panel(50watt)		1	35000	35000
	Total				86000

3.7 machining and labour cost

S/N	COMPONENT	Machining and fabricating	QUANTITY	UNIT	TOTAL COST
1	1.5inch by 1/2inch square pipe (9ft)	Cast iron	1	2500	2500
2	12v battery		1	7000	7000
3	Bolt and Nuts	Mild steel	20	100	2000
4	1inch pipe (9ft)	Polyvinyl Chloride (PVC)	1	2600	2600
5	1/2-inch pipe(9ft)	Polyvinyl Chloride (PVC)	1	3200	3200
6	Pipe filling	Polyvinyl Chloride (PVC)	7	100	700
7	Tube (3yard)	cutting	1	400	400
8	Valve		1	12500	12500
9	Cylinder		1	18000	18000
10	Electric motor		1	5000	5000

11	Solar panel(50watt)	connecting	1	5000	5000
	Total				58900

3.7 Total cost

S/N	Description	Cost
1	Material	86000
2	Machining and labour	58900
3	Material damage	19000
4	Miscellaneous	13000
	Total	166900

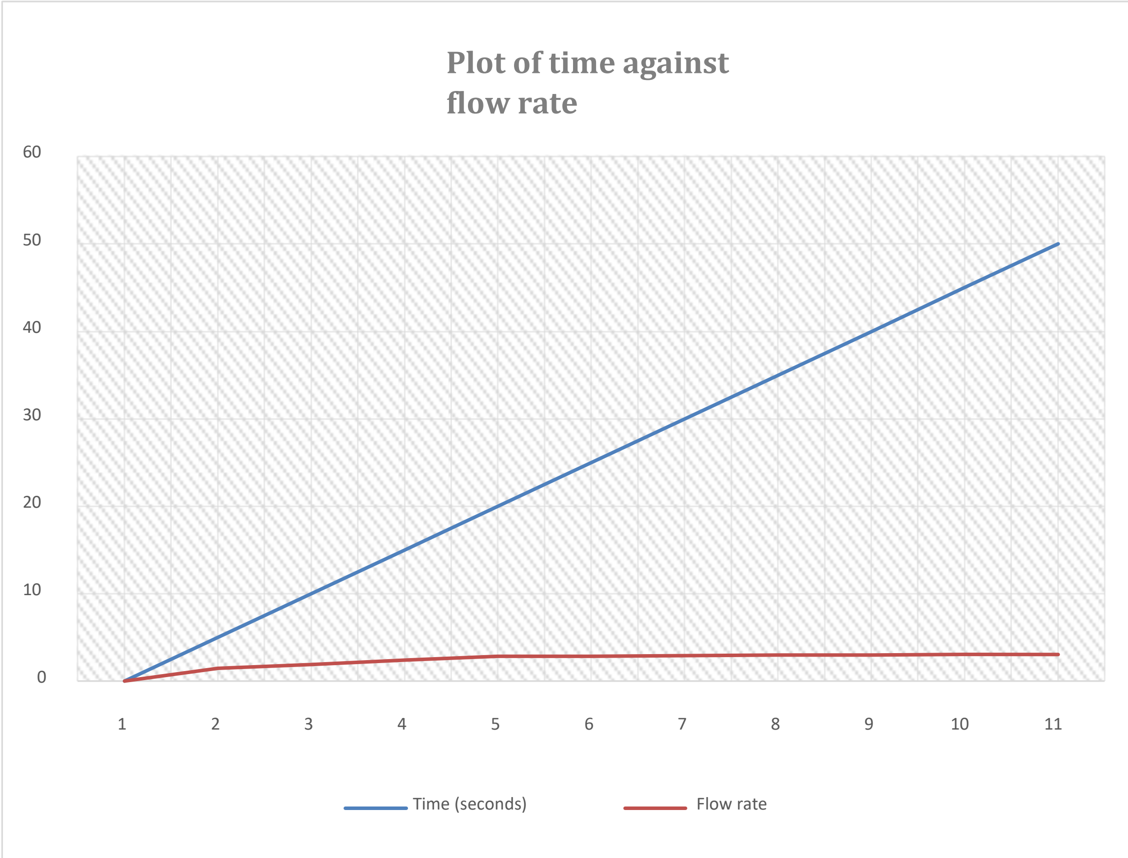
CHAPTER 4
RESULT AND DISCUSSION

4.1 RESULT

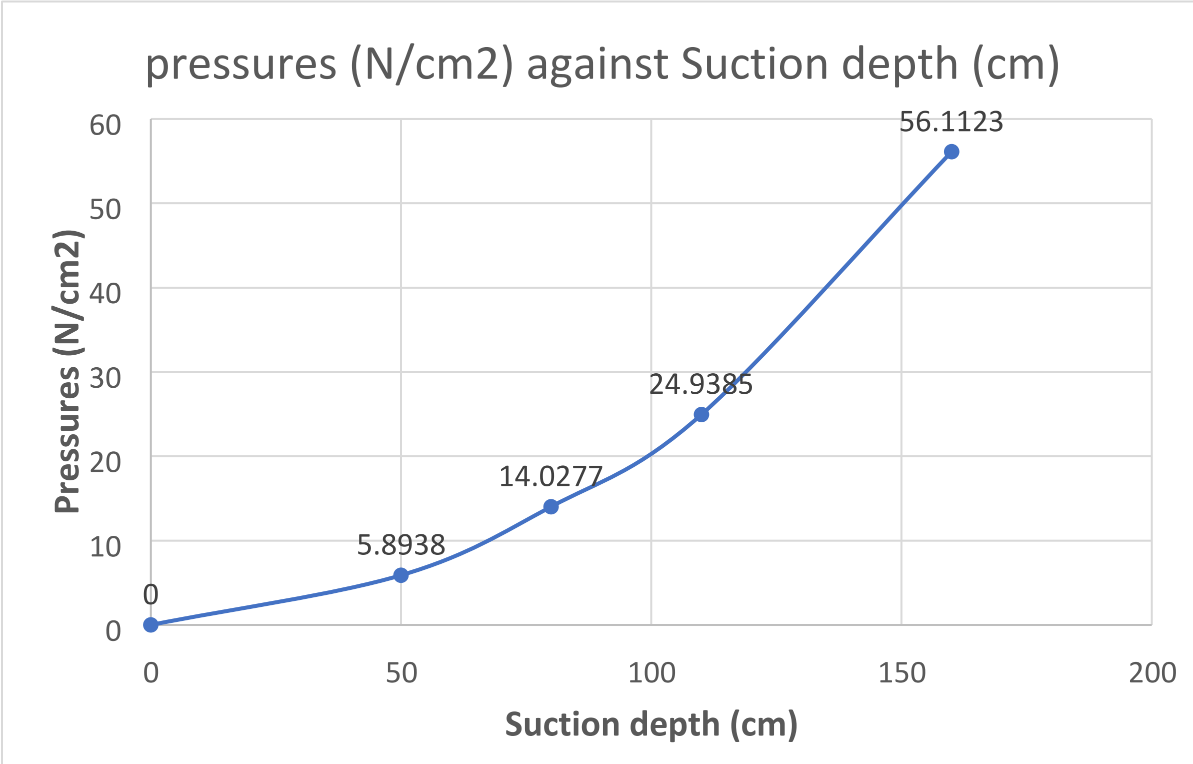
The results obtained from the use of solar powered reciprocating pumping machine is shown in table 4.1.

Table 4.1 discharge per second by a single acting reciprocating pump

Time (seconds)	Flow rate
0	0
5	1.5
10	1.9
15	2.4
20	2.9
25	2.9
30	2.94
35	2.98
40	3.0
45	3.06
50	3.1



SUCTION DEPTH(CM)	TIME TO DISCHAGE(SEC|||
10	3
20	4
30	5
40	6
50	8
60	9
70	10



4.2 DISCUSSION

During the testing phase, the system exhibited a consistent and reliable performance in delivering water. The data revealed that the pump achieved a peak discharge rate of 3.1 liters per minute. It aligns with the design objective of providing a reliable water supply solution for agriculture, irrigation and so on.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The solar powered reciprocating water pumping machine was successfully designed, fabricated and tested. From the design and fabrication, we were able to achieve our objectives which were:

i. Design a reciprocating water pumping machine using the scotch yoke mechanism.
ii. Implement a solar aided electrical source that provides consistent and reliable power supply with the addition of a battery during rainy seasons.

5.2 RECOMMENDATIONS

The concept used in designing the project can be improved upon in the following way.

a) Since in building the scotch yoke mechanism, precision is a major factor, there could be integration of sensors that help in achieving that thereby making it smart.
b) Use of materials that are highly resistant to corrosion to better improve the lifespan of the design.
c) Since its works basely on the principle of converting rotary motion to liner reciprocating motion, better coatings and less wear materials can be used
d) Energy trackers could be put in place to maximize energy capture from the sun movements.

REFERENCES

Eltawil, M. A., Zhao, Z., & Yuan, X. (2012). Renewable energy sources for irrigation water pumping in developing countries: a review. Renewable and Sustainable Energy Reviews, 16(6), 4152-4170.

Gies, F. (1994). Cathedral, Forge, and Waterwheel: Technology and Invention in the Middle Ages. Harper Perennial.

Girma, A., et al. (2018). "Effectiveness of hand-operated water pumps in rural communities in Ethiopia." Journal of Water and Health, 16(2), 301-310

Hassan, F. A. (2007). The Oxford Handbook of the Archaeology of the Ancient Near East. Oxford University Press.

Howes, M. (1984). "The potential for groundwater exploitation by solar-powered pumps in Pakistan." Agricultural Administration, 16(4), 229-248

Jomehpour, M. (2009). "Qanat irrigation systems as important and ingenious agricultural heritage: Case study of the qanats of Kashan, Iran." International Journal of Environmental Studies, 66(3), 297-315

Karassik, I. J., Messina, J. P., Cooper, P., & Heald, C. C. (2008). Pump Handbook. McGraw-Hill.

Khatib, H., et al. (2018). "Environmental impact assessment of solar-powered water pumps compared to diesel-powered pumps." Journal of Cleaner Production, 172, 4239-4248

Khatib, T., & El-Ali, B. (2016). Solar water pumping systems: a review. Renewable and Sustainable Energy Reviews, 62, 968-990.

Koth, P., & Clendenon, C. (n.d.). "Pumps, Traditional." Water Encyclopedia, Science and Issues. Retrieved from http://www.waterencyclopedia.com/Po-Re/Pumps-Traditional.html

Kothari, R., et al. (2010). "Renewable energy technologies for irrigation water pumping in India: A review." Renewable and Sustainable Energy Reviews, 14(4), 1014-1021. This review

Kothari, R., et al. (2010). "Renewable energy technologies for irrigation water pumping in developing countries: A review." Renewable and Sustainable Energy Reviews, 14(7), 2039-2047

Koutsoyiannis, D., & Mamassis, N. (2010). A review of the development of water wheels. Renewable and Sustainable Energy Reviews, 14(1), 173-182.

Kristoferson, L. A., & Bokalders, V. (1986). "Water Pumping: An overview." In Renewable Energy Technologies. Their Applications in Developing Countries (pp. 283-295).

Lewis, M. J. T. (1997). Millstone and Hammer: the Origins of Water Power. University of Hull Press.

McNeil, I. (1990). An Encyclopedia of the History of Technology. Routledge.

Shah, T. (2009). "Taming the Anarchy: Groundwater Governance in South Asia." Resources for the Future Press

Singh, A., et al. (2019). "Effectiveness of solar-powered water pumps in providing clean water to rural communities in India." Journal of Water and Health, 17(1), 1-12

Smout, I. K., & Norman, R. J. (2014). A review of water-lifting devices for irrigation. Renewable and Sustainable Energy Reviews, 29, 334-342.

Sørensen, B. (1978). Windmill technology. Pergamon Press. 8. Koutsoyiannis, D., & Mamassis, N. (2010). A review of the development of water wheels. Renewable and Sustainable Energy Reviews,

Zhang, Y., & Wang, X. (2019). A review of materials for water-lifting devices. Renewable and

Sustainable Energy Reviews, 101, 1-10.

Shah, T., et al. (2007). "Groundwater governance in the Indo-Gangetic and Yellow River basins: Realities and challenges." International Water Management Institute

Shah, T., et al. (2007). "Groundwater governance in the Indo-Gangetic and Yellow River basins: Issues and options." International Water Management Institute

EPA. (2010). Pneumatic Water-Pumping Systems. Retrieved from https://www.epa.gov/sites/default/files/2015-03/documents/pneumatic_water_pumping_systems.pdf

Hosking, R. J., & Usher, S. P. (2001). The application of pneumatic diaphragm pumps in the Southern African mining industry. Journal of Energy in Southern Africa, 12(1), 41-47.

Mendel, R. (2016). Compressed Air Systems: A Guidebook on Energy and Cost Savings. Springer.

Ustun, T. S., Deveci Ozkan, A., & Kurnaz, A. (2015). Comparative life cycle assessment of a solar water pumping system and a diesel water pumping system. Journal of Cleaner Production, 101, 132-143. doi: 10.1016/j.jclepro.2015.04.083

APPENDIX

3.7.1 Bill of engineering materials and evaluation

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4	1inch pipe (9ft)	Polyvinyl Chloride (PVC)	1	2600	2600
5	1/2-inch pipe(9ft)	Polyvinyl Chloride (PVC)	1	3200	3200
6	Pipe filling	Polyvinyl Chloride (PVC)	7	100	700
7	Battery		1	7000	7000
8	Motor		1	5000	5000
9	Cylinder		1	18000	18000
10	Cutting stone		1	2000	2000
11	Solar panel(50watt)		1	35000	35000
	Total				86000

3.7 machining and labour cost

S/N	COMPONENT	Machining and fabricating	QUANTITY	UNIT	TOTAL COST
1	1.5inch by 1/2inch square pipe (9ft)	Cast iron	1	2500	2500
2	12v battery		1	7000	7000
3	Bolt and Nuts	Mild steel	20	100	2000
4	1inch pipe (9ft)	Polyvinyl Chloride (PVC)	1	2600	2600
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