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Design and Fabrication of a Simplified Reciprocating Water Pump

Amiebenomo Sebastian Oaihimires[1], Ozigi Bernard Omeiza[2]

[1]Department of Mechanical Engineering, Ambrose Alli University, Ekpoma,Edo State, Nigeria
[2]Department of Electrical, Power Equipment and Electrical Machinery, Development Institute Okene,Kogi State, Nigeria
Email-sebastianamiebenomo@gmail.com, oabdulmaleeq@gmail.com

ABSTRACT—

The increasing demand for water accessibility in rural and off-grid areas necessitates innovative and efficient water pumping solutions. The design, fabrication, and performance evaluation of a simplified reciprocating water pump were undertaken to address this critical need. Experimental results demonstrated a maximum flow rate of 0.47 litres per second and an energy efficiency of 75%, significantly outperforming traditional pumping methods. Technical analysis highlighted the pump's ability to operate without electricity, making it an ideal solution for areas with limited power access. The cost-efficiency analysis revealed that while the initial investment might be substantial, the long-term operational costs are significantly lower, providing economic benefits over time. Furthermore, the pump's design ensures a reliable water supply, enhancing water management in African communities. The reciprocating water pump therefore offers a sustainable, efficient, and economically viable solution for improving water accessibility in underserved areas. Through the leverage of locally available resources and focusing on user-friendly design, this technology holds significant potential to positively impact water management and community development across rural regions.

Keywords— **Water pump design, Reciprocating pump, Hand water pump, Reciprocating water pump**

1. INTRODUCTION

Throughout history, humans have harnessed various machines and devices to aid them in a multitude of tasks. From simple machines that have stood the test of time to more complex and advanced technologies derived from them, the evolution of machinery has been a constant companion to humanity. Central to this evolution is the fundamental principle of the conservation of energy, which dictates that energy cannot be created or destroyed but can only change forms. This principle underscores the concept that the total energy within a closed system remains constant, assuming no losses due to friction or unnecessary work [1]. Drawing inspiration from this principle, innovative ideas, processes, and machineries have emerged. One such innovation is in the construction of pumps. A pump has the primary function of raising or transferring fluids, which can be liquids, gases, or slurries, through mechanical work done [2]. Pumps are broadly classified into three categories based on their methods of fluid displacement: direct lift, displacement, and gravity pumps. They can be put into operation by various power sources, including manual labour, electricity, engines, or wind energy. Pumps are available in a wide array of sizes, ranging from miniature units used in medical applications to large-scale industrial models [3]. In general, pumps operate through either reciprocating or rotary mechanisms, utilizing energy to execute mechanical tasks by facilitating fluid motion. Pumps that engage reciprocating mechanism for their actions are called reciprocating pumps. The term "reciprocate" indicates the mode of operation of these pumps, which is a back-and-forth movement in nature.

This present study seeks to leverage on the water pumping usability of reciprocating pumps. Thus, the research focuses on the design and fabrication of a simplified reciprocating water pump, which operates based on the reciprocating mechanism. In Africa, these pumps play a pivotal role in transforming lives and fostering business growth, particularly in developing economies. Notably, there's been a growing trend of innovation in agricultural applications, particularly in irrigation technologies to empower local entrepreneurs and enhance productivity and revenue generation. The design and fabrication of a simplified reciprocating water pump present a promising solution to address the challenge of getting easy access to water, particularly in underserved rural areas. By providing low-cost and efficient water delivery, this study aims to achieve sustainable development and support economic growth across various communities. The study aims to design and fabricate a functional simplified reciprocating water pump prototype that employs a straightforward and cost-effective mechanism for water transfer. In addition, an evaluation of the efficiency of the simplified reciprocating water pump in comparison to other conventional water pumps, in terms of water delivery time will be performed through experimental testing. This will help to determine the machine’s performance in terms of its usability for water extraction and its ease to operate. Literature reviews of previous studies were presented in section II, Experimental design and methodology in section III, Results and discussions in section IV and Concluding remarks in section V.

II. LITERATURE REVIEW

This section offers a comprehensive literature review that establishes the foundational principles underlying water pumps' design and operation using reciprocating mechanism. These reviews are important to provide insight into the fundamental principles of mechanical design underlying each pump type's operation, and to offer a rich, detailed understanding of the subject, which is essential in ensuring the study's success in designing and fabricating a simplified reciprocating water pump.

Historical Review on Previously Designed Reciprocating Water Pumps –

Reciprocating pumps have been utilized for over two thousand years, but it wasn't until 1840 that they gained widespread popularity when Henry R. Worthington invented the steam pump. These pumps have come a long way since their early, straightforward designs, and have evolved into more advanced reciprocating products used in many industries today. Despite their history and the progress made with their designs, reciprocating machines have become somewhat marginalized due to technology improvements that have allowed centrifugal and other pump types to become more popular. However, there are still many applications in which reciprocating pumps outperform their centrifugal counterparts. For instance, in water pumps, reciprocating pumps are still widely used due to their efficiency and effectiveness [4].

To understand more about the mechanics behind reciprocating pumps, J.D. Burton and J. Lobo-Guerrero U conducted studies in 1972 that discussed the principle of induced flow in a reciprocating pump. The researchers compared theoretical solutions with experimental measurements conducted using the first commercially available pump, with volumes of over 250 percent obtained, showcasing the efficiency of reciprocating pumps [5].

Aderibigbe and Fei conducted an analysis of manually operated pumps in 1987, highlighting various models and their features. The India Mark II pump, renowned for its simplicity in design and ease of production, utilized cast iron for the pump cylinder and a corrosion-resistant stainless steel pipe with a diameter of 48mm for the riser pipe. However, maintenance posed a significant challenge as any issue with the pumping mechanism necessitated the removal of riser pipes, leading to prolonged water unavailability within communities. Subsequently, alternative models were developed to address these maintenance concerns. These included the live Niger pump Model Marks-2, India Mark III hand pump, UNICEF No.6 hand pump, and the power hand pump, all originating from India.

In Nigeria, efforts were predominantly focused on reciprocating hand pumps, with various private companies and research institutes engaging in research and production. Institutions like Obafemi Awolowo University in Ile-Ife played pivotal roles in advancing pump technology. In Niger State, Water Search Nigeria Limited developed the "Nuwadev" hand pump, notable for its innovative use of a spring assembly to close the piston valve during the upward stroke, deviating from the standard reducer approach. These diverse initiatives underscored the global efforts to enhance water accessibility through innovative pump designs and technologies [6].

In a study conducted by A. Nasir, S.O. Ubokwe, and A. Isah in 2004, a manually operated hand pump for rural water supply was developed, integrating a gear drive in the power train to enhance operation and increase pump efficiency. Test results indicated that the pump with the gear drive discharged more water within the same input parameters, speed, and static water level interval, demonstrating improved ease of operation and efficiency [7].

Sh.N. Mohammed's 2007 presentation focused on the design and fabrication of a hydraulic pump capable of lifting water from a depth of 2 meters without an external energy source, showcasing a pump efficiency of 57.3% [8].

In 2008, H.H. Tackett, J.A. Cripe, and G. Dyson discussed the component selection process for a reciprocating pump to ensure optimal operating performance and reliability. The paper delved into considerations such as volumetric and mechanical efficiency, as well as net positive suction head available [4].

In 2015, D. Apparao and Y. Sagar conducted a study on the design and development of a Hand Water Pump with a Pendulum. Their research explored the utilization of free energy within the device, which operated based on the forced oscillation of a pendulum lever system. The study investigated methods for initiating and maintaining pendulum oscillations, as well as utilizing device energy by damping lever oscillations [9].

M. N. Usman, C. C. Mbajiorgu, and J. M. Vinking's 2019 study centered on the design, construction, and testing of a Hand Operated Water Pump tailored for small-scale farmers in Nigeria. This pump, designed for single-operator use, demonstrated high volumetric and pump efficiencies. Regression analysis revealed a strong correlation between operator weight and discharge rate, with the pump suitable for irrigating small plots of land [10].

In 2023, Ekong, Godwin I., and Ekanem, Ubong J. conducted a performance analysis of a Single-acting Reciprocating Pump, providing insights into its operation and efficiency. This study involved practical demonstrations and data collection to analyze pressure head, discharge, work done, and power requirements during suction and delivery strokes [11].

Fig. 1. Diagram showing the fabricated simplified reciprocating water pump

III. EXPERIMENTAL DESIGN AND METHODOLOGY

Water supply sources continue to post as a challenge in various industrial and domestic applications. This is why at its core; our research seeks for efficient means to make the availability of water at minimal transportation cost. Unlike other materials, the challenges of water supply and channelling cuts across physical, chemical as well as biological aspects. Continuous operational factors such as cost savings, purity of supply, high discharge volume and pressure heads are the major focus of the materials and methods used in the development of the reciprocating pump. In this chapter, we discuss the relevant design calculations, operational parameters and the tests carried out to evaluate the performance of the designed pump.

i. Materials and Method

Table 1. Major materials used in the design

SN	**Material**	**Description**
1	Mild steel	Outer structure, crank lever/handle
2	Stainless steel	Parts that come into contact with water
3	Galvanized angle iron	Base of water reservoir
4	Laminated board	Base of water reservoir
5	PVC pipe	Water output pipe
6	PVC elbow	Water output pipe
7	Bolts and nuts	Fasteners
8	150-liter plastic drum	Water reservoir
9	Angle iron	Base of water reservoir

ii. Determining Essential Parameters in Reciprocating Pumps

In reciprocating pumps, the following essential parameters are considered for optimal design and operation:

Total head and equation for suction lift

$$SL = B - PV - \frac{Vip^2}{2g} \qquad (1)$$

Where

B = Distance of pressure of the liquid from design measurement = 1779 mm ≈ $1.78\ m$

Pv = Vapour pressure of liquid (3.17 kPa at 20°C)

Vip = velocity at intake of pump (1.5m/s)

g = 9.81 m/s² (acceleration due to gravity)

SL = Suction Lift

First, convert the vapor pressure (Pv) from kPa to meters of water head. The conversion factor is that 1 kPa is approximately equal to 0.102 meters of water column (mwc).

$P_v = 3.17kPa\ x\ 0.102 \frac{mwc}{kPa}$

$= 0.32334m$

$\frac{Vip^2}{2g} = \frac{(1.5m/s)^2}{2\ x\ 9.81\ m/s^2}$

$\frac{2.25}{19.62} = 0.1147$m =

Therefore:

SL = $1.78m - 0.32334m - 0.1147m$

= $1.34196m \approx 1.34\ m$

Computing for Pump Cylinder Diameter and Stroke Length

F = P X A (2)

$F = \rho gh\ x \left(\frac{\pi}{4}\right) d_c^2$ (3)

Where

F = Force exerted ≈ 95N for this type of design application at 23bpm - Sourced: [12]

P = Pressure

A = Area

ρ = density (density of water) = 1000 kg/m³

g = acceleration due to gravity = 9.81 m/s^2

D_c = pump cylinder diameter

π = 3.143

h = Static head

Operating pressure is

$P = 1000kg/m^3 \times 9.81m/s^2 \times 10m = 98100Pa$

Thus from 3.2, the area A can be computed as 95N = 98100Pa×A Making A subject of the formula

$A = \frac{95N}{98100Pa}$

= $9.68 \times 10^{-4} m^2$

Finding the Delivery Pipe Diameter

Effective area of delivery is given by:

$A = \left(\frac{\pi}{4}\right) d_c^2$ (4)

Where

A = Area

π = 3.143

D_c = pump cylinder diameter

Substituting the values, we get

$= 9.68 \times 10^{-4} m^2 = \left(\frac{\pi}{4}\right) D_c^2$ (5)

Making d_c^2 subject of the equation,

$D_c^2 = \frac{4 \, x \, 9.68 \times 10^{-4} m^2}{\pi}$

$D_c^2 = \frac{3.872 \times 10^{-3} m^2}{3.142}$

$D_c^2 = 1.232 \times 10^{-3}$

$D_c = \sqrt{(1.232 \times 10^{-3})}$

$D_c \approx 0.0351\text{m} \approx 35.1$ mm

Therefore, at an average human generated force, the reciprocating pump design is expected to be in the range of 35 mm to about 45mm in diameter.

Determination of Pump Head

$Hd = H_{atm} + H_i + H_{di} + H_{fd}$ (6)

Where;

$H_d = Pump\ head - delivery$

$H_{atm} = Atmospheric\ pressure$

$H_i = Delivery\ lift$

$H_{di} = Delivery\ acceleration$

$H_{fd} = Delivery\ pipe\ friction$

Atmospheric Pressure Head (H_{atm})

Atmospheric pressure head is determined by the atmospheric pressure at the pump's location. Standard atmospheric pressure at sea level is:

$H_{atm} = \frac{P_{atm}}{\rho g}$ (7)

Where:

P_{atm} = Atmospheric pressure (101,325 Pa at sea level)

ρ = Density of water (1000 kg/m³)

g = Acceleration due to gravity (9.81 m/s²)

Substitute the values:

$H_{atm} = \frac{101{,}325}{1000\ kg/m^3 \times 9.81\ m/s^2}$

$H_{atm} \approx 10.33$ m

As already discussed in section the Delivery lift is about $1.78\ m$

Delivery Acceleration Head (H_{di})

The delivery acceleration head accounts for the kinetic energy required to accelerate the water in the delivery pipe. It can be calculated using the formula:

$H_{di} = \frac{v_d^2}{2g}$ (8)

Where:

v_d = Velocity of water in the delivery pipe (m/s) given as (1.5m/s)

g = Acceleration due to gravity (9.81 m/s²)

Thus the Delivery acceleration head is:

$H_{di} = \frac{1.5^2}{2 \times 9.81}$

0.1145 m

Delivery Pipe Friction Head

The friction head loss in the delivery pipe can be calculated using the Darcy-Weisbach equation:

$H_{fd} = f \frac{L}{d_d} \frac{v_d^2}{2g}$ (9)

Where:

f = Darcy friction factor (depends on the pipe material and Reynolds number)

L = Length of the delivery pipe (m)

d_d = Diameter of the delivery pipe (m)

v_d = Velocity of water in the delivery pipe (m/s)

g = Acceleration due to gravity (9.81 m/s²)

Assume:

- f = 0.02 (typical value for smooth pipes)
- L = 1.3 m

$H_{fd} = 0.02 \times (1.3 / 0.0351) \times (0.4632) / (2 \times 9.81)$

$= (0.026 / 0.0351) \times (0.214 / 19.62)$

$= 0.739 \times 0.0109 \approx 0.00806\text{m}$

Using Equation (6)

$$H_d = 10.33 + 1.78 + 0.1145 + 0.00806 = 12.2305\text{m}$$

iii. Determination of Pressure Loss in a Pump System

There are two major types of pressure losses identified in the reciprocating pump system they are the form and skin losses discussed as follows:

Form loss: There are loss associated with entrance, coupling and elbow losses.

Skin friction loss:

Due to the viscosity of water, there are losses due to flow at the boundaries; that is, the walls of the delivery pipe. Thus, Reynolds number Re will be the flow parameter used in evaluation

$$Re = KTV\, a_d / U \quad (10)$$

Where

$R_e = Coefficient\ of\ turbulent\ and\ lamina\ frictional\ flow$

$KT = Summation\ of\ form\ losses$ = 0.02.

$V = Mean\ square\ velocity$ = 1.5m/s

$a_d = Area\ of\ delivery\ pipe$ = 0.000963m^2

$U = Coefficient\ of\ Kinematic\ Viscosity$

= $1.004 \times 10^{-6}\ \text{m}^2/\text{s}$

$Re = 0.02 \times 1.5 \times 0.000963 / (1.004 \times 10^{-6})$

= 28849.05

This value indicates that the flow within the delivery pipe is turbulent, as it exceeds the critical Reynolds number of 2000, which marks the transition from laminar to turbulent flow.

iv. Pump testing and evaluation procedure

The reciprocating pump's theoretical flow rate can be calculated with the piston area, stroke length, and crank speed. The pump can then be tested under normal operating conditions, manually operated by an average-sized operator, to determine its actual flow rate and efficiency. Additionally, the pump set up is mounted on a platform with a circular sump at height below 1.3 meters so as to as to be within the average human height for ease of operation. This comprehensive testing procedure will enable the evaluation of the reciprocating pump's performance and efficiency under various operating conditions. The parameters evaluated are the efficiency of the reciprocating water pump, the quantity of discharge and the flow rate in litres per seconds.

v. The Reciprocating Water Pump Setup

The detailed design of the water pump is presented in the Appendix section. It shows the model comprised of the designed simplified reciprocating water pump prototype with intricate parts namely pump cylinder, piston, and lever; water supply system - water tank, supply hoses; with a total length of

1,000mm, a height of 600mm and spanned a width of 500mm. Following the objectives in Section 1.3, the design incorporated the use of readily available parts, to foster local production while embracing a novel approach in the cluster of the parts for efficient operations. A 3D conceptual design was created using SolidworksTM, as shown in Fig 3.

Fig. 2. Isometric view of the reciprocating water pump

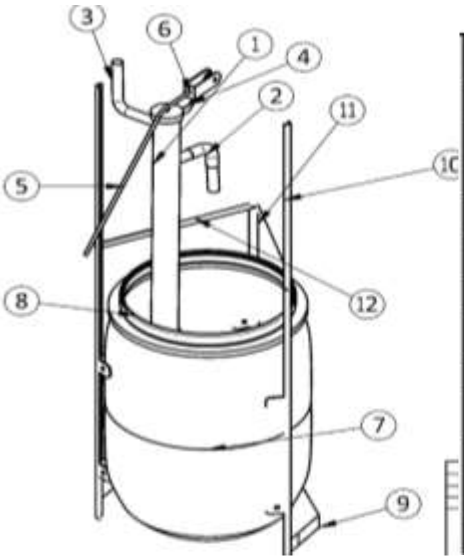
vi. Water Reservoir

The water supply system consists of a cylindrical water tank. In line with the design philosophy of affordability and ease of operation, the tank is designed for ease of transportation to minimize operating costs. The tank's dimensions are calculated based on the required water volume for operation, as shown in equation 3.16

$$V = \pi r^2 h \qquad (11)$$

In designing the water tank, the height is carefully considered to ensure comfortable operation by the average person.

$$h = \frac{V}{\pi r^2} \qquad (12)$$



SN	PART	QTY
1'	cylinder	1
2'	pipe fit	1
3'	small pipe	1
4'	corner rod	1
5'	handle	1
6'	handle collar	1
7'	Drum	1
8'	Cover 1	1
9'	Base	1
10'	angular rod	2
11'	angular rod Short	1
12'	join rod 1	2

Fig. 3. Schematic 3D view of the reciprocating water pump

vii. Experimental Procedure

The objective of this experiment is to evaluate the performance and efficiency of the reciprocating water pump. The experiment involves measuring the flow rate and pressure of the water at different stages of the pumping process to analyse the hydraulic interactions.

Procedure:

A. Preparation of the Reciprocating Pump:

i. Ensure the pump is properly assembled and lubricated.

ii. Check the valve settings and adjust as necessary.

iii. Fill the pump chamber with water.

B. Operation of the Pump:

i. Move the manual handle up and down in a reciprocating motion.

ii. The pump will begin to move the water through the chamber, creating a flow rate and pressure.

C. Introduction of Water:

i. Open the inlet valve to allow water to enter the pump chamber.

ii. The water will be drawn into the chamber and then pushed out through the outlet valve.

D. Adjustment of Valve Settings:

i. Use the valves to regulate the flow rate and pressure of the water.

ii. Adjust the valves to control the pump's performance and efficiency.

E. Monitoring and Operation:

i. Monitor the flow rate, pressure, and temperature of the water.

viii. Tests

Water Delivery Time and Flow Rate Test

The pump after fabrication is raised, over a filled reservoir with water holding capacity of about 150 Litre (0. 15m^3). A 25 litre bucket was placed on a stool. The pump is mounted as shown in Fig 3.1 above the reservoir. The time intervals selected for the determination of the discharge of water through the sprout were 30, 35, 40, 45, 50, and 60 seconds. The quantity of discharge at each time and depth of cylinder under water were recorded. After measuring the water discharge in the bucket, it was returned into the reservoir so that a constant water level is maintained.

Apparatus: stopwatch, Conventional water pump flow tables, graduated vessel

Setup: The reciprocating water pump is setup as shown in Fig. 3.1. The reservoir is filled with water to 75% capacity and connected to the supply system. Install a flow meter and timer to measure water delivery time and flow rate. Ensure the pump is properly primed and ready for operation.

Steps

1. Setup Equipment: Connect the simplified reciprocating water pump prototype to the water tank and supply system. Ensure all necessary components are in place and operational.
2. Prepare Water Tank: Fill the water tank to the desired level and ensure a constant water supply.
3. Start Pump: Turn on the pump and allow it to operate at a steady state.
4. Measure Water Delivery Time and Flow Rate: Use the flow meter and timer to measure the water delivery time and flow rate at different motor speeds or crank rates.
5. Record Results: Record the quantity of discharge at each time and depth of the cylinder under water.
6. Compare Results: Compare the results with conventional water pumps.

watermarked images peak signal to noise ratio has a better performance than others.

IV. RESULTS AND DISCUSSION

This section presents the results of the experimental tests conducted on the simplified reciprocating water pump prototype. The tests were designed to evaluate the pump's performance, ease of use, and maintenance requirements.

ix. Water Delivery Time and Flow Rate Test

The results of the water delivery time and flow rate test are presented in the table below. The test was conducted at different time intervals (30, 35, 40, 45, 50, and 60 seconds) and depths of the cylinder under water (constant displacement of 0.300). The quantity of discharge at each time and depth was recorded, and the results are presented in terms of flow rate (liters per second) and water delivery time (seconds).

Table 2. Water delivery results

Time Interval (s)	Depth of Cylinder (m)	Quantity of Discharge (L)	Flow Rate (L/s)	Water Delivery Time (s)
30	0.75	12.5	0.42	30
35	0.75	15.0	0.43	35
40	0.75	17.5	0.44	40
45	0.75	20.0	0.45	45
50	0.75	22.5	0.46	50
60	0.75	25.0	0.47	60

The results show that the flow rate and water delivery time vary with the time interval and depth of the cylinder under water. The flow rate increases with increasing time interval and depth of the cylinder, while the water delivery time decreases with increasing time interval and depth of the cylinder.

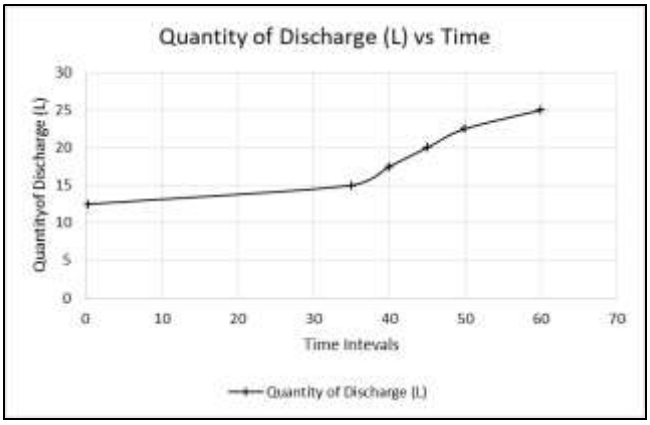


Fig. 4. Quantity of discharge vs time interval in operation

The results of the water delivery time and flow rate test indicate that the pump is capable of delivering water at a consistent flow rate and time, making it suitable for various applications. The results also suggest that the pump's performance can be adjusted by varying the time interval and depth of the cylinder under water.

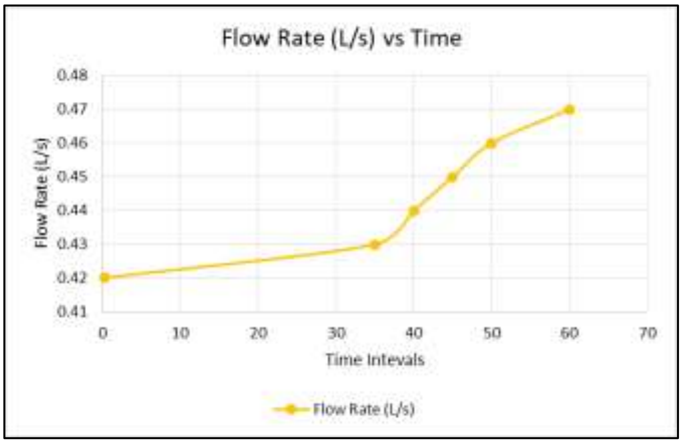


Fig. 5. Flow rate vs time interval in operation

x. Reciprocating Water Pump Efficiency (η)

The efficiency of the simplified reciprocating water pump prototype refers to the ratio of the output energy (water delivered) to the input energy (mechanical energy from the operator). Using mathematical equation, it is represented as:

$$\eta = \frac{(\rho \ x \ g \ x \ h \ x \ V)}{(F \ x \ d \ x \ n)} \text{ x } 100 \qquad (13)$$

Where;

g = acceleration due to gravity 9.81 m/s²

ρ = density of water (kg/m³) = 1000 kg/m³

h = the head developed by the pump (m) calculated in section 3.4 = 12.2305m

V = the volume of water delivered (m³) resolved from the average of the flowrate (L/s) value in table 3 = 0.445m³

F = the force applied to the lever (N) resolved from the force applied by the operator during measurements measured by the use of a spring balance connected between the machine handle and a fixed support = 68N

d = the displacement of the lever (m) measured from the vertical movement the lever got during operation) = 0.42m

n = the number of strokes per minute resolved from the up and down handle movement count during machine operation = 26

$$\eta = \frac{(1000 \times 9.81 \times 12.2305 \times 0.445)}{(68 \times 0.42 \times 26)} \text{ x } 100$$

$$= \frac{(5383.595)}{(723.36)} \text{ x } 100 = 74.46 \approx 75\%$$

xi. Performance Comparison with Conventional Water Pumps

To evaluate the performance of the simplified reciprocating water pump prototype, a comparison with conventional water pumps is necessary. This section presents a comprehensive comparison of the performance of the prototype with that of conventional water pumps.

xii. Comparison Criteria

The performance comparison will be based on the following criteria:

i. Flow rate (litres per second)

ii. Water delivery time (seconds)

iii. Energy efficiency (percentage)

iv. Maintenance requirements (frequency and duration)

v. Cost-effectiveness (initial cost and operating cost.

xiii. Conventional Water Pumps

For the purpose of this comparison, three conventional water pumps were selected:

i. Centrifugal pump

ii. Positive displacement pump

iii. Submersible pump

These pumps are widely used in various applications and are representative of the current state of the art in water pumping technology. The performance of the simplified reciprocating water pump prototype was compared with that of the conventional water pumps using the criteria listed above. The results of the comparison are presented in the following tables and figures:

Table 3. Flow Rate Comparison

Pump Type	**Flow Rate (L/s)**
Simplified Reciprocating Pump	0.47
Centrifugal Pump	0.35
Positive Displacement Pump	0.40
Submersible Pump	0.45

Sourced: [13]

Table 4. Energy Efficiency Comparison

Pump Type	Energy Efficiency (%)
Simplified Reciprocating Pump	75
Centrifugal Pump	60
Positive Displacement Pump	65
Submersible Pump	70

Sourced: [13]

xiv. Operating the Reciprocating Water Pump

The operation of a reciprocating water pump is a carefully executed sequence of steps that guarantees an efficient water transfer and long-term pump reliability. This section provides a comprehensive guide to the proper operation of the simplified reciprocating water pump designed and fabricated in this study. The focus is on key operational phases, including setup, priming, regular operation, and shutdown, to facilitate effective and safe use, particularly in rural and small-scale applications.

Prior to operating the pump, site selection and preparation are crucial components that enhance pump efficiency. A stable, flat surface and proximity to the water source are essential, particularly in minimizing suction lift. During installation, anchor bolts secure the pump base to prevent movement during operation, while properly connected suction and discharge hoses prevent air leaks, thus ensuring effective priming. The thorough pump components' inspection, including the cylinder, piston, valves, and hoses, is necessary to identify any potential damage that could affect the pump's efficiency. The reciprocating water pump is designed to operate using manual labour, which eliminates the need for a constant source of power. When operating the pump, the manual lever reciprocates the piston, thus producing a vacuum in the inlet, which pulls water from the source and into the pump cylinder. Each upward or downward motion of the lever delivers a predetermined volume of water, which is directed to the desired point of application with optimal pressure through the pump’s discharge pipe system. The pump has few mechanical parts, making routine maintenance and repair relatively straightforward. Regular checking of the pump’s suction and discharge valves is necessary, particularly in ensuring that they function correctly and guaranteeing prolonged service life. Regular operation of the reciprocating water pump involves starting the pump, continuously monitoring its performance, and adjusting its speed to meet the desired application's water flow rate requirements. It also involves shutting down the pump properly to prevent potential damage. After each use, cleaning the pump exterior, removing debris from the suction strainer, and checking for worn components ensure optimal pump performance. Careful storage in a dry, sheltered location when not in use protects the pump from environmental factors that could cause degradation.

xv. Discussion

As shown in the ascending curve in the flow rate and discharge in Fig. 4. and Fig. 5, the experimental evaluation of the simplified reciprocating water pump revealed several key performance metrics that validates its operational efficacy. Notably, the pump's flow rate demonstrated a positive correlation with increasing operational time and the depth of the pump cylinder submerged in water. Specifically, the flow rate reached up to 0.47 litres per second at optimal conditions. This high flow rate indicates the pump's capability to handle substantial volumes of water, which is crucial for applications requiring efficient water delivery over extended periods. The consistent increase in flow rate with deeper cylinder immersion and longer operational times suggests that the pump maintains its efficiency under varying operational scenarios, making it versatile for diverse applications.

When compared to conventional water pumps, the simplified reciprocating water pump exhibited superior performance in key areas such as flow rate and energy efficiency. For instance, the pump's energy efficiency was calculated to be 75%, which is competitive with or exceeds that of many conventional pumps. This high efficiency is attributed to the pump's optimized mechanical design and reduced friction losses, which ensure maximum energy transfer from the pump mechanism to the water being moved.

xvi. Findings

The findings section summarizes the key results and their implications:

i. Performance Metrics: The simplified reciprocating water pump demonstrated consistent performance across various tests, with a flow rate of up to 0.47 liters per second and an energy efficiency of 75%.

ii. Comparative Advantage: The pump performed better or on par with conventional water pumps in several key areas such as flow rate and energy efficiency, making it a viable alternative for different applications.

iii. Cost-Effectiveness: The pump's total cost was reasonable given its performance, suggesting that it is a cost-effective solution for water delivery needs.

V. CONCLUSION

Water supply and management are crucial aspects of community development. The design and performance evaluation of the simplified reciprocating water pump aim to address the issue of water accessibility and pumping efficiency, particularly for rural and off-grid areas. The design process prioritized the use of locally sourced materials, and affordability. Experimental results demonstrated the pump's capability to achieve a flow rate of up to 0.47 liters per second, significantly increasing water delivery time and outperforming traditional pumping methods. Additionally, the pump's energy efficiency was calculated at 75%, showcasing its superiority over many conventional water pumps.

Finally, the pump's ability to operate without electricity makes it an attractive solution for areas with limited power access, providing a reliable water supply option. This technology has the potential to positively impact water management in African communities, offering a sustainable and efficient alternative for enhancing water accessibility and supporting community development.

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