



RESEARCH ARTICLE

DESIGN AND DEVELOPMENT OF A MANUAL PUMP FOR AGRARIAN COMMUNITIES

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ABSTRACT

Pumps efficiency depends largely on the rotating impellers to provide rotary motion for constant supply of water for either domestic or industrial purposes. More so, all manually operated pumps uses the same principles of operation. However, to maintain the kinetic energy required to pump fluid to the desired destination, energy is required. The stress and fatigue associated with manual operations generally creates epidemiological conditions among users of locally fabricated manual pumps mostly propelled by hands. Again, the ease at which some of these pumps fail in these rural communities calls for urgent attention. The aim of this project was to design, fabricate, test run and deliver a locally made manual pump with a higher efficiency, ease of use and low fatigue to peasant farmers. Also the project can be used as a teaching aid for undergraduate students. The method adopted in the actualisation of the set goals include the re design of the impellers and the volutes using locally available materials. Also, to reduce the effects of muscular skeletal disorders among famers, bearings are also incorporated. The results when compared with the existing hand propelled pump showed a remarkable difference in the volume of water discharged with respect to time and a significant drop in fatigue level. The overall ease of use minimised the effects of muscular skeletal disorders among farmers.

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INTRODUCTION

Over the years, it had been difficult for farmers in the rural areas of Delta North Senatorial District to produce farm crops, especially vegetable fruits all year round. This is as a result of lack of infrastructural facilities such as dams, irrigation systems and other agro based facilities that may aid food production in large quantities in the area. Worst still is the absence of electricity to power some of the water pumps giving to some selected unmerited farmers as political patronage. In addition to some of these problems, government at various levels make unfulfilled promises to these peasant farmers so as to get their votes during elections. After victory, little or budgetary allocations are made to address these infrastructural decay. However, after a careful analysis of this ugly trend, a manually operated hand propelled pump that will assist the coastal people of this region in their farm work was conceived, designed, developed and tested.

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This water pump was designed to serve dual purposes; in that it will assist the farmers of the region to overcome their challenges by producing their desired agro based products all year round in a reliable, economic and most efficient manner. On the other hand, the pump shall be used as resource materials for teaching and demonstrating the principles of operation of pumps at under graduate levels. Over the years, pumps had been studied extensively, in one of such studies, (Nasiru, 2004) observed that the major problems associated with some imported pumps include availability, reliability of the pumps at all times, high level of fatigue and low efficiency. The paper added that the cost implications of maintaining some of these pumps are on the high side. Consequently, some communities remain without water for some reasonable time when there exists a fault. In order to solve the perennial water crisis in a community in India, (Waghmare, 2015) designed and developed a manually operated spiral tube water wheel pump. The mode of operation of the wheel pump is the use of spiral action in the pumping of water to the desired destination. In a similar work, (Uche, 2014) designed, fabricates and tested a dual power water pump capable of lifting fluid from one destination to another. The paper added that a flow rate of 14

litres and 24 litres per minute was achieved when operated manually and operated using DC motor respectively. As a way of providing water all year round for rural dwellers in Bangladesh, (Islam, 2007) designed and developed a foot pedal pump for low lift irrigation. This pump was constructed using available local materials and was able to lift water from shallow depths of about 2 meters to irrigate small plots like vegetables and seed beds. The ergonomics and economics of water pump production and maintenance was the main consideration of (Shamshad Ali, 2012) in the design and development of compound lever handle for hand pump. The paper added that the design and the inclusion of hand lever overcame the high level of fatigue experienced by users of manually operated water pumps for domestic and industrial applications. Users of pump fabricated locally often complain about the high energy level required to operate the water pumps, to this end, (Faruk, 1995) pointed out that a better technology that requires less manual power be introduced into pump designs and manufacture to eliminate the health problems associated with use of the facility (Samantha Marshal, 2011) Extensively studied the water problems in Kenya and came out with gamut of variables largely responsible for water crises in Kenya. The paper added that the problem identified if corrected will reduce water crisis incidence in that region (Manager of Assets Management, 2011). Studied the classes of pipes, the sizes and the materials required for optimal performance of pumps. The paper added that the essence of the study was to achieve the 100 years economic life of span of water facilities installed in southern Australia. The data obtained from this work was published for national use. (Younes, 2008) Identified hydraulic problems as the major reason why pump fails in pumping stations. The paper sought for the sources of these hydraulic failures with the aim of providing solution to enhance the reliability of the system. In a related study (Dhamellya, 2013) carried out an investigation on the remote and immediate causes of failures in bearings with emphases on railway bogies. However, the study provided a list of remedies to these failures applicable in all engineering systems including bearings used in pumps.

MATERIALS AND METHODS

The methods adopted for this research work include preliminary investigation of the myriads of problems associated with rural water supply for both agricultural and domestic purposes. The conventional manually operated pumps often imported and donated to rural dwellers were studied extensively to determine their mode of failures with the intent of establishing their mean time to failure. The components in the system with low reliability were identified, studied, redesigned and developed with locally available materials to guarantee effectiveness, ease of use, availability and maintainability at all times. The various components of the pump were designed and developed using standard best practices in line with the governing equations. The designed and the selected parts were assembled as required to form a system now referred to as FUPREPUMPI. The developed pump was subjected to a performance evaluation test so that we can ascertain and compare the performance attributes with the existing pumps. The following items were used for this test, they are, and the equipment/apparatus used for this

performance test were the complete pump assembly, a 200 litres bucket, a stop watch, a graduated jug and a 20 litres bucket. The pump was assembled with a 100 litres underground tank for water storage. With the stop watch set at 10 seconds intervals, the pumps lever was activated until the time elapsed. At this point the water is allowed to drip until the last drop. The time, stroke length, the rate of discharge, the cadence the head and the number of strokes were recorded. More so, the governing equations for the development of the manually operated pump are presented below for each parts used for fabrication.

Power required

To determine the power required for the hand pump operation, equation 1 will be considered:

$$P_w = E \cdot n \tag{1}$$

where: P_w = power (Watts), E = output energy, n = cadence in strokes per second and $E = mg\Delta H$ 2

where: m_w = mass of water lifted per cycle, g = gravity, ΔH = head

$$m_w = V \rho_w \tag{3}$$

V = swept volume per stroke, ρ_w = density of water
At the suction point the hydrostatic pressure Δp will be

$$\Delta p = \rho_w \times g \times \Delta H \tag{4}$$

Piston Design

Let the area of the piston facing the foot valve be A_p .

$$A_p = \frac{\pi d_p^2}{4} \tag{5}$$

Area of the piston facing up be a_p .

$$\text{Hence, } a_p = A_p - a_r \tag{6}$$

Where a_r is the area of the piston rod. $a_r = \frac{\pi d_r^2}{4}$
 d_r = piston rod diameter.

The piston rod diameter can be obtained using

$$d_r = \left(\frac{4F_w}{\pi \sigma_{pa}} \right)^{\frac{1}{2}} \tag{7}$$

where, F_w = Weight of water, σ_{pa} = allowable stress.

Weight of water can be calculated using this equation

$$F_w = (A_p S + a_{rm} \Delta H) \rho_w g \tag{8}$$

Where, ρ_w = density of water (1000 kg/m³), g = acceleration due to gravity, S = stroke length, a_{rm} = rising main cross sectional area and ΔH is the pump head.

Force acting on the piston during downward stroke will be

$$F = F_w + F_E \tag{9}$$

Where, F_E is the minimum effort required

The force required to hold up a column of water according to Joseph L.(2010) can be calculated as $F_h = \rho_w g h A_c$ 10

Where F_h = Force, ρ_w = density, g = acceleration due to gravity, A_c = cylinder cross sectional area.

From literature, actual delivery (Q), the piston diameter (d_p), the stroke length (S), the number of strokes per minute (N), and the volumetric efficiency (η_v). The volumetric, or hydraulic, efficiency is an indicator of the actual discharge over the swept volume per stroke.

Swept volume per stroke, $V = A_c S$ 11

Where S = piston stroke and V = swept volume.

RESULTS

The result obtained from the test showed a remarkable significant difference from the other existing pumps as shown in the table below. As the discharge rate improved tremendously, the fatigue experienced by operators dropped significantly. This is evidenced by the long operations carried out by operators with ease. The table below shows the performance data of the pump as recorded. For a mechanical system like this, a performance evaluation test was undertaken to be able to examine and ascertain the effects of force on the structural members of the pump, it was also used to analyze the discharge rate per stroke of the pump during performance. The performance test only commenced having ensured the flow of water from the spout.

Table 1. Performance evaluation data of FUPREPUMP1

S.No.	No of stroke	Discharge rate	Stroke per second	Head(m)	Time in seconds (s)	Stroke length (m)
1	5	215	0.5	1	10	0.16
2	10	435	0.5	1	20	0.16
3	15	645	0.5	1	30	0.16
4	20	860	0.5	1	40	0.16
5	25	1030	0.5	1	50	0.16
6	30	1245	0.5	1	60	0.16

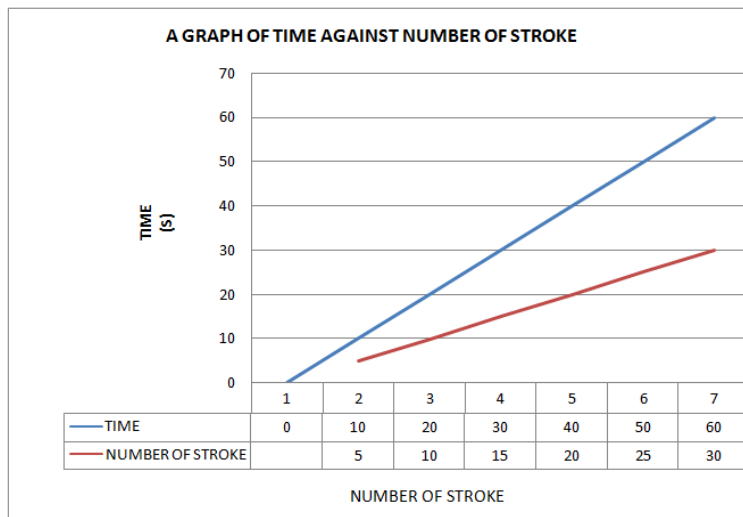


Fig.1. Graph of time against number of stroke

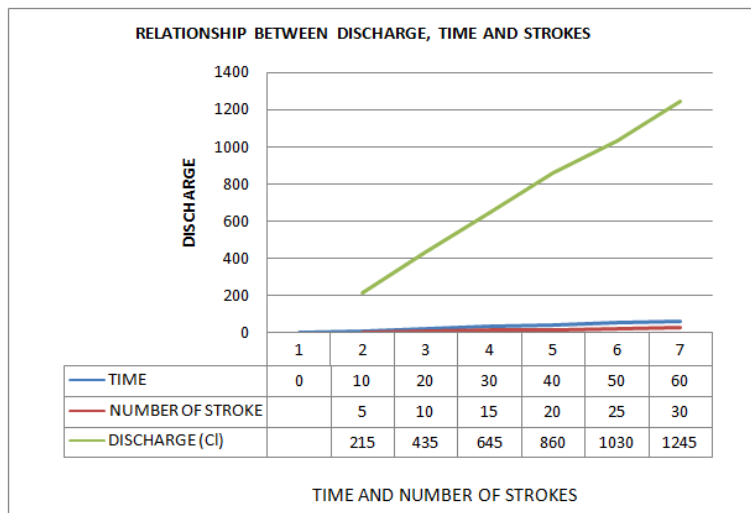


Fig. 2. Relationship between discharge, time and number of stroke

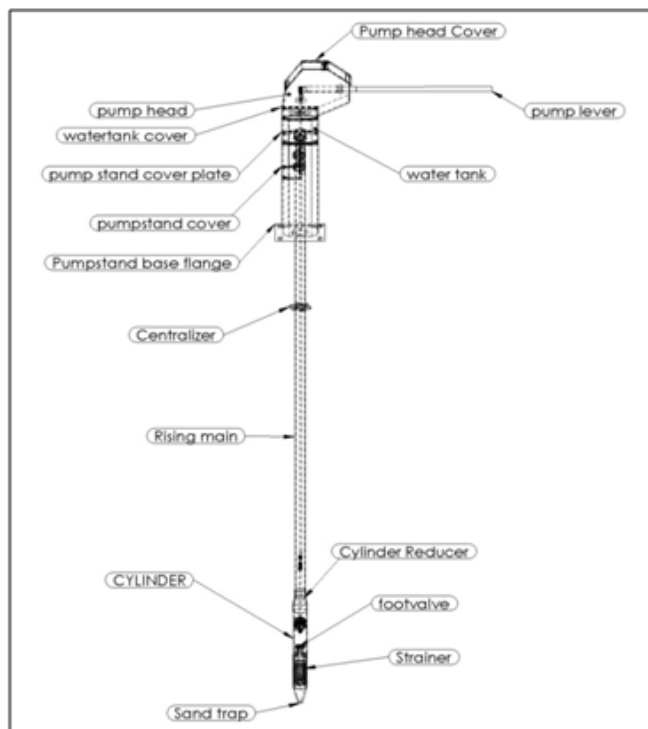


Figure 3. pump design configuration showing various components used

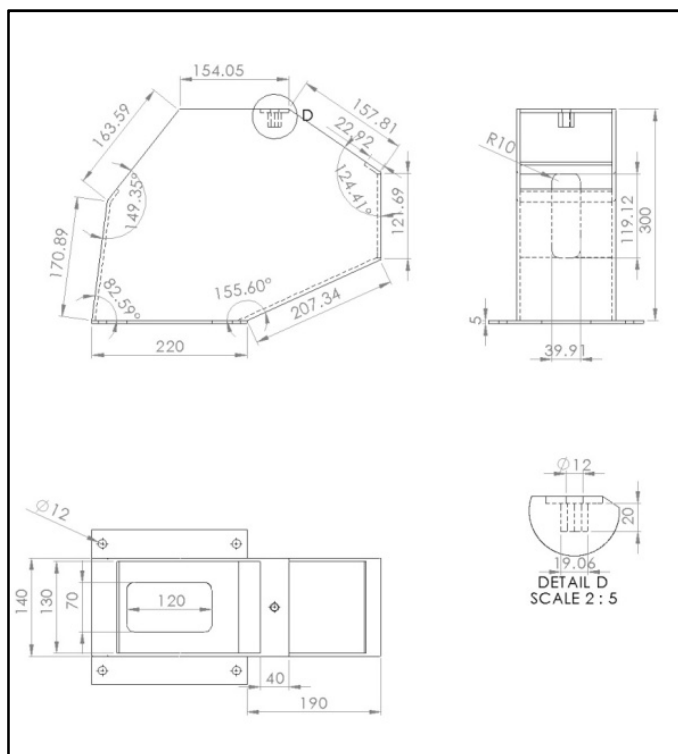


Figure 4. Detailed engineering drawing of some parts used for assembly

Figures 3 and 4 below shows the pump design configuration as carried in the work. Figures 1 and 2 show the graphical representation of the time against stroke length and discharge against time and number of stroke respectively. Similarly, figure 3 shows the detailed drawing of various components assembled and arrangement in the developed water pump.

CONCLUSION AND DISCUSSION

The major aim of this project was to design and develop a manually operated pump that can be used locally to provide communities with clean water and thus serve as means of supply water to local farmers for irrigation purposes. This to a greater extent had been achieved. Adequate investigation was carried out on some existing but obsolete manual pumps, and some latent design criteria such as availability and reliability of the pumps at all times were improved upon. The result obtained from the performance evaluation test showed that the pump discharge rate is directly proportional to the pump speed and is entirely independent of the pressure against which the pump is delivering. Also, some major changes which often affect water quality over time were affected by introducing some safe and affordable engineering that can be sourced locally. The current innovation as observed can serve as a guide for students in tertiary institution to gain practical knowledge on the basic principle behind the operation of manual pumps. In addition to this, government at all levels are encouraged to invest and promote the mass production of this novel pump for its rural dwellers most especially now that the economy is trying to diversify. However, certain questions beg for answers, thus, how soon will government key into this developmental programme? If soon, will government not use it as political settlements to those who may not need the pumps as done in the past? With this, policy makers, nongovernmental organisations, philanthropist and other well meanings Nigerians are encouraged to come and address the plight of this farmers in order to guarantee food security in our remote communities and Nigeria at large.

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