DEVELOPMENT AND EVALUATION OF A DOUBLE PEDAL OPERATED PISTON PUMP

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ABSTRACT

A study was undertaken to design and construct a low-lift double pedal, double cylinder operated pump for use in small irrigation project areas. The double pedal pump was operated by one adult man power.The pump discharge rate, speed, maximum lift, discharge length, suction head and efficiency were determined.The average discharges of the pump ranged from 10.1 to 1.6 litres per minute were noted against heads of 0.35 to 2.1m. It was observed that the discharge rate depends on effort applied by operator and suction head. Efficiency of the pump was 57 percent against a head of 0.35 m. The double pedal pump can be constructed using local materials and skill. It would be suitable to irrigate small plots like vegetables and seed beds with less physical effort.

Keywords: Pedal pump, Suction head, Discharge rate, Efficiency, Discharge length, Irrigation

1. INTRODUCTION

Scarcity of water resources is one of the main challenges in the world and it is considered as one of the limiting factors for economic development especially for agriculture.With the supply of irrigation water, most of the agricultural lands can be brought under cultivation of high yielding crops. The productivity of the land now producing food under natural condition can be increased considerably by the application of supplemental irrigation (Islam *et al.,* 2007).

Irrigation system is aimed at increasing and improving agricultural yield, particularly in moisture-deficient environments.It plays a vital role as a leading input because the productivity of other inputs such as improved seed and fertilizers largely depend on the availability of ensured water supply in the fields.

In Africa, where the majority of farmers are still smallholders with one to three hectares (ha), small-scale private irrigation schemes (SPRI) are likely to bring higher returns per hectare than government-led schemes (Takeshima *et al.,* 2010). SPRI benefits farmers in a variety of ways. It usually leads to higher profitability of various crops (Yaro, 2004). It also benefits farmers (including female farmers) by producing more food crops in the “slack” period of rain fed agriculture (Ogunjimi and Adekalu, 2002). SPRI enables households to irrigate garden vegetables, water livestock, and undertake microenterprises (Westby *et al*. 2005).

In Nigeria different manually operated water pumps for low lift irrigation are used especially in the north where proper mechanization are employed including irrigation application. The pedal pump seems to be an appropriate irrigation technology in rural areas, where labours are abundant and most of the farmers are poor (Iqbal, 2010). Such kind of irrigation technologies are operated and maintained by farmers themselves from their own capital for producing crop in the small fragmented lands. The average small farm sizes spreading over a number of scattered plots are unsuitable to irrigate with a large size of stream (Islam *et al.,* 2007).

The socio-economic condition of Nigerian farmer does not permit large scale irrigation investment. Hence, introduction of pedal pumps for the irrigation of small scale farms can play a vital role for increasing food grain production in Nigeria. Capital intensive technology like deep tubewells and shallow tubewells are beyond the purchasing capacity of the poor farmers. However, they can afford labour intensive technologies such as pedal pumps, hand pumps, rower pumps, treadle pumps and many more due to their lower cost.

The current success of manually operated pumps can be explained in terms of factors like appropriate design, low cost, effective marketing, and high cash returns (Orr *et al.,* 1991). Some researchers (Obijiaku, 2011; Sermaraji, 2014) had focused their endeavour on the development of low lift labour-intensive devices and had succeeded in developing pumps such as treadle pump, rower pump, wheel pump, diaphragm pump, blower pump and many more. But these pumps still are not popular in the country due to their low efficiencies and discharges, short service lives, high friction losses and many other mechanical troubles.

According to survey report (Faruk and Pramanik, 1995) many users of these devices complained about their health troubles and desired to get a better technology requiring less manual power and mechanical troubles. High initial maintenance cost, non-availability of spare parts, requirements of large irrigable land and similar other restrictions make the poor illiterate farmers reluctant to use deep tubewells and shallow tubewells. But double pedal pumps can be locally produced at low-cost with all the spare parts available in the country. Thus, the objective of this study was to design, develop and test a double pedal piston pump with a relatively high discharge rate and improved ergonomics for safe operation.

2. MATERIALS AND METHODS

2.1 Design Considerations

For efficient design of the double pedal pump, factors such as workability, safety of the operators, ease of maintenance, and minimal cost of machine by ensuring that construction materials are sourced locally were considered.

2.2 Design calculations

Area of piston (A)

The area of piston was determined using equation 1.

$$A = \frac{\pi d^2}{4} \tag{1}$$

Where,

$d = diameter\ of\ piston$

Volume of Cylinder (V)

$$V = \frac{\pi d^2 h}{4} \tag{2}$$

Where,

$d = diameter\ of\ cylinder$

$\mathrm{h} = \text{height of cylinder}$

Pump discharge

$$Q = \frac{Volume\ \ of\ water\ collected\ L/min}{time\ spent} \tag{3}$$

Pump speed

$$P_s = \frac{numberofstroke}{timespent}, \text{in stroke/min} \quad (4)$$

Pump efficiency

$$E_P = \frac{\text{acctual volume}}{\text{theoretical volume}} \times \frac{100}{1} \quad (5)$$

2.3 Description of the Developed Pedal Pump

The pedal pump consists of frame, cylinders, pistons seal, lever, non-returning valve, spring and pedals. Fig. 1 gives the developed pedal pump.

Frame

The two design factors considered in determining the material required for the frame are weight and strength.The frame was constructed with 25 mm by 25 mm mild steel angle iron. The frame provides firm support for the entire assembly. Based on anthropometric considerations, the overall dimension of the frame was chosen as 580 mm x 500 mm x 900 mm.

Cylinders

The cylinder is a chamber where water is collected temporarily from the inlet pipe after suction before going out through outlet. Cylinders from internal combustion engine of Peugeot 504 were used.The internal and external diameters of the cylinder were about 88 mm and 93 mm respectively.

Pistons

The piston which has a length of 71 mm and diameter of 87 mm was sealed with a circular rubber seal and glued to the surface of the piston.The piston reciprocates in the cylinder to create a partial vacuum and suction pressure where the water is sucked in at higher pressure and expelled through the outlet pipe.

The Manifold System

The manifold which comprises of pipe, valve, nipple, elbow, non-returning valve was created at the lower part of the pump and also at the side which helps in the suction and delivery of water.

Pedals

The pedals were made of angle iron connected with a rod, which was used to move the piston. Operator forces the pedal downward with his foot which in turn causes the piston to move downward. The size of the pedal was 410 mm x100 mm and was found to be comfortable to place a foot on it.

Principle of Operation

The pump is easy and requires minimal energy to operate. During the upward movement of the piston, a negative pressure [vacuum] is created in the cylinder, which opens the non–returning valve and water enters the pump chamber of the cylinder. High pressure generated in the pump chamber as the piston moves downward closes the non-returning valve. This pressure is due to compression of water which in turn opens the valves and water flows from the suction to delivery side of the cylinder. Water which accumulated in the cylinder discharges as the process is repeated.

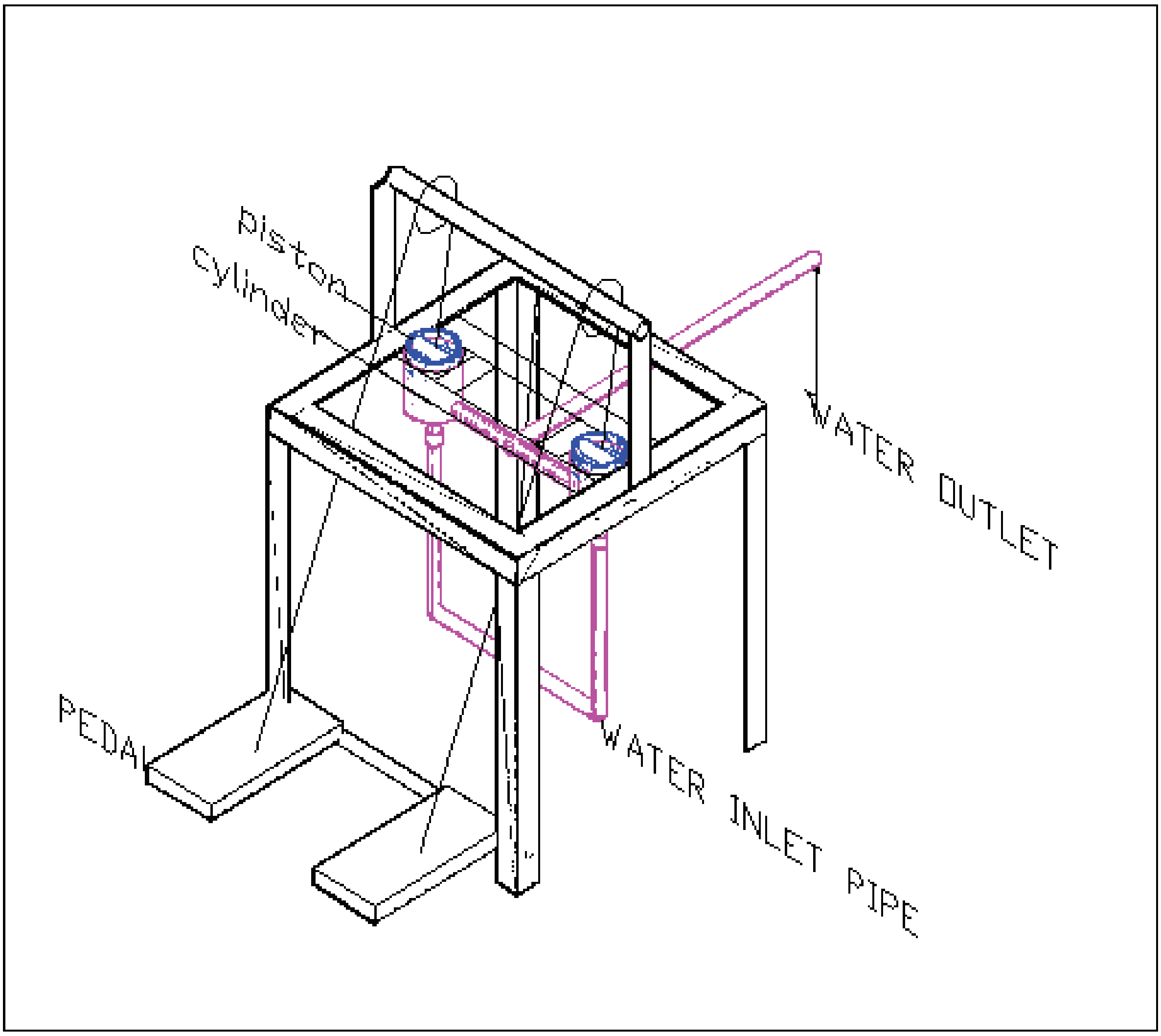

Fig. 1: Isometric View of the Double Pedal Pump

3. Experimental Procedure

The pedal pump was tested at soil and water Engineering laboratory, Agricultural and Bioresources Engineering Department, Michael Okpara University of Agriculture, Umudike.

The pump was tested at different suction head and was operated manually by an average sized man under the normal operating conditions. The pump was set up on a plat form over a bucket of cross sectional area of $0.07m^2$ and height of 1m. The depth of water in bucket was varied by reducing the water level. The number of strokes that an operator was capable to give in one minute was termed as stroke per minute (spm). For each operation, one litre of water was collected using a measuring cylinder.Each test was carried out in three replications and in each case the operation period, number of stroke and volume of water were measured. The discharge rate in litre per minute was determined.

Pump Performance

The performance of the pedal pump was evaluated based on the following parameters:

i Pump Speed

During the operation of the pump, the number of strokes were counted for a known time. The time was recorded using a digital stop watch. Pump speed was calculated using equation 6.

$$Pump\ speed = \frac{number\ of\ strokes}{time\ (\mathrm{min})} \quad (6)$$

ii Pump Efficiency

The efficiency of pump was calculated from the following equation:

$$E_p = \frac{\text{actual volume}}{\text{theoretical volume}} \text{ x} \frac{100}{1} \qquad (7)$$

Where; theoretical volume = stroke x cross sectional area of the pump

$$Actual\ volume = \frac{volume\ of\ water\ collected\ in\ litres\ per\ minute}{number\ of\ strokes} \qquad (8)$$

4. RESULTS AND DISCUSSIONS

.The depth of water level (i.e. suction heads) varied from 0.35 to 2.1 m depending on laboratory facilities and the stroke length of the pedal pump. Maximum discharge length, pump efficiency and mean pump speed of the double pedal pump obtained were 5.8 m, 57% and 60 strokes/min, respectively. The double pedal pump has a maximum discharge rate of 10.1 litres. Table 1 show that increase in suction head leads to a decrease in discharge rate. Islam *et al.* (2007) recorded pump efficiency of 46.53 % for a single cylinder and piston. Higher pump efficiency obtained in this study was attributed to the additional cylinder used. The constructed double pedal pump was found suitable for operation under a suction head up to 0.35 meters for several minutes (10 minutes). The operation of the double pedal pump was found more comfortable and suitable. It was quantified by the maximum operation time during which an average sized man can operate the pump without much physical troubles.

Table 1: Effect of Suction Head on Discharge Rate

Time(minute)	Number of stroke	Suction head(meters)	Pump speed(stroke/min)	Discharge (L/min)	Delivery head(m)	efficiency%
1	62	0.35	62	10.1	2.6	57
2	120	0.70	60	16.2	3.0	52
3	180	1	60	24.3	3.8	46
4	244	1	61	29.4	3.8	46
5	300	1	60	35.5	3.8	47
6	360	1	60	43.6	3.7	47
7	420	1	60	51.7	3.8	47
8	478	1	60	58.8	3.8	47
9	536	1	60	63.9	3.8	46
10	593	1	59	72.0	3.8	47

Table 2: Performance Test Data of the Double Pedal Pump

Time(minute)	Number of stroke	Suction head(meters)	Pump speed(stroke/min)	Discharge (L/min)	Delivery head(m)	efficiency%
1	62	0.35	62	10.1	2.6	57
2	120	0.70	60	16.2	3.0	52
3	180	1	60	24.3	3.8	46
4	244	1	61	29.4	3.8	46
5	300	1	60	35.5	3.8	47
6	360	1	60	43.6	3.7	47
7	420	1	60	51.7	3.8	47
8	478	1	60	58.8	3.8	47
9	536	1	60	63.9	3.8	46
10	593	1	59	72.0	3.8	47

5. CONCLUSION

The pedal operated piston pump was constructed to reduce various waterborne diseases and facilitate the production of crops through irrigation during the dry season. The pump was tested to find out the discharge rates and efficiencies at different time intervals. The result from the test shows that the pump has volumetric efficiency of 57 %. It could pump water at a maximum of 10.1 litres per minute. The pump is capable of drawing water from a depth of one meter effectively and therefore expected to be suitable to supply irrigation water for small farm lands.

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