Determining the Role of Treadle Pump Technology for Transforming Irrigation Practices in Rural Areas

Adeogun, E. O and M. Y. Kasali
Department of Land and Water Management Engineering,
National Centre for Agricultural Mechanization, Ilorin, Nigeria.

ABSTRACT

The study on the role of treadle pump technology in transforming irrigation practices in rural areas was carried out in National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. This study was centred on determining the performance test evaluation of the technology by the research staff of Land and Water Management Engineering Department. The treadle pump popularly known as super money maker was a manual operated pump that could pull water from shallow well, surface water such as pond, river or any other water sources for irrigation purposes.

The performance evaluation test carried out included the following performance indices such as: discharge capacity, suction lift, efficiency and power requirement in terms of brake horse power. Optimally, the treadle pump discharge about 1.2 l/s at 2.5 m suction lift with efficiency of 89.7 %.

From the analysis of data obtained for the pump, for a given number of stroke, measured discharges were obtained at different delivery heads of 1 m to 6 m for six times at different suction head with a given average value as test data. Results showed an inverse relationship between the discharge and delivery head, in which the discharge decreases with increase in delivery head. The discharge varied from 1.3 l/s to 0.8 l/s for 1 m and 6 m head respectively. The force required to operate the treadle increases as the height of lift, thereby leading to consequent rise in power consumed to operate the treadle over a rising height.

From the analysis of test carried out, the pump could produce a discharge between 0.7 to 1.2 l/s with a suction lift up to 2.5 m. The pump was however recommended for use and to be extended to farmers practising irrigation in rural areas for more effective use of water for agricultural production.

Keywords: *Treadle pump, Irrigation, Discharge capacity, Total head, Efficiency, Power.*

I. INTRODUCTION

The challenge of developing manual pumps for irrigation purposes in rural areas in Nigeria has given way to a growing awareness of the need to make irrigation available to small scale farmers with a view of improving an agricultural growth strategy which will go a long way to reducing hunger and poverty. Over the past decade, a small but significant revolution has been taking place in small-scale irrigation in the developing world with the introduction of treadle pump technology [1]. This simple human-powered device can be manufactured and maintained at low cost in rural workshops in developing countries such as Nigeria.

The introduction of treadle pump technology seems to be ideal for the small farmers to be successful in small scale irrigation in rural areas since large scale developments have failed to come up to expectations. The evidence available to date indicates that there is much to be gained by taking up this technology [2]. Treadle pump works by drawing water from a river or shallow ground water and discharging it into a canal for gravity irrigation or by using pressure to force it from a reservoir into a pipe leading to sprinklers or hoses. Of all irrigation systems available i.e. surface, sub-surface, sprinkler, trickle or drip irrigation, it is surface irrigation system that is by far the most common in rural areas of the country and practically the only system used by small-scale irrigation farmers.

Treadle pump is now being regarded as an attractive technology, this is because of the relative simplicity in the mode of its operation. This technology is also cheap to operate and maintain and also easy to repair due to availability of its spare parts unlike conventional diesel pump that require certain technical competence with cost of maintenance [3]. This technology is increasingly popular among smallholder farmers that have access to the benefit of small-scale irrigation system. With the possibility of having access to surface water orunderground water such as dug out well, the treadle pump can be owned, operated and managed by one household or an individual in rural areas for ease of accessibility of water and that the required lift is relatively small.

A. Background to the Treadle Pump

The treadle pump was invented in the late 1970s by a Norwegian Engineer, working in Bangladesh named Gunnar Barnes [2]. The development and promotion of this work was sponsored latter by Lutheran World Federation and

International Development Enterprises (IDE). Since then this technology has been disseminated in many parts of the industrially developing world from Asia to Africa [4].

In the last 20 years, the design has undergone a number of modifications and refinement in order to deal more effectively with different types of water source.As described, [5] the transfer of the technology that involved the modification to make the pump more suitable for open wells, which are common in some places than the shallow tube wells.

As summarised in [5] the advantages and benefits of treadle pump which includes ease of operation, low cost, simple construction, adaptable and of high capacity among others. The performance of treadle pump operation are based on the force required to operate the treadle and the power demand as human workload to determine how long it is possible to operate it.

The force required to operate the treadle is determined by pressure head of the column of water to be lifted and the area of the piston, or plunger disc as ascertained by [6]. Hence, the force required on each treadle has to exceed F which is given mathematically below

$$F = p.a = (\rho g L)(\pi d^2/4) \quad (1)$$

Where ρ is the density of water, g is the acceleration due to gravity, L is the height of lift and d is the diameter of the cylinder.

$$F = 7705 d^2 \mathrm{L} \quad (2)$$

While the power demand is determined from the mechanical energy for pumping which is the product of the force on the plunger and the distance the plunger moves. Thus for each stroke, the energy required E is given by the equation

$$E = Fl \quad (3)$$

Where l is the distance moved by the plunger (i.e. stroke length),

Substituting for F, the energy equation can be re-written as

$$E = 7705 d^2 L l \quad (4)$$

The power consumed depends on how quickly the plunger is operated. For operator working at n cycles/min for a twin cylinder pump, the power (P) would then be

$$P = 2En/60 \quad (5)$$

Which simplifies to

$$P = 257 d^2 l L n \quad (6)$$

The most important irrigation methods in terms of their wide spread use and adaptability to various water lifting devices are furrow, basin and border. The basin and furrow are considered as more efficient water application techniques under small scale irrigation and are therefore considered the most suitable to irrigation using treadle pump. The choice of any method for water application using the pump depends on the season, the size of the farm, topography, soil physical properties, the nature and yield of the water source and the crop to be irrigated. Whatever the irrigation method used, the amount of water applied and the frequency of application are important considerations.

The evidence available to date indicates that there is much to be gained by taking up this type of technology. The reported impacts as outlined by [2] on farming practices have been substantial and include the followings:

- Increased land area under irrigation
- Reduced work time compared with bucket irrigation
- Full irrigation of fields, resulting in improved crop quality
- Reduced frequency of irrigation to two or three times per week
- Less strenuous irrigation work compared with bucket irrigation
- Additional and new crops grown each season
- Increased number of growing circles as crops are able to grow faster with full irrigation.

The objective of this study was to carry out testing and performance evaluation of treadle pump technology at the centre (NCAM) preparatory to the extension to farmers with a view of transforming irrigation practices in rural areas.

II. METHODOLOGY

The methodology employed in carrying out the testing and evaluation of treadle pump technology are classified under the following categories.

A. Operation of the Pump

The money maker pressure irrigation pump available for testing and evaluation was known as treadle pump. The performance test evaluation was carried out in National Centre for Agricultural Mechanization (NCAM), Ilorin by the Engineers in the Department of Land and Water Management Engineering.

B. Treadle Pump Operational Procedure

The treadle pump consists of two cylinders usually made from a steel plate fitted with two pistons side by side and a chain over a rocket bar connects the two pistons so that when one piston is being pushed down, the other one is coming up. Each piston is connected to a treadle which is

pedalled with the feet of an operator – like pressing the pedals on a bicycle. A pipe connects the pump to the water source which is about 32 mm in diameter.

A special very thick-walled hosepipe was used (to avoid collapsing of hose during suction lift) as the inlet hose attached by rubber strips with an inlet filter so as to filter the water and helps with priming the pump. A delivery hose pipe of 25 mm in diameter was attached to the outlet pipe which takes the water from the pump to where it is needed. The upward movement of the pistons pushes water through a second valve into a delivery pipe. This valve closes on the downward stroke to stop the flow from reversing. In this way it is possible to maintain a pressure in the delivery pipe that can be used to deliver water.

C. Priming and its limits

Priming is achieved first before a pump is set for use. Priming is more or less a process of removing all the air from the suction pipe and the cylinders whereby volume of water fill up the available space in the pump. This pumping of water into the pump is achieved only when the piston has moved a considerable distance and the pressure have dropped enough to be below the suction pressure and so open the inlet valve to allow water into the pump. When the pump is primed and running normally, the whole cylinder is filled with water and the seals are wet, so the air volume will disappear and the pump would start pumping.

D. Basic Components of the Pump

The basic components of the treadle pump are the cylinders, the pistons, pump manifold, non-return valves and the treadles as shown in fig. 1. The basic design and operating principles have been clearly illustrated by [7]. These components works simultaneously for successful operation of the pump. If there is any mal-function of any part, it disrupt the whole process of pumping water.

E. Definition of Parameters

The following parameters are used to define the testing and evaluation procedure used for the pump. These are Total Head, H(m); Delivery Head, H_d (m); Suction Head, H_s (m); Theoretical Discharge, Q_t (l/s); Measured Discharge Q_a (l/s); Displaced Volume, V_d (l); Measured Volume, V (l).

a) Total Pumping Head

This is the total height through which the water must be lifted from source to delivery point. It is referred to as the sum of the suction lift and the delivery head. If the suction lift is 4 m and the pump delivers a 7 m head, then the total pumping head is 11 m.

b) Measured and Theoretical Discharge

There are two forms of discharge determined during the course of the testing. These are measured discharge and theoretical discharge. Measured discharge is a given volume of water that is measured over a time in a given number of strokes of pumping (cadence i.e. the frequency with which the treadles moves up and down) while the theoretical volume is determined from the area of the cylinder and the height of the stroke in the pump.

c) Piston Stroke Volume

This is the volume of water lifted during each stroke of the pump. It can be calculated by multiplying the area of the piston by the piston stroke length.

III. RESULTS AND DISCUSSIONS

Extensive testing was done by the Engineers of Land and Water Engineering Department and the results are outlined. In Table 1, the treadle pump specification was outlined with the test data in Table 2. The test was carried out over different delivery heads of 1 m to 6 m for six different times for each height at different suction head. An average value was then determined as expressed in Table 2. It was indicated that the output from a pump depends on a variety of factors, [5]. These includes suction lift, cylinder diameter, variations in internal friction, occasional air leaks in the installation, hard filters, skill and care of the installation team, weight and agility of the operator.

Optimally, the treadle pump discharge about 1.204 l/s at 2.5 m suction lift with efficiency of 89.7 %. From this indication, the treadle pump has a high discharge capacity for its high efficiency. Treadle pumps are pressure pumps, the cylinder diameter was 121 mm but the cylinder length and hence the stroke length was slightly shorter. The pump was reported to produce a discharge between 0.5 – 1.2 l/s with a suction lift up to 2.5 m

From the analysis of data obtained for treadle pump in table 2, for a given number of stroke, measured discharges are obtained at different delivery heads of 1 m to 6 m at different suction head. Results showed an inverse relationship between discharge and delivery head, in which discharge decreases with increase in delivery head. The discharge varied from 1.28 l/s to 0.837 l/s for 1 m and 6 m head respectively.

The force required to operate the treadle increases as the height of lift increased, thereby leading to consequent rise in power consumed to operate the treadle.

IV. OBSERVATIONS AND CONCLUSIONS

During the cause of the pump testing, it was observed that higher discharges can be achieved using heavier operators and increasing the speed of pumping. The heavier operators would be able to exploit the treadle pump that requires more effort,

they would be also to use them at greater suctions. It was also observed that the pump do become hard to operate at suction lift greater than 6 m.

On the treadle pump, it is possible for operators to move their position along the treadles, so that they can change the force needed on the pistons while maintaining a steady and comfortable foot force. This movement also means that the pump can accommodate operators of different weights, each finding a suitable and comfortable pumping position. This is an important aspect of pumping. It can be much less tiring when operators can change their position, rather than trying to produce a particular force at a fixed position on the treadles.

From the analysis of test performance carried out on treadle pump, it is however, concluded that the pump be made available for farmers to use especially in rural areas for irrigation of their farm for availability of water source. Treadle pump can be used for large farm because of its high discharge capacity.

V. RECOMMENDATIONS

Taking into consideration the objective of this study, this study also aims at bringing into focus any observable design defects and operational difficulties that could be encountered during the course of the operation of the pump. For the design and fabrication of improved treadle pump for rural use and the subsequent usage of the pump at the centre preparatory to their extension to farmers, the following recommendations are outlined.

- The cost of owing the treadle pump by small-holders and low income earners is justified. The inherently low cost of the treadle pump allows many of the ability to obtain and maintain the pump.
- Non-traditional manual pump powered by peddling is preferred to diesel pump or electrically operated for its maintenance cost. Operator stands on the pump, holding on to handle and feet pedal the treadle.
- The treadle pump is ideal for pumping water from wells, rivers or lakes. It is however extremely suitable for varying environmental locations. The treadle pump can pump effectively up to 7 m in depth.
- The treadle pump is highly effective in pumping water in the range of 0.6 to 0.8 l/s with a lift of 4.5 m. This pump can easily pump 15 gallons per minute in moderately low elevations and less higher elevations.

VI. ACKNOWLEDGEMENT

The work reported here forms part of a study programme sponsored by National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria on some pumps made available to the centre with a view of making preparation of their extension and subsequent usage by the small-holder farmers in rural areas in the country.

This study was carried out in NCAM Irrigation Research Field with due acknowledgement to the Executive Director of the Centre and the Engineers of the Department of Land and Water Management Engineering for their unflinching support in the course of the study.

VII. REFERENCES

[1] Batchelor, S, 1996. Treadle pumps - the Cambodian experience. Waterlines, 14 (4), 19-22

[2] Lambert, R A and Faulkner, R D, 1991. The efficient use of human energy for micro-scale irrigation. Journal of Agricultural Engineering Research 48, 171-183

[3] Shah, T, Alam, M, Dinesh Kumar, M, Nagar, R K and Mahendra Singh, 1999. Pedal pump and the poor: social impact of a manual irrigation technology in South Asia.

[4] Perry, E and Dotson, B, 1996. The treadle pump - a technology adapted to the needs of small farmers. GRID 8 (March 1996), 6-7

[5] Stickney, R E, Piamonte, V, de Sagun, Q and Ventura, I, 1985. Human-powered pump for low-lift irrigation. Paper presented to American Society of Agricultural Engineers Summer Meeting, 1985. ASAE Paper No. 85-5054.

[6] Chancellor, F and O'Neill, D, 1999. Gender-sensitive Irrigation Design: Gender considerations relating to treadle pump adoption: experiences from Zambia. Report OD 143 (Part 3), HR Wallingford, Howbery Park, Wallingford Oxon, OX 10 8BA, UK.

[7] Elson, R and Shaw, R, 1993. Technical Brief No. 35 / Low-lift irrigation pumps. Waterlines 11 (3), January 1993, 1518

Table 1. Treadle Pump Specification

SPECIFICATION	TREADLE PUMP
Type of Operation	Manually operated
CYLINDER	
Cylinder Type	Double
Cylinder Height	15.2 cm
Cylinder Diameter	12.1 cm
Cylinder Effective Height	7.2 cm
PISTON	
Type of Piston	Double
Piston Stem Length	-
EFFICIENCY	
Max. Pump Efficiency	90 %
DISCHARGE	
Measured Discharge	1.06 l/s
Theoretical Discharge	1.154 l/s
VOLUME	
Measured Volume	13 litres
Displaced Volume	0.805 l/s
BREAK HORSE POWER	
Max. Brake Horse Power	0.12 Hp

Table. 2 Test data on Treadle Pump

Delivery head (m)	1	2	3	4	5	6
Suction head (m)	2.0	1.9	2.0	2.0	2.0	2.0
Total head (m)	3.0	4.0	5.0	6.0	7.0	8.0
Displaced volume (lt)	0.805	0.805	0.805	0.805	0.805	0.805
Measured volume (lt)	13	13	13	13	13	13
Time (s)	11.5	11.4	11.6	11.5	12.3	14.5
Stroke (N)	18	18	19	18	18	18
Theoretical discharge (l/s)	1.28	1.289	1.270	1.284	1.176	0.837
Measured discharge (l/s)	1.15	1.146	1.118	1.131	1.055	0.736
Efficiency (%)	89.7	88.97	87.95	85.97	89.7	88.9
BHP (hp)	0.05	0.067	0.083	0.104	0.093	0.089
Required Force (N)	112.81	225.62	338.43	451.24	564.05	681.58
Power Consumed (Watts)	25.44	51.14	79.93	101.77	118.99	121.9

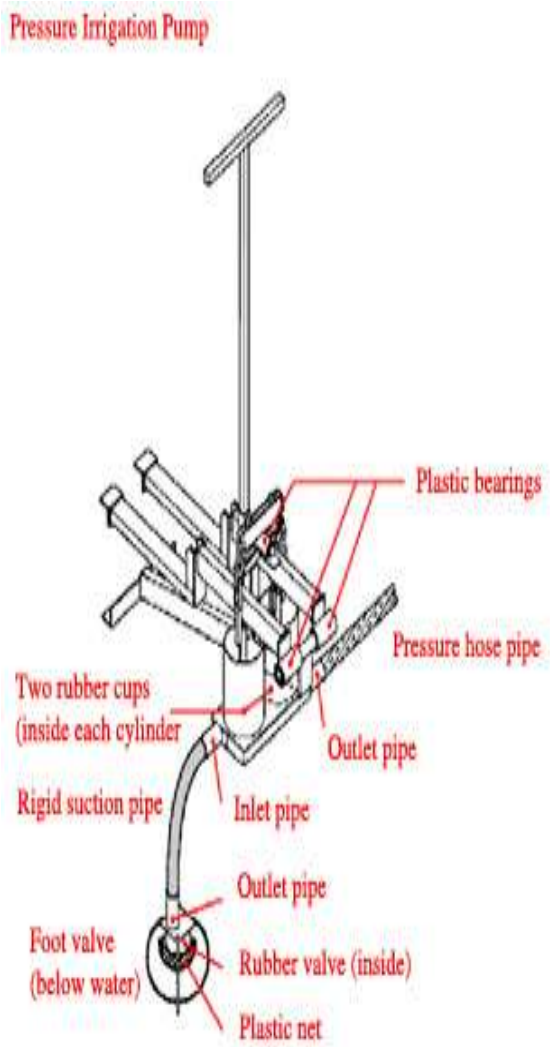

Figure 1. Basic Components of a Treadle Pump

Figure 2. Isometric Projection of a Treadle Pump