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Research Article

Modification of Rope and Washer Pump to Engine Operated for Irrigation in South Western Oromia, Ethiopia

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Abstract

Suitable methods of water lifting and distribution are the most important aspects that determine the efficiency and success of an irrigation system. The rope and washer pump, a water-lifting device made with appropriate technology, has been effectively used in a number of developing nations all over the world. Engine operated rope pumps are one application of the "rope and washer" pumping principle, driven or powered by an electrical, petrol or small diesel motor. The aim of this study was to modify the rope and washer pump to engine operated for small-scale irrigation applications in southwestern Oromia, Ethiopia. The modification of the rope and washer water pump was undertaken with the intention of solving the suction head problem that rural people are facing during the dry season for crops and vegetable farming at the group or household level. Engine-operated rope and washer pump efficiency is mainly affected by engine horsepower for the used head and pipe diameter. The performance of the modified rope and washer pump was conducted using two different diameters of PVC pipe (2" and 4 "), as well as two discharge heads (6 m and 8 m). Using a 5 hp engine, the maximum head and pipe diameters achieved for this study were 8 m and 4 inches, respectively. The maximum efficiency of the pump was 2.532 l/sec and 12.178 l/sec using 2 and 4 inch pipe diameters, respectively, at an 8 m head.

Keywords

Engine Operated, Head, Irrigation, PVC Pipe, Pump, Rope and Washer

1. Introduction

Agriculture in Ethiopia is dominated by smallholder rain-fed systems but, low and erratic rainfall limits productivity and food security. Consequently, investment in small-scale irrigation has been identified as a key poverty reduction strategy [1]. Recent estimates indicate that the total irrigated area under small-scale irrigation in Ethiopia has reached to 853,000 hectares during the last implementation period of PASDEP-2009/10 and the plan set for development of small scale irrigation is 1,850,000 hectares, which is planned to be achieved by the end of the five years growth and transformation plan (GTP) [2]. In noticing that farming is the primary occupation in rural areas, many organizations have worked to increase crop yield through improved irrigation techniques [3]. Reliable irrigation techniques have been shown to increase crop yields between 100%-400% [4]. The resulting increase in grain volume translates to increased sales and income, and allows farmers to cultivate higher-value crops, adopt new technologies, and increase financial returns. Despite the benefits of irrigation, too few farmers have a steady source of irrigation due to the financial

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limitations of acquiring commercial irrigation technologies [5]. Suitable methods of water lifting and distribution are the most important aspects that determine the efficiency and success of an irrigation system.

The rope pump is based on an ancient Chinese technology, which was introduced in the 1990s to Central America. Over the past decade efforts have been made to transfer the technology to various parts of Africa [6]. In Ethiopia this process started in 2005. At present more rope pumps have been produced in Ethiopia than in any other sub-Saharan country [7]. The basic rope pump is usually installed to conform even when principally in use for irrigation [8]. Modifications to basic designs may be worthwhile [9]. Increased productivity, like garden irrigation it was observed that several families started irrigation on small plots. Good performance data on how various design modifications are performing in the longer term would help in identifying the best variations in design [10].

Engine operated Rope Pump is one of the application of the 'rope and washer' pumping principle, driven or powered by an electrical, petrol or small diesel motor [11]. The main application of this pump is as a deep well irrigation pump for small scale irrigation. When farmers have access to shallow wells with a water table of no more than 7 m, pumping is usually done with suction pumps that are powered by a diesel or gasoline engine [12]. For pumping from deeper wells, submersible electrical pumps are often used. However many small farmers in developing countries have no access to electricity and alternatives such as a generator sets with a submersible pumps or long-shaft diesel pumps are expensive and complex to operate and maintain [13]. The engine driven rope pump is a low cost alternative for making productive use of water from deeper wells for irrigation.

The pump part of an engine operated rope pump is similar to that of a hand rope pump. Critical parts will be adapted to the higher load and PVC tubing and pistons are larger. The rotating shaft of the pump is connected with the shaft of the engine with V belts, using a large pulley transmission to adjust the RPM of the engine to the low RPM of the rope pump [14]. Where there is access to electricity the pump can be driven by an electric motor, or else it can be driven by a small diesel or gasoline engine. As in the case of the hand rope pump, the basic model of the motorized pump cannot pump higher than just below the pump shaft, which makes the pump most suitable for low pressure irrigation. To pump to tanks of 3 to 5 m high, an additional post must be added. Engine driven rope pumps are recommended for depths up to 60m [15]. The pump will be produced locally, using simple techniques and materials that are locally available. The engines are either purchased on the local marked or imported.

The water lifting method to the field for irrigation in the country and in Oromia too is mostly traditional [16]. The water is transported to the field with the help of bucket; water points and area to be irrigated are far apart; the ground and/or river water is at deeper position to convey to area to be irrigated. The existing rope and washer is also due to its low delivery head, it is not appropriate to convey water to the field and it need modification. Also its power source is human power. From the field observation the users need engine operated rope and washer pump. In addition some accessories or parts of rope and washer are not available in the market everywhere abundantly. This study intention to replace, parts of rope and washer pump by the material that can be available locally. Therefore, the aim of this study is to modify the rope and washer pump to engine operated technologies for small scale irrigation to solve the problem delivery head that rural people are facing during the dry season for crops and vegetable farm in group or household level.

2. Materials and Methods

2.1. Materials

The materials used for manufacturing of the pump were PVC pipe of two inch and four inch, rubber washer (piston), Ø8 mm and Ø10 mm nylon rope, 2"and 4" Tee sockets, 4"and 6" reducers, 5 hp engine, belts, pulley, sheet metal, round bars, flat iron, and various bolt and nut size. The instruments used for data collection were stopwatch and 60 Liter water container.

Important parameters related to engine operated rope and washer pump

Head the discharge rate is inversely proportional to the head of water.

Pipe diameter as pipe diameter increases there is more discharge rate obtained.

Engine horsepower the more diameter of pipe used for pumping and more head considered there should be high engine horsepower required.

Working principles of the engine operated rope and washer pump

An engine operated rope pump pushes water from the bottom of a well and less flow speed of river at rive side using rope with rubber washer (seal) attached on rope [17]. As engine starts on, drive wheel start turning and rope pump works by creating a seal inside the riser pipe and pushing the water upward. When the drive wheel is turned by engine power, friction allow the rope and washers (seals) to travel up from the riser pipe and down into the well, directed by guide box at the bottom of the well. After the washer travel through the guide box they enter the riser pipe. As the washer enters the riser pipe there is a water level between the bottom of the riser pipe and the surface water levels which become trapped and forced upward then drain water out.

Parts of engine operated rope and washer pump

Rope: - Rope comes in many sizes, materials, colors and with many different properties. The important thing about rope for a pump application is its water absorption and its elasticity [18]. Strength is not an issue because it is extremely rare for a pump rope to handle more than 10 pounds. Elasticity is important because a rope that will stretch when under a working load or when wet will decrease the tension, therefore limiting the necessary friction with the drive wheel. Absorption is critical for two major reasons. The first being sanitation and prevention of bacterial growth. A rope that absorbs water may stay wet for extended periods of time, allowing for bacterial growth. The second reason is because of the added pumping weight that should be avoided [19].

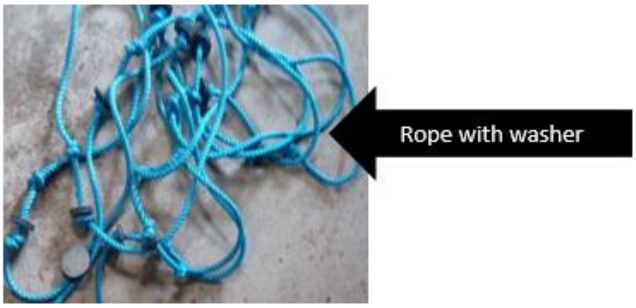

Figure 1. The Rope.

Pipes: - The piping is used as the cylinder in the piston cylinder concept of the rope pump design [20]. As the rope (with some sort of seals) passes upward through the pipe, the trapped water is forced to ground level and exits via the out spout.

Washers: - for the evaluation of the pump rubber sheet was used to make the washer. The washers should be fit with the riser pipe and force water up towards the surface.

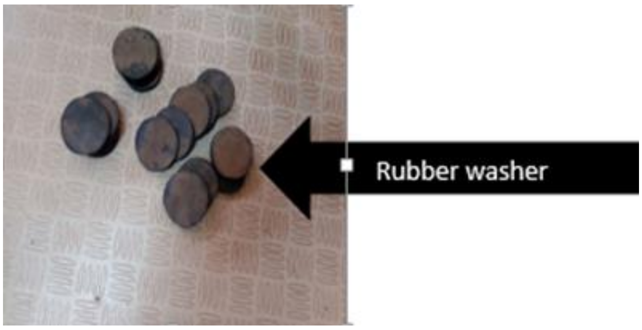

Figure 2. The washer.

Bottom Guide: - it is the backbone of the pumping system that directs and guides the circulation of rope and washes through the pipe and on driven wheel which contains flat pulley, which made from alumuliem shaft, slid bearing and round bar.

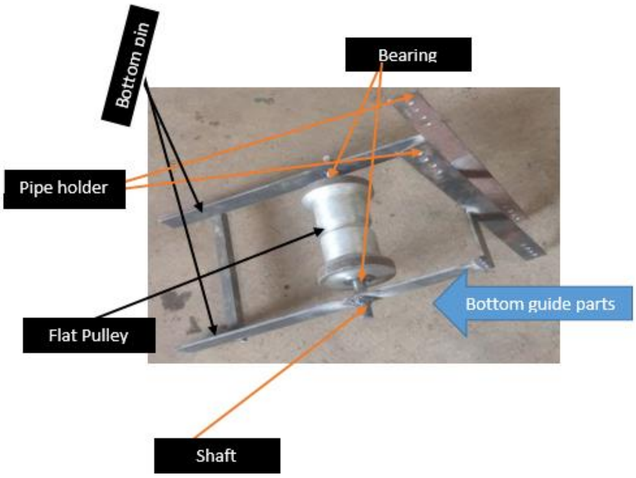

Figure 3. The rope and washer pump bottom guide.

Figure 4. The modified engine driven rope and washer pump.

2.2. Methods

Description of study area

The study was conducted and evaluated at Jimma zone Dedo district Waro Kolobo Kebele on Gilgel Gibe river at different discharge and heads.

Treatments and Experimental design

The treatments considered for the experiments were two different diameters of PVC pipe and two discharge head. The two PVC pipe diameter used were two inch and four inch diameters with five replication test.

Possible modifications done for this study

a) Replacing parts by locally available material such as flat driver wheel from sheet metal.
b) Improved guide of rope and washer pump from aluminum shaft to minimize contamination.

Parameters estimated:

Pump discharge

The pump discharge in m^3/s was calculated by dividing the amount of water filled to the known volume by the measured time.

The discharge or capacity of the pump was calculated by

$$Q = \frac{V}{T}$$

Where Q = V/T discharge of the pump, L/s
V = volume of water, L
T = time required to fill

Total head

Two level of depth (6 m and 8 m) was considered.

PVC pipe diameter

Two level of pipe diameter (2 inch and 4 inch) was considered.

The collected data and field test considered parameters were:

1) Static head of the pump
2) Discharge
3) Capacity of the modified Rope and washer pump
4) Time taken to fill the known volume container

Data management and statistical analysis

The collected data were organized and analyzed using Simple descriptive statistics.

3. Results and Discussion

The collected data were analyzed at different pressure head and with different pipe diameter.

Result analysis for test 1

Table 1. The effect of head difference on discharge rate at 2 inch pipe diameter.

Variable	Mean	SD	C.V	Minimum	Maximum
PD1	2.0000	0.0000	0.0000	2.0000	2.0000
H1	6.0000	0.0000	0.0000	6.0000	6.0000
H2	8.0000	0.0000	0.0000	8.0000	8.0000
T1	17.830	1.1286	6.3297	16.500	19.500
T2	23.776	1.5038	6.3250	22.000	26.000
Q1	3.3740	0.2136	6.3311	3.0700	3.6400
Q2	2.5320	0.1574	6.2158	2.3100	2.7300

Where PD is pipe diameter (inch), H is head (m), T is time (sec) and Q is discharge rate (lit/sec).

The experiment show that static head has inverse relationship with discharge rate. More discharge (3.3740 lit/sec) was obtained at lower head (6 m).

Result analysis for test 2

Table 2. The effect of head difference on discharge rate at 4 inch pipe diameter.

Variable	Mean	SD	C.V	Minimum	Maximum
PD2	4.0000	0.0000	0.0000	4.0000	4.0000
H1	6.0000	0.0000	0.0000	6.0000	6.0000
H2	8.0000	0.0000	0.0000	8.0000	8.0000
T1	3.6940	0.0956	2.5867	3.5900	3.8500
T2	4.9300	0.1290	2.6173	4.7900	5.1400
Q1	16.698	0.5814	3.4821	16.300	17.700
Q2	12.178	0.3157	2.5924	11.670	12.530

Where PD is pipe diameter (inch), H is head (m), T is time (sec) and Q is discharge rate (lit/sec).

The experiment show that static head has inverse relationship with discharge rate. More discharge (16.698 lit/sec) was obtained at lower head (6m).

Result analysis for test 3

Table 3. The effect of pipe diameter on discharge rate at 6 m head.

Variable	Mean	SD	C.V	Minimum	Maximum
H1	6.0000	0.0000	0.0000	6.0000	6.0000
PD1	2.0000	0.0000	0.0000	2.0000	2.0000
PD2	4.0000	0.0000	0.0000	4.0000	4.0000
T1	17.830	1.1286	6.3297	16.500	19.500
T2	3.6940	0.0956	2.5867	3.5900	3.8500
Q1	3.3740	0.2136	6.3311	3.0700	3.6400
Q2	16.698	0.5814	3.4821	16.300	17.700

Where PD is pipe diameter (inch), H is head (m), T is time (sec) and Q is discharge rate (lit/sec).

The experiment showed that pipe diameter has direct relationship with discharge rate. As pipe diameter increases there is the probability of more discharge rate. The more discharge rate (16.7 lit/sec) was obtained from 4 inch pipe diameter of at the same head level of 6m.

Result analysis for test 4

Table 4. The effect of pipe diameter on discharge rate at 8 m head.

Variable	Mean	SD	C.V	Minimum	Maximum
H2	8.0000	0.0000	0.0000	8.0000	8.0000
PD1	2.0000	0.0000	0.0000	2.0000	2.0000
PD2	4.0000	0.0000	0.0000	4.0000	4.0000
T1	23.776	1.5038	6.3250	22.000	26.000

Variable	Mean	SD	C.V	Minimum	Maximum
T2	4.9300	0.1290	2.6173	4.7900	5.1400
Q1	2.5320	0.1574	6.2158	2.3100	2.7300
Q2	12.178	0.3157	2.5924	11.670	12.530

Where PD is pipe diameter (inch), H is head (m), T is time (sec) and Q is discharge rate (lit/sec).

The experiment showed that pipe diameter has direct relationship with discharge rate. As pipe diameter increases there is the probability of more discharge rate. The more discharge rate (12.2 lit/sec) was obtained from 4 inch pipe diameter of at the same head level of 8 m.

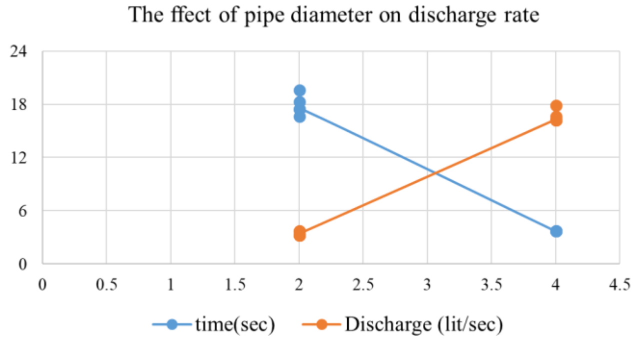

Figure 5. The effect of pipe diameter.

Figure 5 showed that the tendency of the discharge rate increase when raising the diameter of pipe. The discharge rate of the different diameter of pipeline shows that the bigger diameter pipe presents the higher discharge rate.

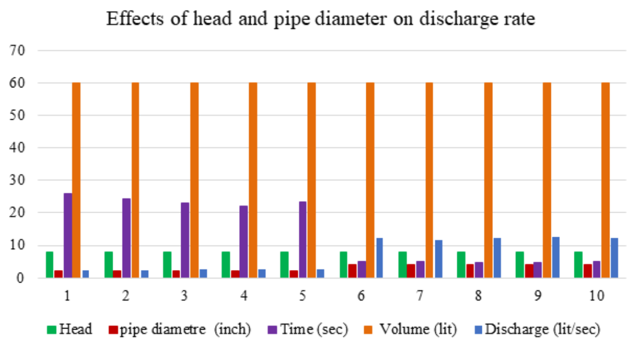

Figure 6. The effect of head and pipe diameter.

Figure 6 showed that the tendency of the discharge rate increase when lowering static head and raising the diameter of pipe. The discharge rate of the different static head and diameter of pipeline shows that the lower static head and bigger diameter pipe presents the higher discharge rate.

4. Conclusions and Recommendation

The Rope and Washer Pump, a water-lifting device made with appropriate technology, has been effectively used in a number of developing nations all over the world. The rope and washer pump's benefits include its affordability, robustness, ease of use, and relatively high pumping rate, all of which allow for its construction and upkeep in tiny villages. The maximum head and pipe diameter performed for this study were 8 m and 4 inch respectively, using 5hp engine. The maximum efficiency of the pump was 2.532 l/sec and 12.178 l/sec using 2 inch and 4 inch pipe diameter respectively at 8 m head. The study can conclude that engine-operated rope and washer pump capacity is mainly affected by engine horsepower, head size, and pipe diameter. For the larger pipe diameter with a lower static head and a higher static head, there is a higher and lower discharge capacity, respectively. The engine-operated rope and washer pump should be recommended for small-scale irrigation systems and can work appropriately for lifting water at a maximum head of 8 m with a 5 hp engine.

Abbreviations

GTP	Growth and Transformation Plan
H	Head
hp	Horse power
PD	Pipe Diameter
PVC	Polyvinyl Chloride
Q	Discharge
RPM	Revolution per minute
T	Time
V	Volume of water

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Author Contributions

Roba Adugna: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing

Adem Tibesso: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing

Abu Dedo: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Visualization, Writing - original draft, Writing - review & editing

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Data Availability Statement

The analyzed data during this study which supports its findings are available only upon official request to the corresponding authors.

Conflicts of Interest

The authors declare no conflicts of interest.

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