32nd WEDC International Conference, Colombo, Sri Lanka, 2006

SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Research and development on traditional water lifting devices: Endless piston water pump

Janaka J. Wijetunge, Sri Lanka

This paper deals with the research and development work carried out on a traditional water lifting device known as the Rope Pump, with a view to increase its pumping rate and efficiency. The research work resulted in developing and modifying the traditional device to a considerable extent. The newly designed pump, named as the Endless Piston Water Pump (EPWP) delivers 100% more water at the expense of 50% less energy than the traditional pump. Moreover, the EPWP may be installed in boreholes as well as in open wells. The above improvement is possible because the EPWP remedies two shortcomings in the Rope Pump, -namely, the escape of water between rope knot and riser pipe and the slip of the rope on the main pulley

Introduction

A sustainable water supply has been an essential requirement for flourishing of individual communities, and thus entire cultures, the world over. Hence, since time immemorial the mankind has devised various means by which water that is naturally available at some depth below the ground level and in natural water-ways like rivers can be lifted to the ground where it is used.

Even though most of those devices are inefficient and output volume of water is inadequate, the basic principles behind some of them are worthy of consider-ation. Consequently, such traditional devices ought to be developed through appropriate technology so as to be able to provide water, especially to the rural poor of the developing world, more efficiently (Kennedy & Rogers, 1985). One such water lifting device that has been traditionally used for centuries in China and Europe called the Rope pump was selected for the present project aimed at improving the efficiency of such traditional water lifting devices.

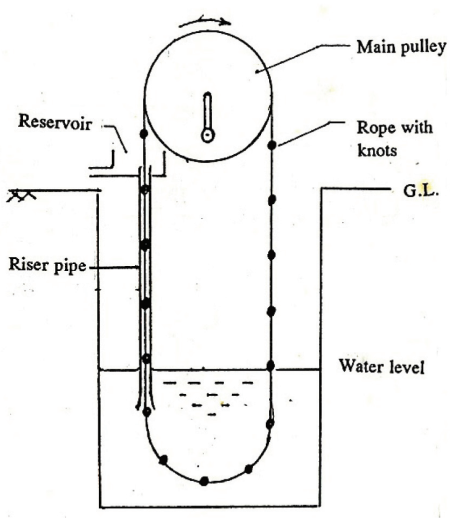

Figure 1. Basic components of a Rope pump

Traditional device – Rope pump

Introduction

In the traditional device, a rope with equally spaced Knots is pulled up through a riser pipe as illustrated in Figure 1. The water is lifted due to the upward move-ment of knots through the riser pipe. Nylon ropes which are available in the market in sizes ranging from 2 mm to 14 mm in steps of 1 mm are used to make knots to suit the internal diameter of the riser pipe. The shape of the knots is as shown in Figure 2.

Mechanism and shortcomings

The study of the movement of knots inside the riser pipe using a glass tube revealed that a water column gradually builds up inside the riser pipe as the main pulley is turned, and when water is pumping out there is a continuous water column from bottom to top of the riser pipe. Due to gravity there may be a downward flow also. Hence, if the water to come out of the pipe, the velocity of the downward flow due to gravity must be exceeded by the velocity of the upward flow due to the moving knots.

Since the knots do not match well with the cylindrical riser pipe, this downward flow or the leakage may be considerably high resulting in less output volume of water and low efficiency. This is the first shortcoming of the rope pump. The second is that there can be considerable slip between the

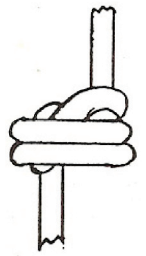

Figure 2. Shape of the knot

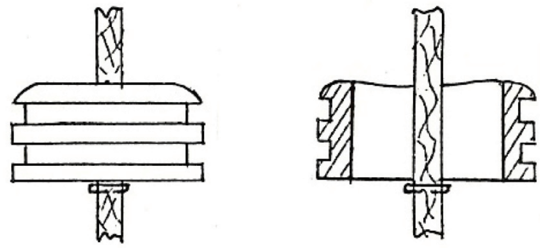

Figure 3. PVC-Piston

rope and the main pulley, depending on the rope speed.

Objectives of the research

There are two main objectives: (1) to find an alternative to the knots with a view to increase the pumping rate and efficiency of this device, and (2) to design and fabricate a low cost pumping unit which can be installed in boreholes of diameter 4 inch as well as in open wells.

Definitions of terms used

(a) Water Lifter: This term is hereafter used in this paper to describe knots of the rope or any other thing used instead of knots to lift water. .

(b) Water Watts: This term refers to the output power of the water actually lifted: Water Watts (WW) = mgh, where m is the mass (rate) of water lifted in kg/s, g is the acceleration due to gravity (9.81 m/s2) and h is the datum head in metres.

(c) DBWL: This is the distance between two consecutive water lifters.

Materials and methods

A pumping unit was fabricated for test purposes. In order to carry out controlled tests, the main pulley shaft was chain driven from a variable speed electric motor of 2 V - 24 V DC. With the gearing down system used, the angular velocity of the main pulley which drove the rope could be varied from 0 to 100 rev./min.. This pumping unit was set up over a sump which simulated the well whilst an outlet pipe at the top of the pump discharged to a flow measurement device (water meters which could be read up to 0.1 litres) and back to the sump.

Several types of water lifters were selected for the study. The selected types of water lifters were different either in material or in shape or in both from each other. These water lifters included the knots which the traditional devices use and the pvc-piston (See Figure 3) that was developed by the writer. The discharge at different rope speeds was measured for each type of water lifter whilst keeping the following factors constant:

- Pumping head = 1 m
- Diameter of the riser pipe = 26 mm (internal)
- Diameter of the main pulley = 286 mm (PCD)
- DBWL = 220 mm.

Design features of the PVC-Piston

These are turned out from a pvc-pipe, the outer diameter of which is very slightly (1 mm) less than the internal diameter of the riser pipe. Such combinations of pvc-pipes could be found from the sizes available in the market. A wooden core having a 6 mm bore at the centre is glued and tightly fixed to the pvc ring (See Figure 3).

Two significant design features in this piston over-come the major shortcomings of the rope pump:

(1) The grooves cut around the piston provide better grip with the main pulley and help have a moving water seal between the piston and the internal walls of the rise pipe

(2) The concave top surface help retain and push water trapped between the water lifters more effectively.

Experimental results

A large volume of experimental data was collected, and it is not possible to include all of it here. The most pertinent results are therefore presented.

The flow characteristics of two types of water lifters, namely, the knot which is used in the traditional device and the newly designed pvc-piston are shown in Figure 4.

The ideal line in Figure 4 shows the maximum pumping rate that can theoretically be obtained at the correspon-ding rope speeds using a riser pipe of diameter 26 mm. The Figure shows that the curve for the water lifter developed by the writer, pvc-piston, is very close to the ideal line whereas that for the conventional knots is far away.

It is observed that the pumping rate increases linearly with the rope speed up to around 50 m/min. and thereafter the rate of increase is slightly less. This may be attributed to the fact that there is a higher possibility of occasional slipping of the rope over the main pulley at very high speeds. Also maximum efficiency was observed at the rope speed corresponding to this point of deflection.

The plot of variation of overall mechanical effi-ciency with the rope speed in Figure 5 indicates that efficiency increases rapidly with the rope speed and after reaching a maximum value it decreases slowly. This pump appears to be operating at the optimum efficiency at a rope speed of about 50 m/min.. To achieve this speed, a typical 300 mm diameter

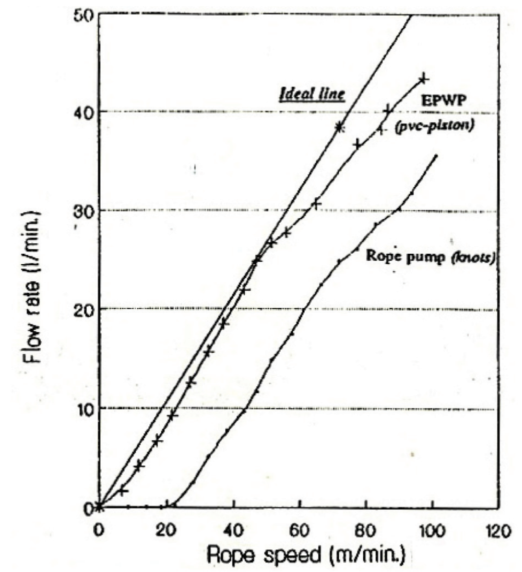

Figure 4. Comparison of flow characteristics: + EPWP, ● Rope Pump

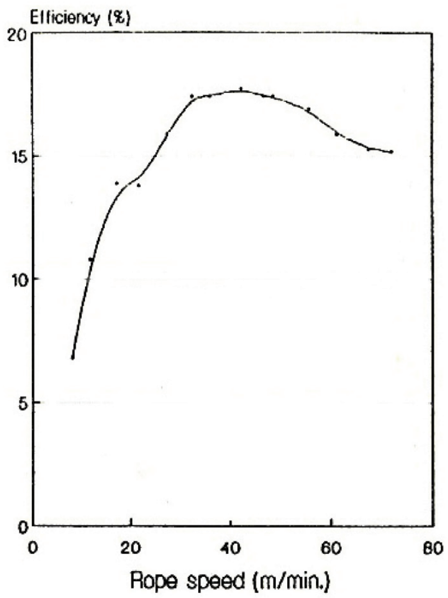

Figure 5. Variation of pumping efficiency with rope speed

pulley will have to be turned at 50 rev./min..

The pumping rate decreases slowly with the increase of DBWL at all rope speeds. Moreover, the newly-developed water lifter, pvc- piston, yields a flow rate of about 100% higher than the conventional knots. The corresponding increase in efficiency is approximately 50%.

Development based on research work

The research work indicated that the performance of the pvc-piston is remarkable as far as its pumping rate and efficiency are concerned. Hence the knots were replaced with pvc-pistons and more extensive tests performed.

Table 1. Performance data

RPM	Rope Speed (m/min)	Voltage (V)	Current (A)	I/P Power (Watts)	Flow Rate (l/min)	Water Watts	Efficiency (%)
46	41.4	12.0	2.9	34.8	11.8	12.0	34.5
50	45.0	13.0	3.0	39.0	13.6	13.8	35.4
56	50.4	14.5	3.0	43.5	15.5	15.8	36.3
65	58.5	16.0	2.9	46.4	18.5	18.8	40.5
72	64.8	17.5	2.8	49.0	21.2	21.6	44.1
78	70.2	19.5	2.9	56.6	23.4	23.8	42.1
86	77.4	21.0	3.0	63.0	26.0	26.5	42.1
96	86.4	22.5	3.0	67.5	28.6	29.1	43.1

Endless piston water pump (EPWP)

Based on the research work a simple water pump was designed and fabricated after making several innovations and modifications to the traditional device. This new device named as the Endless Piston Water Pump (EPWP) can be

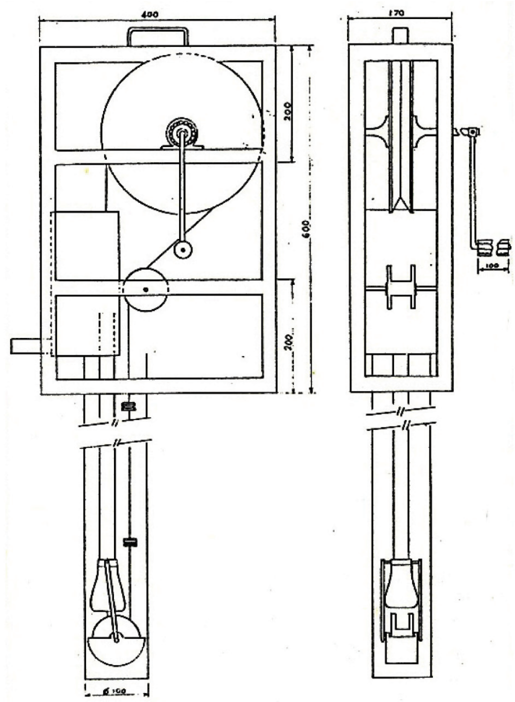

Figure 6. Pumping unit of model EPWP-1

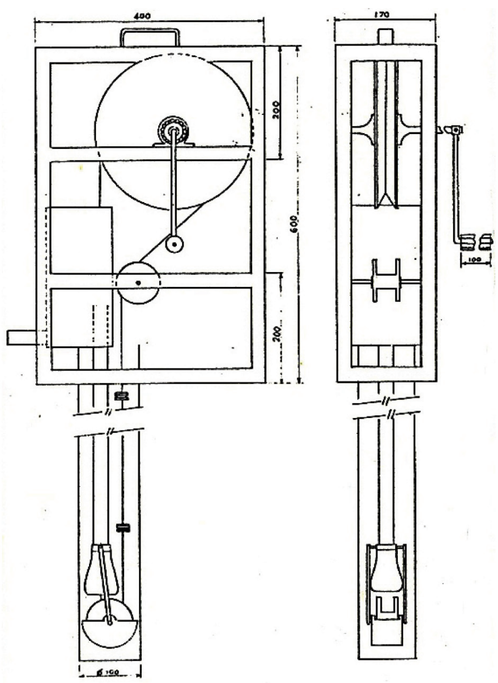

Figure 7. Pumping unit of model EPWP-2

installed in boreholes as well as in open wells.

Two models, EPWP 1 (See Figure 6) which is hand driven, and EPWP 2 (See Figure 7) that may be driven by an electric motor as well as manually were designed and fabricated.

Performance of EPWP

The EPWP was tested at a datum head of 6.2 metres. A riser pipe of internal diameter 20 mm with DBWL = 200 mm was used in the testing. The test results are given in Table 1.

The efficiency computed above is the overall mech-anical efficiency without taking the power losses in the motor and in the gearing down mechanism into account. Hence the net efficiency only of the EPWP should certainly be higher than this.

At 6.2 m static head, the efficiency of the whole system is around 45%. If the power losses in the electric motor and in the gear train are assumed to be 20% and 10% respectively, then the net efficiency of the EPWP would be over 60 %.

Durability

An accelerated durability test was conducted to get an idea of the life of different parts of the EPWP using an electric motor fitted externally. During the 860 hours of continuous pumping the rope and the pvc--pistons did not show any sign of breaking or severe wear out and no mechanical failure was observed.

Conclusion

The research carried out on a traditional water lifting device, Rope Pump, resulted in developing a more efficient water pump named as the Endless Piston Water Pump (EPWP) that can be installed even in 4-inch diameter boreholes.

The main features of the EPWP are as follows:

- Simple construction, employing locally available material and skills,
- Could be used to pump water from open wells or bore-holes, shallow or deep,
- Low cost,
- High efficiency of about 60% means more water at less cost/effort,
- Requires no priming,
- No valves – the most troublesome part of many water pumps,
- Could be manually operated or power driven,
- Maintenance at village level,
- Provides employment at village level in manufacture of parts, installation and maintenance, and
- Could be used for micro-scale irrigation as well as for domestic water supply.

References

Kennedy, W. K. and Rogers, T. A. (1985) Human and Animal Powered Water Lifting Devices. ITDG, London.

Contact addresses

Janaka J. Wijetunge
Senior Lecturer
Department of Civil Engineering
University of Peradeniya
Peradeniya 20400,
Sri Lanka