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Study and design of pendulum assisted hand water pump

Rejsha Khoteja* , Sandhya Mishra , Sarad Niraula , Kshitij Kunwar , Nirajan Ghimire , Krishna Prasad Shrestha , and Pratisthit Lal Shrestha

Department of Mechanical Engineering, Kathmandu University Dhulikhel, Nepal.

Abstract

The designed pump consists of a normal hand pump and a pendulum; held together into a mechanism by a metal structure. This pendulum pump aims to provide a solution for lifting water manually, which requires a large human effort when operated continuously. It is based on a very simple principle of the pendulum, lever two-staged oscillator mechanism. With the help of this principle, the reciprocating motion of the piston in the pump is obtained using the oscillation of a pendulum. The pendulum pump was designed using different calculations and was fabricated adding frame, springs, pendulum to normal piston pump for the actual experimentation. The project purely deals with the mechanical aspect of the pendulum pump, where an experimental approach is implemented to conclude. The average discharge of water at 30°,40°,50° and 60° swing angles were 51ml, 59ml, 70ml,98ml respectively which concluded that the discharge of this designed pump extremely depends on the swing angle of the pendulum as water discharge is increased with increasing angle as seen from experimentation. Also, from experimentation, this designed pump pumps out approximately 9% of more water than a conventional hand water pump taken average discharge of normal pump as reference under the same circumstances. As this pump can be operated with minimum effort compared to a normal hand pump, it can be operated by people of any age and even by physically challenged people. This machine can be useful for small scale irrigation, handling of wastewater, lifting water to small height for household purposes or to lift water from well.

Keywords: Reciprocating motion; Two-staged oscillator; Pendulum; Oscillation; Pump

1. Introduction

Water is an essential need in daily human life. Earth has many water resources on its surface like rivers, swamps, streams and lakes. Water needs to be transported from their source to the point of usage for which various water lifting devices, e.g., electric motors, water pumps, and hand pumps are commonly used [1]. The use of the electrical motors, pump sets are not easily portable and only can be used where there is high electrical supply and voltage. So, the hand pumps become the first choice for humans for their domestic purposes as it is affordable and requires less maintenance.

Manual piston pumps as the name implies are types of pump which uses the hand as the source of power to drive the reciprocating piston pump. These types of pumps are widely used in water pump, family life and production, water supply and agricultural irrigation [2]. It is manually operated by the human hand that requires high force for the suction of water from the ground which makes uncomfortable for the human body. Also, the average human cannot operate hand pump continuously for long period of time because of the fatigue it provides. For such problem, emphasizes the need to model a design which can provide solution to it.

Pendulum hand water pump is such a model which tries to eliminate the problems provided by the conventional hand water pump. Pendulum assisted hand water pump basically provides the advantage of requiring less energy to initiate the pumping system over the conventional ones. In pendulum pump, the input energy needed to start pumping process is provided by the swinging the pendulum at the other end as it can supply large amount of energy with slight pushes [3]. The work becomes easier, long-lasting and effortless with the help of pendulum pump [4]. The pendulum should be occasionally pushed, to maintain the amplitude i.e., the stream of water. The pump works well with all sizes of the pendulum, but mainly with the amplitude of 90° [5]. On increasing angle of swing, the discharge of the given pendulum system increases [6]. Pendulum pump can be used for pumping water out from reservoirs, irrigation purposes, drainage management and other sectors. This project aims to provide solution that requires less human effort than the conventional hand pump.

Table 1: Material Specifications of Pendulum pump

Components	Material	Specifications
Piston Pump	PVC	Bore diameter = 250mm, stroke length = 150mm
Frame	Galvanized steel	Height =120cm, Length = 150cm, Width = 50cm
Springs	Mild steel	Number of coils = 15, Solid length = 15cm
Ball Bearings	Mild Steel	Inner Dia. = 16mm, Outer Dia. = 28mm
Pendulum	Cast iron	Weight = 20kg

2. Materials and method

In the initial stage of this project, the various components of the pendulum were modeled in Solid Works V-2018 which included frame, piston pump, lever, bearings, and pendulum (Fig. 1 and Table 1).

*Corresponding author. Email: rejsha.khoteja@gmail.com

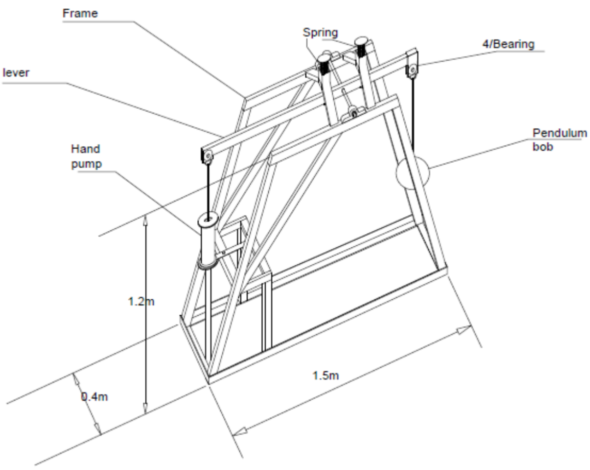

Figure 1: Model of pendulum pump.

Figure 2: Fabricated pendulum assisted hand water pump.

2.1. Working

The pendulum assisted hand water pump works on the principle of Two-stage oscillator (Pendulum-Lever System). Two-stage oscillator is a compound pendulum in which energy is transferred from one pendulum to another. Once the pendulum is provided with some input, it keeps oscillating for some time thus transferring the energy to another pendulum. In year 1999, Sir Veljko Milkovic invented the two-staged oscillator [7].

Firstly, the pendulum is swung with the help of human effort. And, the pendulum oscillates to and fro; this oscillating motion of the pendulum is converted into reciprocating motion of the lever. The force by this motion causes vertical movement of the piston of the pump. When pendulum is at the extreme ends, the component of force acting on the lever due to pendulum is minimum level and lever is at extreme high position on pendulum side due to action of counter weights [8]. The pendulum oscillation period is two times greater than lever oscillation. Piston of pump has reverse effect on lever and its oscillation is dampened. The damping motion of the lever induces the damping of the pendulum; however, the work of pendulum damping force is smaller than the work of the force damping lever [9]. Due to this, the pendulum provides continuous energy to a lever which pressurizes the water and lifts it from lower head to higher head providing a continuous flow of water.

2.2. Experimentation

2.2.1. Discharge of water vs. Swing angle of pendulum:

The discharge of water was calculated with varying swing angle of the pendulum pump. A bucket containing 15 liters of water was taken as the source to pump water at 3.5m depth. Then, the pendulum was raised at angles (30°, 40°, 50° and 60°) and pushed forward leaving it to oscillate (Fig. 2). The observation was done 5 times for each angle and average discharge was calculated against the swing angle.

2.2.2. Comparison of conventional hand pump and pendulum pump:

The comparison was done with identical constraints (equal volume of water, constant angle = 60°, same water depth = 3m). A bucket containing 20 liters of water was taken for this experiment and both pumps operated by same person. The discharge of water at one push of approximately 20N force was noted.

2.3. Calculations

Area of pump cylinder is given by,

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

= 0.04920 m^2

where, *d* is the diameter of the body of reciprocating pump.

And,

Volume of a cylinder is given by,

$$V = A \times l \tag{2}$$

= 0.04920 x 0.15 = 0.00735 m^3

where, *A* is the area of cylinder, *l* is the stroke length of the pump

Here, Weight of water per stroke is given by,

$$W = 9.81 \times 1000 \times 0.00735 \tag{3}$$

= 72.10 N

Then,

Load acting along the length of the spring is given by,

$$F = \frac{\mathrm{yG}d^4}{8D^3 l} \tag{4}$$

where, y is the deflection of spring, d is wire diameter of spring, D is the coil diameter, L is the actual length of the spring, G is Modulus of rigidity

[Modulus of rigidity for mild steel = 75GPa]

Friction force is given by,

$$F_f = \mu R \tag{5}$$

where, R is normal force, μ is coefficient of friction.

1. R = 72.10 + (9.81×0.5) = 77N

2. μ = 0.15 (for contact between mild steel and cast iron)

From above equations (3), (4) and (5),

Net force acting downward during suction stroke = (11.55 + 53.35 +72.10)

= 137N

Now, to find the required minimum weight of the pendulum,

Minimum weight of pendulum required = 137/9.81 = 13.98 kg

The system will be kept in balance by this weight of pendulum. To making pumping more suitable, the weight of the pendulum bob was increased to 20kg.

For Total head Calculation, Mass of the bob plays a major role in deciding input energy of the system and potential energy required for starting oscillations.

Energy transmitted through lever is given by,

Table 2: Observation table for discharge of water vs. swing angle of the pendulum.

Discharge angle	Observations (ml)				
	1	2	3	4	5
30°	54	50	49	50	52
40°	59	62	56	60	60
50°	70	69	72	67	72
60°	95	102	98	100	95

$$E_{\text{in}} = \frac{E_{\text{out}}}{\eta} \tag{6}$$

where, E_{in} is input energy, E_{out} is output energy, η is efficiency

Here, Input Energy is given by,

$$E_{\text{in}} = F \times S \tag{7}$$

where, F = Tension in pivot point, S = Displacement of a pivot point

And, Tension at the pivot point is given by,

$$T = mg\left(3\cos(\alpha) - 2\cos(\alpha_o)\right) \tag{8}$$

where, m_b = mass of pendulum bob, α = current angle of pendulum, α_o =angle of pendulum from initial position to current position = 50°

So, Input energy (E_{in}) = F×S

= 462.48J

From experimentation, total head of pendulum pump was found to be approximately 4m.

Output energy of reciprocating pump is given by,

$$E_{\text{out}} = g \times \rho \times A \times H_T \times L \tag{9}$$

= 9810* 0.0490 *0.15*4

= 288.414 J

where, ρ is density of water, A is cross sectional area of pump, H_T is total head of pump, L is the length of stroke.

Therefore, From equations (7) and (9)

Efficiency of the pump is given by,

$$\eta = \frac{E_{\text{out}}}{E_{\text{in}}} \times 100\,\% \tag{10}$$

= $\frac{288.414}{462.48}$ = 62%

3. Results and discussion

The discharge of water was measured by changing the swing angle of pendulum (30°, 40°, 50° and 60°) with constant mass of bob and length of pendulum. Five observations were taken for each angle and noted (Table 2). Fig. 3 shows the noted discharge of water by each angle in ml.

The average discharge of water at 30°, 40°, 50° and 60° angles were 51ml, 59 ml, 70 ml, 98 ml respectively. Based on the results obtained from this experiment, it was quite obvious that discharge quantity is directly proportional to the swing angle of the pendulum. Discharge of water was increased with the increment in the swing angle of the pendulum. Here, we recognized that on increasing angle of swing, the discharge of the given pendulum system increases [6]. This also showed that the efficiency of the pendulum was extremely dependent on the mass of the pendulum along with the swinging angle.

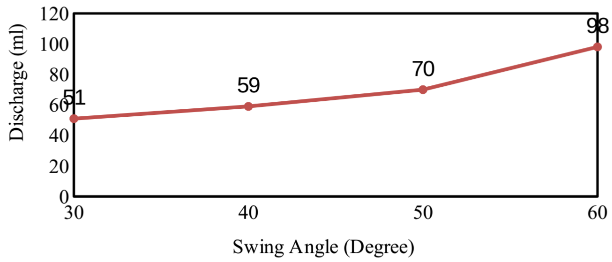

Figure 3: Discharge of water from pendulum pump vs. swing angle of pendulum.

Table 3: Observation of discharge of water from Pendulum pump and Normal water pump.

Observations	Approximate discharge of water (ml)	
	Pendulum water pump	Normal water pump
1	178	168
2	180	165
3	183	169
4	175	163
5	185	160

While experimenting for the comparison of two hand pumps i.e., conventional and pendulum pump, the discharge from each pump was noted. The observations were evaluated on multiple iterations (Table 3).

Approximate average discharge of water from pendulum assisted pump is 180.3 ml whereas, discharge given by conventional pump is 165 ml. Taken this into account, it was seen that pendulum pump discharges approximately 9 % of more water than conventional hand water pump taking the average discharge as reference.

4. Conclusion

Pendulum based hand water pump helps decrease the human effort for the operation of pump. The energy requirement for water pumping is less than the conventional hand pump as it pumps out water even with minimum effort. Here, the discharge of water at 30°, 40°, 50° and 60° swing angles are 51 ml,59 ml, 70 ml, 98 ml respectively which concludes that increasing angle of swing, the discharge of the given pendulum system increases. The average water discharge from pendulum is 180. 3 ml and from conventional pump is 165 ml. Hence, it is responsible to discharge 9 % more water compared to traditional hand pump, considering all other factor same. Its implementation in the site area helps alleviate the work, requires less human effort, discharge more water, convenient to operate and provides continuous discharge. It can easily be operated by different age group such as children, old people and disable people. It can also be used for small scale irrigation, handling of wastewater, lifting of water to small height in household purpose and from well. It is recommended to use it where there is continuous flow of water since total head is not suitable for all geographical region. In order to cope up with total head problem, it is recommended to study relation between mass of pendulum and water discharge with the integration of the electric or magnetic energy automation. It provides innovative solution to new generation so that energy can be conserved and used for other purpose.

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