Gravity Assisted Water Filtration Model for Flood Affected Areas of Pakistan: An Experimental Study

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Abstract-Natural calamities are always uncertain and out of human control and their effects are sometimes long lasting. Drinking water scarcity is one of these effects which badly creates a lot of health issues and even may take someone to death. Especially in flood affected areas where there is a lot of water but not drink worthy. A very easy and cost effective solution of drinking water problem for human needs is demonstrated and investigated in this study. The concept of gravity assisted power is introduced here for the purpose of producing drinking water. The oscillation of a pendulum is the main driving force for the operation. The shaft of the pendulum is linked with a custom made reciprocating piston pump through a scotch yoke mechanism. The effect of pendulum mass and its length on the volume of water filtered is investigated in this study. The filtered water discharge increased as the mass of the pendulum is increased with the increase in its length within the experimental range. The maximum flow rate is recorded as 4.2 l/min. The present prototype in this study presents an easy and cost effective solution for the human needs of drinking water especially in flood affected areas where there is plenty of water but not drinkable.

Keywords-Domestic Water Filter, Flood Affected Areas, Gravity Assisted Power, Pendulum,

I. INTRODUCTION

In gravity assisted power, partial energy is given by means of any input methods like hand operated, motor operated or compressed air operated, while partial energy is given by means of any phenomenon which rotates or oscillates under the action of gravity. The same is the principle which is used in this study, the partial energy was given by the human and partial energy was given by the oscillating pendulum, which oscillates under the action of gravity, once it is operated from human effort. The concept of gravity assisted power is used in many applications like as gravity assisted lamp [i-iii] and in many fashions [iv-viii]. In a gravity powered lamp, a sand filled sack is used to run the generator to light the lamp. One oscillation of the sand filled sack can keep lightening the lamp for next 30 minutes. This device is an oscillating pendulum, which uses the force of gravity to help provide the input power to operate it is referred as Gravity Assisted Power (GAP) technology. This technology reduces the energy required compared to hand-pump water operation [ix]. It also consists of a general purpose piston pump, which is used to pump water from certain head and deliver it in the domestic filter, so in this way the whole setup becomes a complete hand-operated water treatment facility capable of producing 20 gallons per hour of clean drinking water with no added chemicals [ix].

Since Stone Age, manhood has been using the gravitational force to work. In areas with waterfalls, ancestors built water wheels to capture the moving water's energy to drive gristmills or to power machine shops. With the development of new technologies, larger power plants were built using waterfall for electricity production. Gravitational Energy Corporation (GEC), located in Northeast Ohio, has developed a new technology which used the deep-rooted concept of Gravity Assisted Power (GAP). On the other hand rather than using falling water, GEC used a pendulum apprehending the energy from the momentum created by the gravitational force affecting a falling object is the principal theme behind the Feltenberger Pendulum [x].

The first production model, the GP210is a general purpose piston pump that is used to pump water for irrigation or through a filtration system to provide safe drinking water. The GP210's pendulum weighs just 40 lbs (18 kg) and is 48 inches (122cm) long. It is a hand-powered machine that permits its operators to pump up to 1,000 gallons of water per hour. In GP210 reverse osmosis is used and its pressure is 80psi (0.55MPa)with equivalent effort required to maintain the swinging pendulum with no water pressure [x]

GEC has also manufactured a power plant which can produce commercial scale electricity and the main part of this machine is pendulum which is operated by compressed air. Compressed air system is computer-controlled and it showed that the compressed air requirement after short span of time reduced to two-third to maintain operation of pendulum. GAP is not a new concept, but the GAP-based application of the

Feltenberger Pendulum technology is a new way of yoking this free and truly sustainable energy source [x]

In 2010, GEC bequeathed a GP210 modulewith a water filtration system to help the victims in Haiti meet their drinking water needs [xi]. It was sizedto fulfill the drinking water requirement of 4,000 people with just three hours of operation (daily) [xi].

The purpose of this study is to develop a device that can be installed in remote areas and mainly for those people who suffered during earthquake or flood destructions. They have dislocated from their houses and villages and to live a short period of time in the temporary shelters. During that period, the situation arrives that water is available but cannot be used for drinking and cooking purposes because it is polluted and using that contaminated water creates further health problems. To help people in flood or earthquake affected areas, this setup is builtto pump the water into a filtration system even in the absence of electricity or any other power source. By using a pendulum driven pump, this device is designed that is easily transportable, requires no fuel or electricity, makes no heat signature and that is virtually silent yet will produce clean drinking water from any surface fresh water source.

II. Materials and Methods

A. Materials

A custom made Poly Vinyl Chloridem a water pond to the filtration system. The detailed specifications of the pump are given in Table 1. A domestic water filter without the sterilizing unit in operation is used for the filtration of pollutedor contaminated water. A scotch yoke mechanism as shown schematically in Fig. 1 is used to convert the oscillatory motion of pendulum to reciprocating motion suitable for the operation of the piston pump.

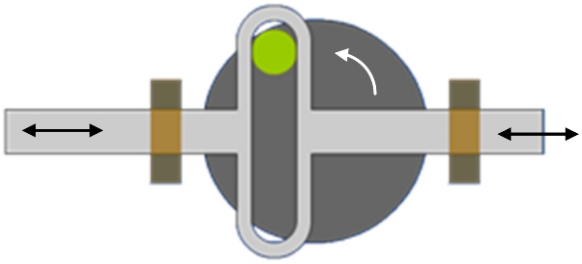

Fig. 1. Scotch yoke mechanism to convert pendulum oscillations to reciprocating motion

Various pendulums of different masses in the range of4.4kg to 7kg is used to drive the piston pump and the length of pendulum rod is varied from 27 inch to 33 inch (63.50cm to 83.52cm) by considering the experimental setup limitations. Two ball bearings are used to support shaft to which the pendulum rod is attached. Steel angle brackets are used to support the whole assembly containing, piston pump, scotch yoke mechanism; pendulum and water filter as shown in Fig. 2.

TABLE I
Piston Pump Components and Specifications

Components	Dimensions	Material
Piston pipe	Length = 0.381m Diameter = 0.0254m	PVC
Cylinder pipe	Length = 0.3048m Diameter = 0.03175	PVC
Piston Rings	Diameter = 0.0254m Thickness = 0.004m	Rubber
Tee	Diameter = 0.01905x0.0254m	PVC
Coupler	Length = 0.0762m Diameter = 0.0381m	PVC
One way Check valve	Diameter = 0.01905m	PVC

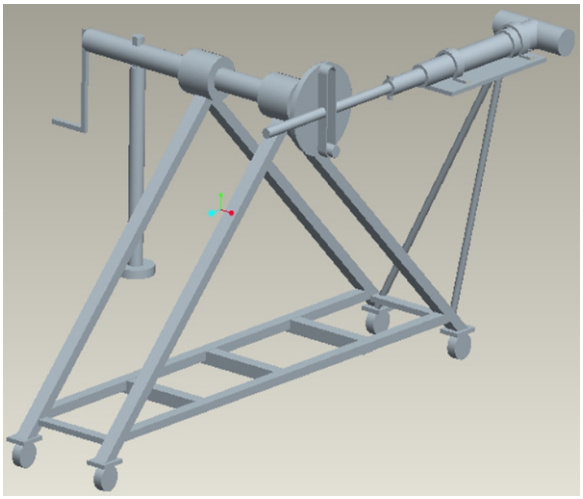

Fig. 2. Three dimensional model of the proposed experimental setup.

B. Methodology

The reciprocating piston pump was custom-made for this study. A piston pipe of 1 inch (2.54cm) diameter and a cylinder pipe of 1.25 inch (3.2 cm)diameter, both of PVC to make this pump. Two grooves were machined and rubber rings were used in these grooves to make the piston-cylinder interface air-tight and leakage proof surface contact. The maximum output (ltr/hr) of the piston was calculated using the relation given in Eq. (1) given by[xii]

$$\text{Discharge} = \frac{\pi \times (r)^2 \times l \times N}{231} \times \frac{1}{1.638 \times 10^{-5}} \quad (1)$$

Where r is radius of piston, l is length of the pump stroke and N is number of the oscillations of the pendulum.

The piston pump was linked to the shaft to which a mild steel pendulum was connected using a scotch yoke mechanism. The scotch yoke mechanism converts oscillations of the pendulum to reciprocation of the piston pump in the cylinder as shown in Fig. 3. The pendulum can be given oscillations with a little effort once it is dropped from some height. This can be done even by two teams of children who can just play with it by pushing the pendulum towards each other. The oscillatory motion of the pendulum is used to operate the piston pump which takes water from a water pond and deliver it to a domestic water filter. Time period for pendulum can be calculated by using the following Eq. (2) [xii].

$$T = 2\pi\left(1 + \frac{A^2}{16}\right)\sqrt{\frac{L}{g}} \quad (2)$$

Where, A and L are the amplitude and length of the pendulum respectively while g is the gravitational acceleration.

As a procedural method, the pendulum was lifted to certain height and then released. The oscillations of the pendulum drive the piston pump through scotch yoke mechanism and pump starts delivering water to the filter system. The time was noted until the pendulum stops oscillating which is termed as 'the time of operation' of the pendulum. The water volume collected during time was used to calculate the actual discharge of the pump. Time of operation of the pendulum and discharge of the pump were examined at various pendulum masses and lengths ranging from 4.4kg to 7kg and 27 inch to 33 inch (63.50cm to 83.52cm) respectively.

III. Results and Discussion

Various experiments were performed at different pendulum massed and lengths and time of operation of the pendulum and pump discharge was examined. The pendulum length was changed sequentially keeping the mass of the pendulum constant. Similarly, the effect of changing the mass at a particular pendulum length on water discharge of the pump was also investigated. The discharge of the pump or flow rate of the filtration system was calculated by dividing the volume collected by the time of operation of the pendulum i.e. the time taken by the pendulum to stop.

Fig. 3. Actual fabricated pendulum driven reciprocating pump with water filter

Fig. 4 and Fig. 5 show the experimental results for masses and lengths of the pendulum in terms of time of operation and finally the discharge of the pump respectively. As can be seen from Fig. 4 that the time of operation of the pendulum is has somewhat nonlinear relationship the length of the pendulum for a particular mass when dropped from a specific height (50cm). But as the mass of the pendulum is increased the time operational time is also increased. This is due to the increased gravitational and inertial forces due to increased mass.

At a particular mass value, the increase in operational time of the pendulum at larger lengths is not as sharp as it is at shorter length as can be seen from Fig. 4. The increasing rate in time of operation of the pendulum diminishes as the length is increased within the experimental domain. This might be due to the long distance, the pendulum has to travel due to increased length and also due to the air resistance. The friction in other moving parts and reciprocating pump might also be a possible reason of this damping effect due to increased length, in the time of operation of the pendulum at a particular pendulum mass.

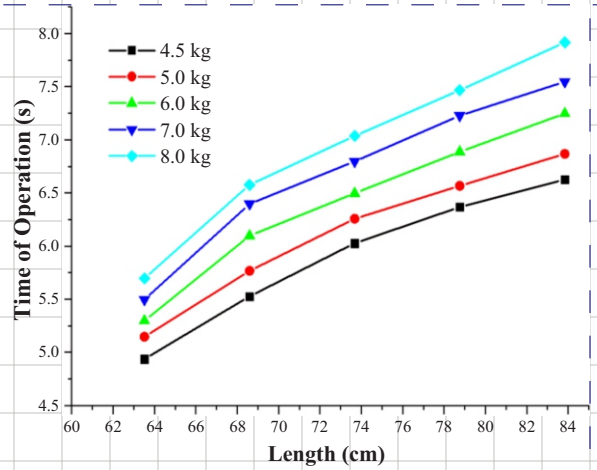

Fig. 4. Pendulum operational time vs Pendulum mass & length

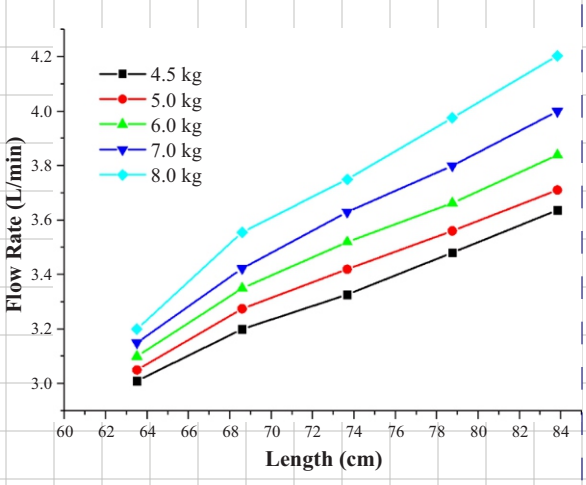

Fig. 5. Dependence of filtered water flow rate on the length and mass of the pendulum

Fig. 5 shows how water flow rate is dependent on pendulum length at various mass values within the experimental domain. For a particular pendulum mass, the volume flow rate of water filter is almost directly dependent on the length of the pendulum. As the length is increased, the water flow rate is also increased. Similarly at any particular pendulum length, water flow rate slightly increases with the increase in pendulum mass. This is again due to the increased inertial force as the length and mass of the pendulum are increased. This effect increases the time of operation of the pendulum which consequently increases pump more water to the water filtration unit. Hence the maximum water flow rate can be achieved at a pendulum mass of 8 kg and 48 cm length within the experimental domain. It was also observed that the free pendulum oscillations are used in this investigation which means the pendulum bob is dropped from some convenient height and then no further force was applied to maintain the oscillations. No actual application, after the first oscillation from certain height and intermittent force on each side of the oscillation of the pendulum can be applied to maintain the amplitude of the oscillations and to drive the reciprocating pump continues to have a continuous flow of water from the filtration unit.

This study presented a very basic principle of using pendulum as the driving force to get the water filtration for drinking and cooking purpose in earth quack and flood affected areas. The pendulum-operated water filtration setup is easily portable and can be driven even by the children while they are playing by pushing the pendulum bob to each other once it is dropped from some convenient height. Only the pumping of water from some downstream to the water filtration unit is considered in this work. The performance of the water filtration unit and the quality of output water does need a careful study in future. The maximum flow rate of water was recorded as 4.2 l/min.

IV. Conclusions

- The aim of this study is to present an easy solution to drinking water problem in especially flood affected areas where people cannot get the clean drinkable water and at the same time it is not possible to install electric filtration system due to absence of power due to mass destruction. In this study, a domestic filter was used to filter water because it requires minimum power which gravity assisted pendulum can provide to pump.
- The water discharge rate was investigated with respect to the mass and length of the pendulum. With the increase in length and mass of the pendulum, the water flow rate is increased almost linearly within the experimental domain.
- The increased inertial and gravitational forces due to increase in length and mass of the pendulum was the main reason of higher water flow rates. The oscillations of the pendulum were used to drive the reciprocating pump. The quality of water filtered and type of filter used requires a further careful investigation.

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