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# Design, fabrication and testing of river water pump for rural communities

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**Abstract**

This paper presents development of river water pump that can operate without fuel and electricity mostly applicable in rural communities that are close to a water stream. The river water pump consists of a propeller, drum, hose, rotary coupling and helical coil. The pump is driven by a propeller which is rotated by moving water. Because these pumps do not require any external energy or fuel, the operating cost for irrigation, as well as for other household purposes can be minimized. In this study, two different shaped pumps were fabricated and tested. Although the general mathematical relations for the design of the pump was kept constant for the two pumps, the variation of the shape of the drum was incorporated for comparing the performances. The main purpose of this study was to compare performance of the cylindrical shaped and conical shaped pump. It was found from this study that by making a conical shape of the drum, the total discharge could be maximized. However, the design of the supporting structure to withhold the pump on the river needs to be modified to balance the unsymmetrical distribution of the mass caused due to the conical shape. Compared to the conventional coil pump, this study also uses double layer of coil to enhance the overall performance of the pump. Thus, this study is expected to support in the product development within this family of the pump.

***Keywords:*** Coil pump; Water powered pump; Propeller; Design; Fabrication

## 1. Introduction

River water pump is a type of positive displacement pump that runs at low RPM. It was invented by H.A. Wirtz in 1746 [1] and consists of a coil of pipe wounded around either in a spiral, conical or cylindrical surface. The coil in this pump usually has more than 3 turns [1].

The river water pump consists of a coil tube, rotary coupling, structural support and driving system as shown in Fig. 1 and Fig. 2. One end of the tube is connected to scoop and another end is connected to rotary coupling. Rotary coupling has only one side moving. Outside of that rotary coupling, delivery pipe is connected. The pumped water is supplied in a pulsating form of air and water alternately.

This pump works by revolving helical or spiral coil into the water which leads to gulping water and air alternately. The pump revolutions force water forward via rotary coupling into the delivery tube. Every turns of the coil consists of alternate air and water column, which forms manometers connected in series. The pumping action of this pump is because of the presence of successive columns of air and water in a coil. Each column of water transmits pressure through the air to the preceding column of water because rotational motion forces water to move [3, 4]. So, each turn of coils consists of a pressure difference. Total pressure produced is equal to the sum of manometric pressure head at each coil. So, the total pressure head of the pump is [5]:

$$\text{Total presure head} = \sum \text{pressure head at each coil} \qquad (1)$$

David J. Hilton [6] found the relation of maximum head that can be obtained at helical coil pump:

$$\text{maximum head} = k * no.\ of\ coil * coil\ diameter \qquad (2)$$

Where k is approximately 0.5.

When pump is used for the lifting water to the head other than designed head, pressure at the inlet of delivery tube also gets changed, which further changes the water level present in each turn of coil to balance the pressure change [5]. As the air is highly compressive in nature, difference in water levels inside each coil are governed by the compression of the air columns. The contraction of air column in the tube is polytrophic process with value of coefficient of contraction 1.15 [5, 7].

$$H_A L_A^{1.15} = H_n L_{An}^{1.15} \qquad (3)$$

Where, $H$ is the pressure head and $L$ is the length of air plug. The subscript $A$ represents values at atmospheric pressure and $n$ represents any position of the coil.

In the case of high head and high discharge, spilling is assumed to take place. During spilling, water flows back from one column to the succeeding column. Because of spilling, head and discharge get decreased [8]. Fig. 3 shows pattern of pressure head pump coil moving from inlet to outlet. As the region B-C is in high pressure area relative to A-B region, spill back is assumed to take place at B-C. The broken line is the pattern obtained in comparatively small head for the same pump.

The flow rate of the pump depends on the amount of water collected by the scoop at every revolution of the coil. When no water is lost during the pumping action, the discharge in a revolution is the amount of water collected in the scoop in that revolution. The average flow rate is [5]:

$$Q = L_{wi} \times A \times N \qquad (4)$$

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With no dynamic loss [5],

$$L_{wi} = \theta \times R \quad (5)$$

Where $\theta$ is angle subtended by water plug in intake coil and given by [5].

$$\theta = 2\cos^{-1}\left(\frac{R - Di}{R}\right) \quad (6)$$

Where, $L_{wi}$ is length of water plug length in intake coil, $R$ is the radius of curvature at the intake coil, $A$ is cross-sectional area of the tube, $N$ is the revolution per second and $D_i$ is the depth of immergence.

Static head of the pump depends on the number of coil and submergence ratio. As number of turns of coil increases, number of manometers is also increased which results in the increase of static head [10, 11]. If the speed of rotation increases, discharge increases but volume delivered per revolution decreases [6]. Increase in rotational speed increases the effect of centrifugal force on the air-water plug. In higher flow velocity, liquid column moves irregularly because of the centrifugal effect. Hilton [6] in a research paper reported that at the speed above 100 RPM, pump ceases to work [6]. The actual height reached by the pump will be greater than that indicated by the pressure gauge in the system [12, 9, 13, 14]. It is because the presence of air reduces effective density of liquid which results in higher height known as airlifting effect.

Kassab et al. [15] studied the performance of multi-layer helical coil pump. Multilayer pump has multiple layers of coils with single intake. The intake may be made either in inside layer or in outside layer. When intake is taken from the outer layer, the head and discharge is comparatively higher than the intake at the inner layer. It is because the outer layer coil has a greater intake diameter than that of the inner layer coil.

Ramli et al. [16] constructed and tested a sling pump (conical shaped coil pump). The crucial angle for sling pump suggested drum is 15º at draft and 45º at edge because it helps in the stability of the pump. The experiment was carried out for 5 m head at different flow of river and different diameter of hose. The experiment shows that the volume of water discharged depends on diameter of hose and water flow rate of river.

This study is focused on developing a river-water pump which is suitable for the context of Nepalese rivers and communities around them. Due to the uneven geographical topography, especially in the hilly regions, the difference in the height between the river surface and nearby irrigation land or houses are usually higher. As a result, the pumping capacity of a coil pump needs to be maximized. This paper studies the possibility of increasing the pumping head and discharge of the coil pump by changing the shape of the drum. Two different shaped model of pumps are fabricated and tested for comparing the performance. Moreover, the concept of multilayer coil pump is also introduced because it has better performance than single layer coil pump. By using concept of multilayer coil pump, both models containing two-layer coil is fabricated and tested.

## 2. Materials and method

As discussed earlier, this study focuses on testing two pumps, designed for the same head, using Equations 1-6, but with varying shape, as well as the materials. For the first model, coils were wounded around a cylindrical drum, whereas for the second model, wounded around a conical drum.

For conical shaped pump, a drum of diameter 715 mm was used, around which two layers of one-inch pipe was wounded as shown in Fig. 2 and Fig. 4. One end of the pipe was open and connected to scoop and the next end of pipe was connected to inside layer (overlapped pipe) and followed by delivery pipe through swivel coupling. The number of turns of outer coil was 17 and inner coil was 18. To drive this pump, a three bladed propeller made of glass fiber was connected. Materials used for the conical drum pump is shown in Table 1.

**Table 1:** Material used for conical shaped pump.

| Parts | Materials | Quantity |
|---|---|---|
| Drum | Glass Fiber | 1piece |
| Hose | HDPE | 80 m |
| Bearings | | 3 pieces |
| Rotary coupling | | 1 piece |
| Propeller | Glass Fiber | 1 piece |
| Frame | MS pipe | 12 m |
| Flange | Mild steel | 2 pieces |
| Shaft | GI pipe | 2.25 m |

HDPE: High Density Poly Ethylene
MS: Mild Steel

**Table 2:** Material used for cylindrical shaped pump.

| Parts | Materials | Quantity |
|---|---|---|
| Drum | MS Sheet | 1 piece |
| Hose | HDPE | 80 m |
| Bearings | | 3 pieces |
| Rotary coupling | | 1 piece |
| Propeller | Aluminium | 1 piece |
| Flange | Mild steel | 2 pieces |
| Shaft | GI pipe | 2.25 m |

Similarly, for the cylindrical shaped pump (Fig. 5), a drum of 700 mm was used around which two layers of 0.75-inch pipe was wounded same as in the conical shaped pump. The delivery pipe of 1 inch was used. The number of turns in outer and inner layers were 16 and 17 respectively. To drive this pump, three-bladed propeller made of aluminum was used. The materials used for the cylindrical pump is shown in Table 2.

Testing of both of the pump was carried in the Sunkoshi River, Sindhuli. Firstly, the velocity of river water flow in the section where installation process was carried out was measured by measuring velocity of the floating material in that place. Secondly, the height of water pumping was measured by using measuring tape and using water level pipe. Similarly, to measure the flow rate of the pump, 20 liters capacity of bucket was used. The bucket was placed in each meter of height and time to fill the bucket was measured by using stopwatch. The corresponding average flow rate of the pump in different lift was calculated. Lastly, due to very slow revolution of the pump, the measurement of RPM was carried by counting the revolution manually. The observed and calculated value of the pump is discussed in the result and discussion section.

## 3. Results and discussion

Testing of both the pumps, one made up of fiber (conical) and other made up of metal (cylindrical) were done in the same river (Fig. 6). The maximum discharge obtained from the conical pump in the given condition was 11500 liters per day. It was observed that the pump drum and propeller was not completely balanced as the material used for these components was of glass fiber. Due to unbalanced mass of the conical shaped pump, the propeller couldn't drive the pump after 6-meters of height. Also, the flow of river was 0.9 m/s which was slightly less than the designed flow (1 m/s). These two factors affected the rotation of the pump resulting in the revolution of 11 per min (18 RPM was designed condition). The

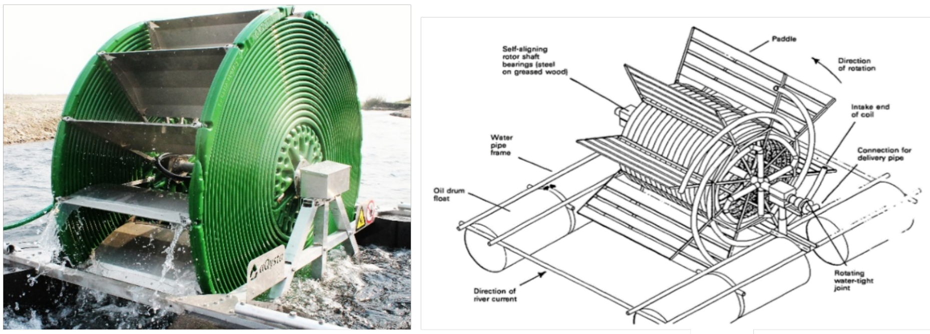
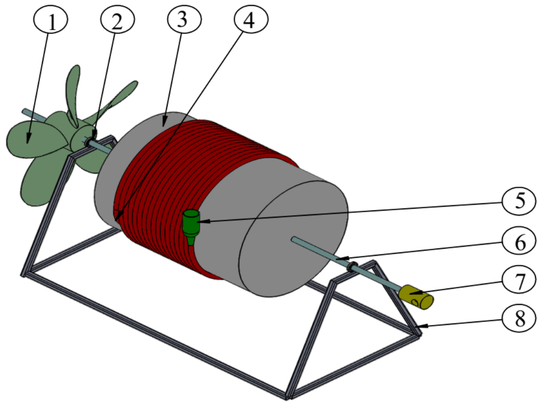



**Figure 1:** Different types of coil pumps. Left: Spiral coil pump -aQysta Barsha Pump retrieved from `https://www.aqysta.com/products/barsha-pump/`. Right: Schematic diagram of coil pump (adapted from [2]).




| Parts No. | Parts Name |
|---|---|
| 1 | Propeller |
| 2 | Bearings |
| 3 | Drum |
| 4 | Coil |
| 5 | Scoop |
| 6 | Shaft |
| 7 | Rotary Coupling |
| 8 | Frame |

**Figure 2:** Components of river water pump.

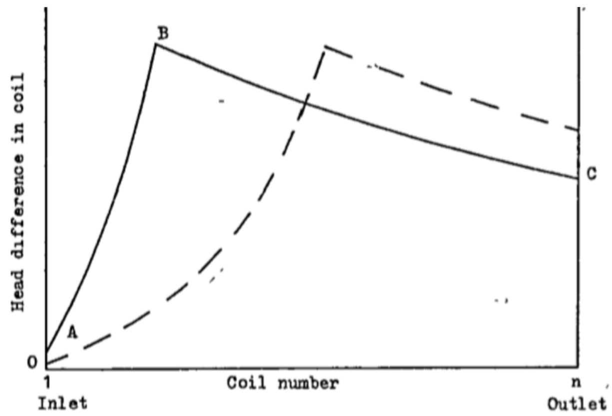



**Figure 3:** Pattern of pressure head on each coil from inlet to outlet [9].

**Figure 4:** Fabricated conical shaped pump.

**Figure 5:** Working model of Cylindrical shaped pump.

decrease in RPM resulted in low discharge of water (11500 liters per day). The performance testing of the conical shaped pump is shown in Fig. 7a.

After the testing of cylindrical shaped pump, RPM was found to be 17, which was also slightly less than the designed RPM. The performance of cylindrical shaped pump is shown in Fig. 7b. It was observed that air bubbles moved up in the delivery pipe because of difference in diameter of coil and delivery pipe (the delivery pipe was 1 inch and coil was 0.75 inch). At very low speed of the pump along with larger delivery pipe, the air could bubble up more easily through the water in the delivery pipe [12], which could reduce its lifting capacity. When water and air move via delivery pipe, the respective plugs become shorter and velocity of water and air inside the delivery pipe is less than the velocity of water at pumping coil. This result in formation of the bubbles. These bubble escape from their position causing decrease in airlifting effect which resulted in discharge at lower head from the delivery pipe.

**Figure 6:** Installation of two pump in Sunkoshi river, Nepalthok, Sindhuli.

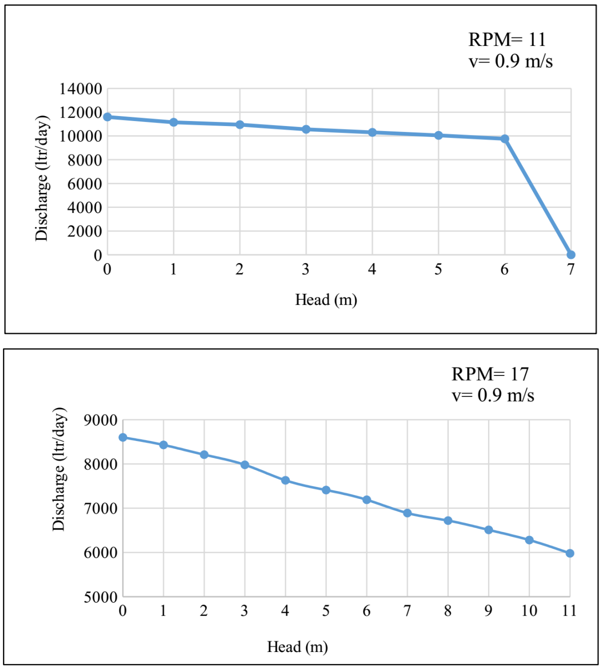



**Figure 7:** Performance of (a) Conical shape pump (upper) and (b) Cylindrical pump (lower).

In both shaped of pump, it was found that discharge of the pumps decreased as increasing lift. It might be because spilling of the water can occur in higher head. As described in Fig. 3, spilling might be higher in higher lift for the same pump. This black flow of water might be the reason for decrease in discharge as increasing lift.

A maximum discharge of 11500 lts/day and a maximum head of 11 meters were achieved from the site testing. Nevertheless, by incorporating some changes in the mechanical aspect of the pumps, the performance of both the pumps could be increased. In the case of the conical shaped pump, the mass balancing was found to be difficult due to the unsymmetrical mass distribution. The static balancing of this pump could be achieved by using a proper frame or anchor underneath the structure. In the case of the cylindrical pump, water leakage inside the drum could be minimized, as well as the diameters of the delivery pipe and the coil could be made equal.

## 4. Conclusion

Two different shaped coil pumps were fabricated and tested. The conical shaped pump was found to be more suitable for higher discharge, whereas the cylindrical pump was suitable for higher head. In both of the pumps, it was found that increase in lift causes decrease in discharge of the pump. Performance of conical shaped pump was significantly affected by the unbalance mass of rotating structure. By improving in the manufacturing process of drum and propeller, mass balance of rotating structure can be obtained. In case of the more conventional cylindrical pump, the structure was found to be more stable, with the maximum head of 11 meters. However, some minor repair for minimizing the leakage and changing the pipes could increase the capacity of these pumps as well. The pump performance was also affected by the size of the delivery pipe. For the larger delivery pipe in comparison to coil pipe, it was observed air escape through water plugs in the form of bubbles resulting in decrease of airlift effect.

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