A manually operated coiled tube pump using plastic drum as a coil supporting structure

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Abstract: This paper describes the development of an inclined axis manually operated coiled tube pump using plastic drum as a coil supporting structure. This pump could be used in small scale irrigation where it is difficult to transport water from lowland to highland area. A physical model of the prototype was fabricated using a small cylindrical plastic container to understand the pumping action of the pump. The prototype of the pump was then constructed considering the availability of material and size in the local hardware. The tests were carried out to collect the amount of water discharged at different angles. The maximum discharge was found 9.0 liter per minute at angle of inclination 20 degrees by the discharge pipe. The human power calculated to manually rotate the pump was approximately 11.36 W (0.15 HP) within five minutes of rotation. The maximum human power is 75 W within eight hours of working hours. Therefore the pump could be manually operated to collect 500 Liters of water per hour by using manual power. Further improvement can be done by using large diameter coiled pipe.

Keywords: inclined axis, coiled pump, plastic drum

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1 Introduction

Manually coiled tube pump is purposely invented to deliver or transfer the water from a river or pond or reservoir to those plantations that are difficult to make irrigation. Apart for irrigation, it can also be used to relieve the burden on the people who live at high and difficult to fetch water at lowland area. Furthermore, this invention is also be used for small scale irrigation. There are a lot of designs were already invented and been used from around the world, but three of them are commonly used such as Water wheel pump, Spiral pump and Archimedes screw pump. In such a developing country as Brunei Darussalam, manually coiled tube pump was not used because most of the farmers were already have automated water pump and most of the irrigation plantations in Brunei were lowland.

The inclined axis coiled tube pump is not well-known though its operation is simple. It works by picking up air and water alternately. The pockets of air become compressed and a monomeric pressure is set up between each adjacent coil when added together, the individual pressure differentials are sufficient to force the slugs of water to the top of the discharge pipe.

A variety of names being used for this type of pump namely monomeric pump, spiral pump and hydrostatic pump (Reimer, 1986). For this experiment it was called as inclined axis coiled tube pump.

A significant development in the design and manufacture of the pump was brought about by inclining the axis of the coil (Basunia et al., 1991; Reimer, 1986; Stucky and Wilson, 1981). The earlier design of the pump was incorporated with lower bearing and coil was supported by sprocket real. This feature represented a significant shortcoming in design and the manufacture of the pump was very difficult for most village workshops.

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A significant development in the design and manufacture of the pump was done by inclining the axis of the pump (Basunia et al., 1991; Morgan, 1979; Mortimer and Annable, 1984) using metallic drum as a coil supporting structure without using lower bearing to fix axis of the pump.

The objective of this research was to design and develop a manually operated internally wound coiled tube pump for small scale irrigation where it is difficult to use power operated pump and it may not be feasible. The features must be achieved in fabricating this coiled tube pump such as less maintenance needed, the design of the pump must be simpler and easy to operate, not using any electrical appliances and more water will be collected in lesser time and more efficient. This study was an attempt to replace the metallic drum with plastic drum in order to reduce power consumption and the operator would fell less tired while operating the pump for a long time.

2 Materials and methods

2.1 Conceptual design for the model of the prototype

First, a model of the prototype was fabricated (Figure 1) to observe the pumping action. The materials used to fabricate the model of the prototype were mostly from recycled materials, inexpensive and easily found in the market. A plastic container of cylindrical shape about 2 liter capacities was used as the coil supporting structure for the model of the prototype. Reinforced plastic tube of about 10 mm diameter was used for the making the coil inside the plastic container (Figure 2). Meanwhile the discharge pipe and handle for rotation were made from PVC pipe of the same diameter. There were no heavy fabrication works being done when fabricate this model of the prototype. One side of the coil was ended at the bottom of the drum keeping an opening on surface of the plastic drum which was considered at the inlet of the coil. The other end of the coil was connected to lower end of a PVC pipe. The upper end of the PVC pipe was bended to act as both the discharge pipe and at the same time it was provided good grip to rotate. The plastic container with coiled tube inside almost 50% submerged when it was allowed floating on a large water container whiles the discharge pipe making an angle 15-25 degrees with the horizontal.

Figure 2 shows the complete assembly looks of the model of the prototype design. The model being assemble using PVC glue and can be dismantle easily without creating any damage to the design.

This model of prototype design then immediately tested at different lift angles: 0° to 40° in a container containing water. As the handle of the discharge pipe was rotate manually using hand, the one third of plastic container easily submerged. As the drum rotates at constant manual speed, it collects both water and air repeatedly. The pocket of water becomes compressed and manometric pressure was set up. Based on the data taken during the testing, the model of prototype worked best at lift angle of 15-25°. Then the actual prototype of the design was started to fabricate.

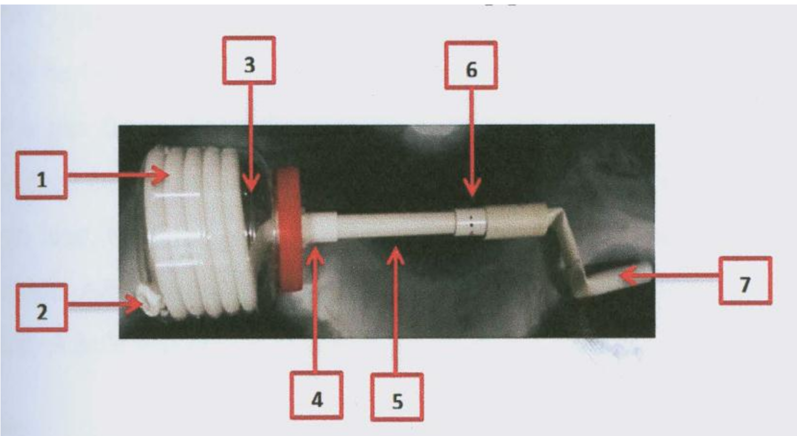

Figure 1 Model of Prototype to understand the pumping action of the pump.

(1-Coiled tube, 2-Water inlet, 3-Cylindrical plastic container, 4-Socket,5-Shaft, 6-Water outlet, 7-Handle)

2.2 Fabrication of the prototype

Since the size of the prototype was relative big and long, hence the fabrication process was divided into several categories i.e. fabrication of cylindrical drum with steel frames (Figure 2), fabrication of support, fabrication of coiled tube, fabrication of aluminum pipe with rotating handle, fabrication of guide and assemble the pump.

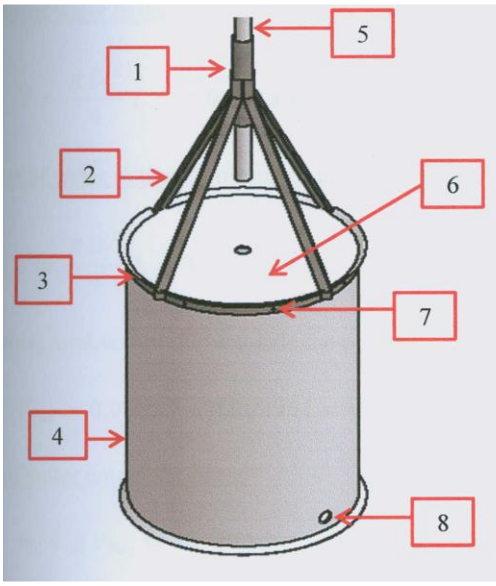

Figure 2 Illustrate the design of the prototype

(1-Mild steel pipe, 2-Angle iron bar, 3-Mild steel metal strip, 4-Plastic drum, 5-Aluminium pipe, 6-Hole for water discharge, 7-Bolt and nut, 8-Water Inlet opening.)

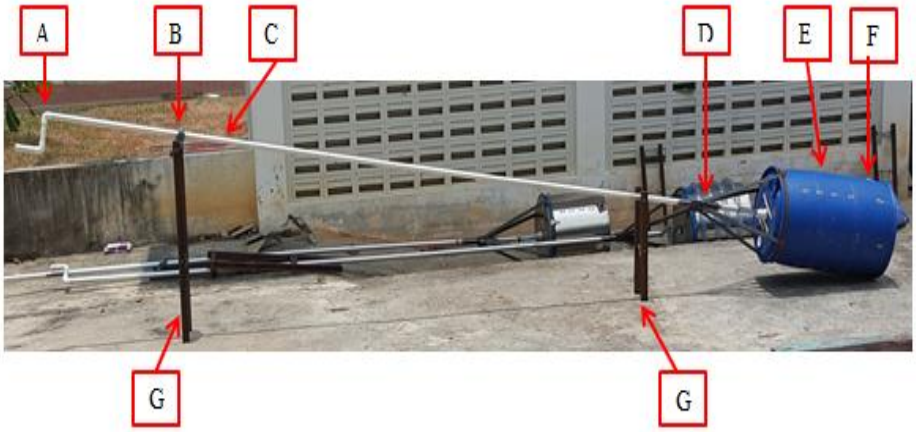

Figure 3 Major components of the pump

(A- Handle, B-Hanger Bearing, C-Water Outlet, D-Support, E-Cylindrical Drum, F-Water Inlet and G-Guide.)

In the fabrication of cylindrical drum, a 38 mm hole was drilled by using hole-saw at centered top surface of the drum. This hole was used for water outlet. Another hole was drilled at the bottom edge of the drum for water inlet. Moreover, there should be an easy access to coil the tube inside the drum, therefore the top and bottom surfaces of the drum were cut by using electrical jig-saw. The eight holes were then drilled using hand drill machine around the top edge of the circumference of the drum. A complete view of the pump is shown in Figure 3.

Mild steel material frame was used to attach the drum with the discharge pipe so that drum should rotate as rigid body with the drum. A 25.5 mm metal strip was cut using cutting machine. This strip was rolled by using rolling machine to ensure that it secured around the circumference of the drum. The drum would easily produce wear and tear when more loads are applied to the drum as it is made of plastic. Hence, the strip was designed to easily reassemble and dismantle from the drum. A draw catch was used to join the end connections of the strip. Eight holes were then drilled using drill machine along the strip. Furthermore, 25.5 mm angle iron bar was then cut into four pieces which was used to connect the strip with 51 mm shaft. The angle iron bar needed to be bent to follow the diameter of the shaft. Then the angle iron bars were welded by using arc welding and MIG welding machine.

A ten meter long flexible plastic tube was coiled inside the drum. The cable ties were used to tighten the tube around the wall of the drum. Any holes on the drum were covered using epoxy glue to ensure no water leaked into the drum. Two sockets were used for the inlet and outlet to ensure that the tube was in placed when rotating the drum.

Aluminum pipe was cut using cutting machine to five meters. Water outlet was drilled using milling machine at the aluminum pipe. High temperature sealant was applied just above the water outlet to prevent the water flow up to the handle. A 25.4 mm PVC pipe was connected to the end of the aluminum pipe by using rivet. This PVC pipe was shaped into L-shaped.

For assembling the pump, first the metal strip was tightened to the drum using draw catch, then eight pieces of bolt and nuts were used to fasten the support to the drum. One end of the aluminum pipe was inserted into the steel shaft and secured it using epoxy glue. The tube was then tightened by using hose clamp to the aluminum pipe.

3 Results and discussion

The pump was tested (Figure 4) after the fabrication and assembly process were completed. There was an open area at the back of the UTB's workshop and also a small hill that was suitable to carry out the test. A manmade pool was made for this testing. The test was carried out to determine the amount of water flow at different angles. Note that the angle of the hill itself was already at angle 15°, therefore the initial test was at angle 15°.

Tables 1-3 show the result of the operation of the pump at angles 15, 20 and 25 degrees, respectively. If the angles of inclination of the discharge pipe with the horizontal surface were more or less than 15-25 degrees, then the pumping action of the coiled tube pump was reduced as a result discharge reduced drastically. So the optimum angle of operation was found to be within 15-25 degrees.

Figure 4 A set up to carry out the testing

Table 1 Water discharged at an angle of 15 degrees

No	Time, *t* s	No. of turn, *n*	Total discharge x 10^{-3} (m^3)	Total discharge Liter, L	Discharge, *Q* x 10^{-4} (m^3 s^{-1})	Speed, N r/min
1	300	130	28.90	28.90	0.963	26
2	300	135	44.795	44.795	1.493	27
3	300	133	40.460	40.460	1.344	26
Average	300	132	38.052	38.052	1.267	26.3

Table 2 Water discharged at an angle of 20 degrees

No	Time, *t* s	No. of turn, *n*	Total discharge x 10^{-3} (m^3)	Total discharge Liter, L	Discharge, *Q* x 10^{-4} (m^3 s^{-1})	Speed, N r/min
1	300	120	46.240	46.240	1.541	24.2
2	300	123	57.800	57.800	1.927	25.0
3	300	127	62.135	62.135	2.072	24.6
Average	300	123	55.317	55.317	1.847	24.63

Table 3 Water discharged at an angle of 25 degrees

No	Time, *t* s	No. of turn, *n*	Total discharge x 10^{-3} (m^3)	Total discharge Liter, L	Discharge, *Q* x 10^{-4} (m^3 s^{-1})	Speed, N r/min
1	300	121	34.68	34.68	1.156	24.0
2	300	125	46.24	46.24	1.541	24.5
3	300	123	49.91	49.91	1.664	25.4
Average	300	123	43.61	43.61	1.454	24.7

Tables 1-3 show that more water was collected when the angle of operation was 20° and less water collected at angle of operation 15°. At angle 15°, since it was almost horizontal to the water level, less water was collected due the water inlet had less contact with the water. The speed at angle 15° was faster than the other two angles. However, when the angle was at 25°, the water did not flow continuously because the water inside the coiled tube faced difficulty to move up to the water outlet. The highest discharge was obtained at angle of operation of 20 degrees.

Table 4 Power in pumping and pump efficiency at different angle

Angle	Water Power Pumping (P_{out}) (W)	Water Power Pumping (P_{out}) (HP)	Break Power Pumping (P_{in}) (W)	Break Power Pumping (P_{in}) (HP)	Pump Efficiency, η (%)
15°	1.263	0.0168	12.112	0.1615	10.43
20°	2.432	0.0324	11.235	0.1498	21.65
25°	2.366	0.0315	11.262	0.1502	21.01

The water power pumping in the inlet (input) and outlet (output) were calculated to determine the human power that was used and compared them with given average maximum human power. The pump efficiency was based on 5 minutes of rotation only. Basunia and Gee-Clough (1999) mentioned that the efficiency could be 50%-60% at lower speed range. The efficiency calculated in this project however was within 10%-21.6%. The efficiency of the present design could be raised by further improvement using relatively large diameter reinforced plastic pipe for making the coil. However, when the testing was carried out, few limitations on the design had been discovered as shown in Figure 5 below. At point 1, bolt and nut was used to connect the support and the drum. Since the weight of the drum was heavier and it was made of plastic, it may create wear and tear to the drum. At point 2, epoxy glue was used to secure the aluminum pipe to the support. However the epoxy glue may easily break when more force is applied to the pump. At point 3, as aluminum pipe has low modulus of rigidity, it bents when rotating the pump even though two supports were applied along the aluminum pipe.

Figure 5 Critical analysis of the pump

(1-Metalic frames attaching with drum, 2-Connection of metallic frames with discharge pipe, 3- Rotating shaft)

4 Conclusions

Some difficulties were occurred during the construction of this coiled tube using plastic drum as coil supporting structure. It the critical analysis the rust formation was observed at the connection of the metal strip and angle iron bars because that areas were continuously in contact with water. As the connection of the support and aluminum pipe was secured by epoxy glue only, when there was more force applied during the rotation, the glue might easily break due to greater torsion in between the connections.

Furthermore, the maximum human power that a person can handle in a day is around 75 W. During the testing, only approximately 12 W of human power was used which was around 16% of human power. However, human power of a woman and a man is different. For this test, the manual power was calculated based on the power availability of a woman to rotate the pump.

The advantages of this internally coiled tube pump are that the coiled tube was secured from sharp or foreign object since it was inside the drum and also the coiled tube would never misalignment. Since the diameter of the tube is 38 mm, larger size of tube diameter will give more water flow than collected. As the design of this pump is simple and the material used is easy to get, less maintenance is needed except for the bearing itself. However, in term of manufacturing, it was little bit difficult to assemble or coil the tube inside the drum. So it can be assembled outer circumference of the drum

The purpose of this project was to collect more water flow in less time. From this experiment, the average amount of water flow collected was approximately 9.0 liters per minute. Hence, the expected daily usage for the water flow collected would be approximately around 500 liters per hour. The manual operation of the pump was relatively easy because the working mechanism was just by rotating the half-submerged drum in water.

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