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An Internally Wound Coiled Tube Pump Using Metallic Drums Locally Available in Brunei Darussalam

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Abstract: The coil tube pump is remarkable in its simplicity and efficient in pumping water by only one moving part. In order to develop manually operated internally wound coiled tube pump using metallic drum as a coil support structure, a model of the prototype design was fabricated and tested. This model turned out to be a success coiled tube pump design which then used as reference for fabricating the prototype. The fabrication of the coiled tube pump prototype was done and the pump was tested. The best angle of inclination to operate the pump was 25° and the discharge was 570 L/h at a manual speed of rotation 24 rpm. The required manual power was 14.2 W to rotate the pump at around 24 rpm. This pump can be used in small scale irrigation by pumping out the water from the low land area where water sources was located such as lakes or very slow flowing rivers to high land area on the hills in the rural area where it was difficult to operate automated pump.

Key words: Inclined axis, coiled pump, metalic drum, angle, speed, prototype

INTRODUCTION

The coiled tube pump is remarkable in its simplicity. 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 pocket of water to the top of the delivery pipe.

A variety of names being used for this type of pump namely monomeric pump, spiral pump and hydrostatic pump. Laboratory tests were carried out on the coil tube pump with horizontal axis at Loughborough University and a model for predicting the behavior of the pump has been developed (Reimer, 1984). They concluded that the stream powered pump developed was only one version of a wide range of possible pumps. They further suggested that work in the field might develop other useful models of the coil pump. The design of the pump went through various stages of improvement. The pump has gone through varies stages of development keeping the axis horizontal and inclined (Basunia *et al*., 1992; Morgan, 1979; Mortimer and Annable, 1984).

A significant development in the design and manufacture of the pump was brought about by inclining the axis of the coil (Reimer, 1984; Basunia *et al*., 1992). The earlier design of the pump was incorporated with lower bearing and coil was supported by sprocket real. This feature represented a significant drawback in design and the manufacture of the pump was very difficult for most village workshops. Recent work at the Universiti Teknologi Brunei (UTB) have produced four different versions of pump using both plastic and metallic drum as coil supporting structures. The present study deals with one of the version of the inclined axis coil tube pump using metallic drum as coil supporting structure (Zepri, 2016).

The objective of this project was to develop a manually operated coiled tube using metallic drum which available in Brunei as the coil supporting structure. The coil was made on the inner surface of the drum. The pump design must be able to use for small scale irrigation usually a farmer in a rural area where they found difficulties to get power supply to operate automated pump especially on the hills near the river. Usually not all automated pumps were feasible to be used in rural area. The following features that must be achieved in fabricating this coiled tube pump are ease in manufacture with less maintenance, pump able to rotates full cycle, durable, user friendly, lightweight and able to pump water manually from low land area to high land area in inclination position.

MATERIALS AND METHODS

A model of prototype was made (Fig. 1) to understand the pumping action of the pump. The materials used to fabricate the model of prototype were

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mostly from recycled materials, inexpensive and easily can be found in the local market. The drum was used as the coil support structure. Aluminium tin and reinforced plastic tube was used for the tube which being coil inside the drum. Meanwhile the discharge pipe and handle for rotation were made from PVC pipe. There were no heavy fabrication works being done when fabricate this model of prototype.

Figure 1 shows the complete assembly looks of the model prototype design. The model was assembled using PVC glue and could be dismantled easily without creating any damage to the design. This model of the prototype design was tested at lift angles of inclination 0-40° in a container of water. As the handle of the discharge pipe was rotate by hand, the one third of the bottom part of coil supporting structure submerged automatically in water. As the drum rotated at constant human 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 the prototype worked best at lift angle of 40°.

A prototype of the manually operated internally wound coiled tube pump design was made based on the idea gathered in testing model of the prototype. It consists of seven important components or parts which play different roles during the pumping process.

The first component was the metallic drum. In this project, a 550 mm diameter of stainless steel drum was used (Fig. 2). The drum acted as coil support structure and it also supported the complete weight at the lower end of the delivery pipe. Inlet and outlet hole were drilled using hole saw on the drum. Inlet hole was made at location where the water and air entered repeatedly while the outlet of the coiled tube was connected to the discharge pipe.

Support for the drum was the second important component that must be exist in this coiled tube pump as it was needed to support the drum and gave smooth rotation to the drum during the pumping process (Fig. 3). It made of mild steel plate and tube and also angle iron. Rolling machine, drilling machine, disc cutter machine, Arc welding and MIG were used to fabricate this support. It clamped on the drum strongly using draw catcher and tightens using bolts and nuts.

Fig. 1: Model of the prototype

The third component that must be exists in coiled tube pump was the coiled tube itself. Coiled tube used to collect a quantity of air and water repeatedly where monomeric pressure exists. Reinforced plastic tube with diameter of 38.5 mm was coiled inside the drum connected to the inlet and the other end of the tube was connected to the inlet of discharge pipe. Both connections tighten up using hose clamp and PVC glue.

The fourth component was the discharge pipe. Discharge pipe was important to rotate the drum and also used for conveying the water. About 5 m long of aluminium pipe with diameter of 38.4 mm was used as the discharge pipe of the pump. The inlet of the discharge pipe was connected to the outlet of the coiled tube with hose clamp. A water discharge outlet was drilled using

Fig. 2: Support for the metallic drum

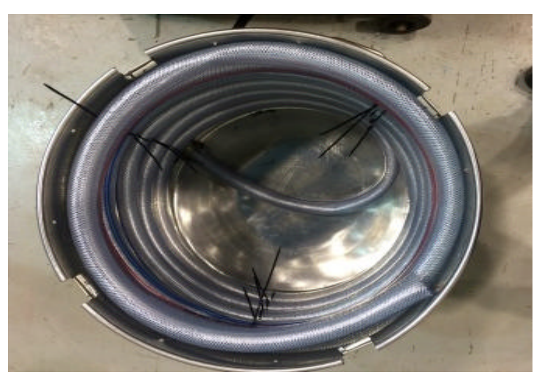

Fig. 3: Tube coiled inside the drum

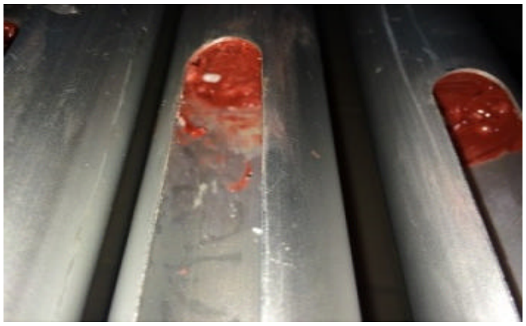

Fig. 4: Sealant used to create water blockage

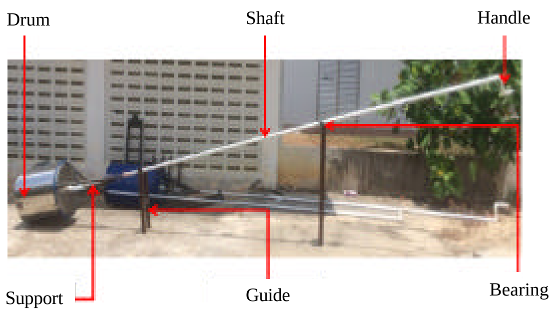

Fig. 5: Complete prototype of the pump assembly

milling machine on the discharge pipe, four meter away from the inlet point. A sealant used to make blockage (Fig. 4) to stop water from flowing through the handle at end point of the water discharge outlet. Discharge pipe connected to the support using epoxy glue which hardens as it dried and gave sturdy connection which allows the discharge pipe to rotate the drum during the pumping process.

The fifth component was the handle. It used to control the rotation of the pump. PVC pipe with 25.4 mm diameter was used as pump handle and connected to the end of the discharge pipe with rivet. Guide and bearing were additional components which gave benefits to the coiled tube pump during the pumping process which marked them as the sixth and the seventh components that must be exists in developing the prototype of manually operated internally wound coiled tube pump. Guide used to control the movement of the pump while the bearing gave smooth rotation during the rotation which enables the user to manually operate the pump effortlessly. Both made of mild steel hollow bar and fabricate using disc cutting machine and drilling machine. Bolts and nuts were used to assemble the design and hanger bearing was chosen since it could control the movement and also the angle of the pump.

Figure 5 shows the complete assembly of manually operated internally wound coiled tube pump prototype. The overall total mass of the pump was about 17 kg. The prototype then tested on the man-made pool on the hills near the UTB mechanical workshop at three different lift angles 15°, 20° and 25° which could be reached by the pump where the head was about 1.7 m from the ground. The tests were repeated three times at each angle of operation to get an average value at each condition.

The pump worked similarly as the model of the prototype. The overall mass of the pump during testing increased to 30 kg as the water and air taken repeatedly. However, the pump still rotates smoothly due to the buoyancy force that exist on the water makes the pump weight much lighter than its original weight. The drum itself only experienced one third submerged in the water during the pumping process.

RESULTS AND DISCUSSION

The pump was tested 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°.

Table 1 and 2 show the result of the operation of the pump. If the angles of inclination of the discharge pipe with the horizontal surface were within 22°-25°, then the pumping action of the coiled tube pump was increased as a result discharge increased (Table 1). So, the optimum angle of operation was found to be within 25° using metallic drum as coil supporting structure.

The project faced challenges when setup the pump on the hills as the hills did not have flat surface ground which made both guide and bearing handle were not rigidly positioned. Wind blew out some of the water that flows out from the discharge pipe away from the water collector which affects some of the recorded values. Inconsistence speed delivers by human allows more human error affected the recorded values. The longer the rotation was the more energy given out which make the user exhausted.

Based on the recorded data (Table 2) pump worked best at 25° lift angle giving the highest volume of water within 5 min of operation. This proved that this prototype coiled tube pump works efficiently at inclined surface such as hills near the water supply to pump up the water to the ground at high land area. At 15° lift angle, the speed of rotation increased. This was because of the easy control of the pump due to low head where human could easily control the rotation of the pump and generate at fastest speed.

Table 1: Volume of water collected in 5 min at different angles of rotation at manual a speed 24-26 rpm

Lift angle (θ)	Volume, V (L)	Volume flow rate, v×10^{-4} (m^3/sec)	Mass flow rate (kg/sec)	Revolution (5 min)	Speed (rpm)
15°	40.9	1.3647	0.1365	130	26.0
20°	37.1	1.2363	0.1236	120	24.0
25°	47.2	1.5734	0.1573	122	24.4

Table 2: Calculated data at 25° lift angle (best lift angle)

Measurement types	Result
Power in pumping water (W)	
Lift angle = 25°	2.56
Input power by human (W)	
Lift angle = 25°	14.20
Pump efficiency (%)	
Lift angle = 25°	18.00
Buoyancy	
Force (N)	9.81
Pressure (water and air) (kPa)	8.61
Density of drum materials (kg/m^3)	24.00

The lift angle that pumps could reach on the tested hills only up to 25° angle. According to the model of prototype, this pump still worked well at 40° lift angle. Different hills will give different lift angles and as long it between 20°-40°, this coiled tube pump can pump sufficient amount of water out from low land area to highland area. Power input required by human to operate the pump at 24.4 rpm where the lift height was at 1.66 m from the ground was calculated about 14.2 W with pump efficiency of 18.0%. This was the amount of power generated by the human labour which was calculated from 5 min of operation. Thus, power requirement as mentioned above falls within the range of power developed by a labour. Average healthy human can developed 75 W within 8 h of working day. Based on the statement, the coiled tube pump was very suitable for manually operation by just using human power.

The density of the coil support structure was around 24 kg/m^3 while the density of the water was 1000 kg/m^3. This showed that the density was less than the density of water which eventually proved that the coil support structure would float on the water with one third submerged based on the observation during the testing. Figure 6 shows critical points on the coiled tube pump which could affect the pump performance and failure. Point A, B and C were the three areas that needed to be taken into consideration. The lid at point A must be sealed properly to avoid any water entering the drum. If there was water in the drum, drum will be fully submerged in the water. Point B shows the tube connected to the discharge pipe (shaft). The hose clamp must be tightening up to avoid any loose which could affect the flow of water through the discharge pipe.

Point C was the most critical position of this pump. If the epoxy glue which used to hold the tube and the shaft breaks, the coil support structure will lost the momentum of rotation making its impossible to rotate the structure. Automatically the pump system failed (Fig. 7).

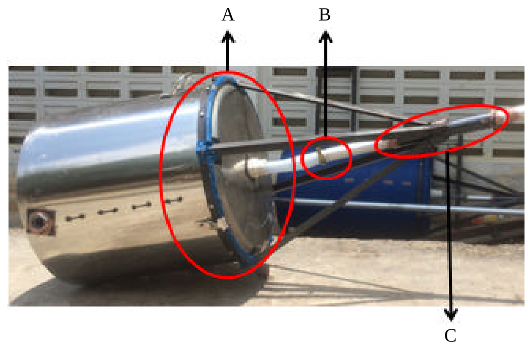

Fig. 6: Critical points on coil support structure

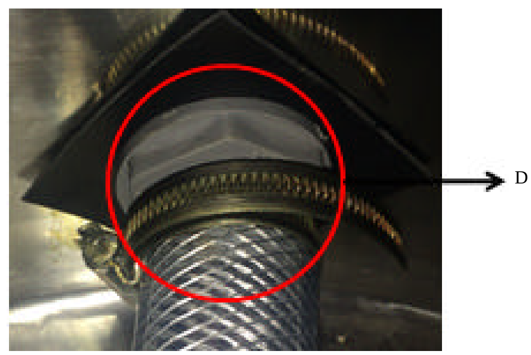

Fig. 7: Critical position inside the drum

Point D was same like with point B. The differences were that point D was located inside the drum connected to the inlet hole of the drum while point B located outside the drum travels out from the drum outlet and connected to the inlet of the discharge pipe (shaft). This critical position must be secure tightly with hose clamp at the PVC sockets connector. If the clamp loosens, the water cannot be pump out through the discharge pipe. Instead the water will fill up the drum and make it heavier and let the drum submerged completely in the water.

CONCLUSION

The best discharged was 570 L/h at lift angles 25°. The pump efficiency was found about 18%. The maximum human power that a person can handle in a day is around 75 W. During the testing, only approximately 14.2 W of human power was used which was around 19.0% of human power. So, there is further scope to increase the discharge of the pump by using large diameter coiled tube. 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 is difficult to assemble or coil the tube inside the drum. So, it can be assembled outer circumference of the drum. From this experiment, the average amount of water flow collected was approximately 9.5 L/min. Hence, the expected daily usage for the water flow collected would be approximately around 570 L/h. The manual operation of the pump was relatively easy because the working mechanism was just by rotating the half-submerged drum in water. This type manually operated coiled tube pump could be used to pump water to high heads from lakes or very slow flowing rivers.

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