GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

CONSTRUCTION OF A VERTICAL AXIS SAIL WINDMILL FOR PUMPING WATER FOR IRRIGATION PURPOSES IN GHANA

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Abstract

Wind pumping in many instances represents the most effective and economic alternative in areas where other forms of energy are difficult or expensive to obtain. In a developing country like Ghana there exists many opportunities for which wind power can be used effectively and economically to pump water. This paper highlights the construction of a sail windmill with a view to converting the kinetic energy of the wind into reciprocating or rotating motion at the end of the handle of a hand pump which is to be used for pumping underground water from a hand-dug well or bore hole and where possible to generate some amount of electrical power. The technical and economic problems encountered in the construction and steps taken to solve these have been reported. The present construction which has a mechanism that enables the mill to work at very low wind speeds is also capable of delivering a high starting torque. The windmill was locally made using the local materials, skills and tools. The durability and reliability of the windmill was ensured by using quality and chemical-resistant materials.

1.0 Introduction

It is believed that the largest available source of fresh water lies underground and the total ground water potential is estimated to be one third the capacity of oceans (Punmia, 1985). Pumpage from wells constitutes the majority of artificial discharge of ground water. Ghana is an agricultural country in which majority of the people live in villages and have agriculture as their profession. Since rainfall pattern is unreliable, erratic in nature and the amount is also sometimes insufficient for the cultivation of crops, irrigation will help in the general development of the country's agriculture. This will in turn improve the standard of living of the people. There are instances where the most dry areas have become prosperous and civilised, mainly due to the introduction of irrigation facilities. Wind power will principally be of interest as an option for pumping water in relatively remote areas where a prime-mover would have to be installed close to the water source and conveniently fuelled. The principal element of wind pump cost is financing the capital investment. Wind pumps are also sensitive to financial constraints, principal discount rate and amortization period. With even a modest wind regime, they appear to be perhaps one of the most economical options for lifting water given present-day high fuel prices in Ghana. In general farm wind pumps are sufficiently reliable and inexpensive to maintain and have a long operational life. Studies conducted recently in Ghana revealed that places along the coastal savanna belt which exhibit fairly favourable wind regimes could be harnessed for pumping water. (Twum,1991). Windmills without a safety system usually have a short life. An exception can be made for very small windmills with a diameter of less than one meter which can be so strong or have a tower which is so low, that they can survive heavy storms. Normally a well-designed safety system is required which must perform three functions: Limitation of the axial forces or thrust on the rotor, limitation of the rotational speed of the rotor and limitation of the yawing speed (rotation of the head around the tower axis (Kragten, 1989).

2.0 The figure below shows the assembled drawing of the windmill.

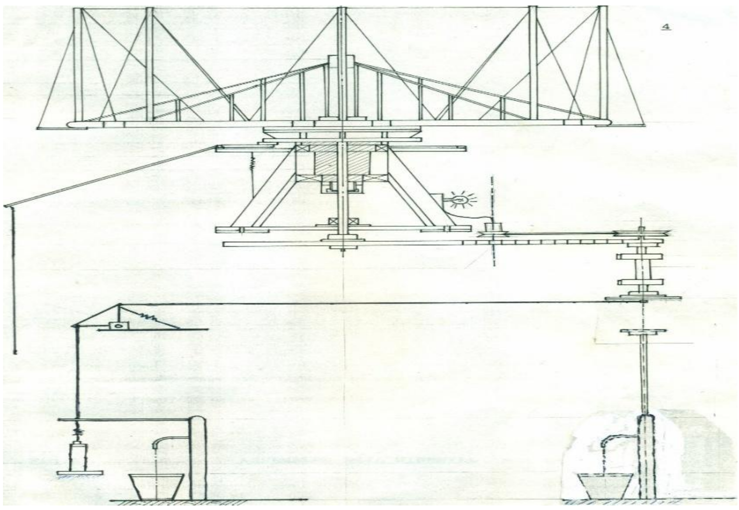
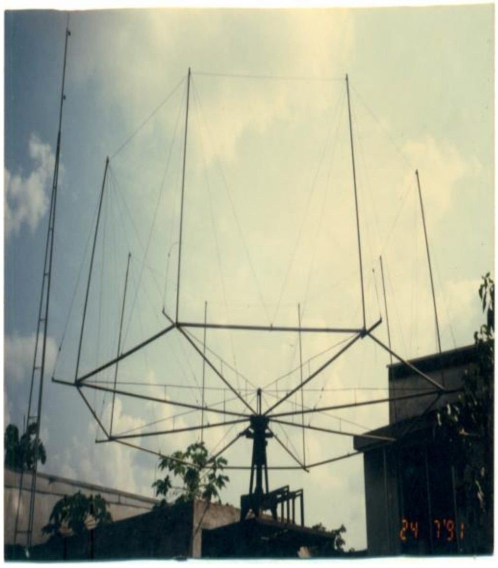


Fig 1.Assembled Sail Windmill

3.0 Description of Parts of the Wind Mill

3.1The Rotor

The structure is an octagonal rim of galvanized steel pipes welded to a central hub by the same pipes. To ensure a level or flat bottom of the rotor, iron rods of about 5mm diameter are used to reinforce it. These rods or struts are attached to the pipes joining the octagon to the central hub, and the extended hub. At the ends of the joints of the octagon are erected eight pipes of which each is of height 2m, for attachment of the sails. The diameter of the rotor is 6m and that of the central hub is 300mm. This hub has holes which coincide with those on another hub. These two hubs are joined together with bolts and nuts which allow the rotor to rotate with the hollow shaft in the bearing housing. Strong wires are used to reinforce the vertical pipes to make them more resistant to the wind force to be exerted on the sails which they hold. Fig.2 below shows the rotor. The light arrows show the direction of travel of the aerofoils at the instant they are in the positions shown. The dotted arrow shows the direction of the actual wind. The heavy arrow shows the direction of the "relative wind" The length of any of the arrows represents the speed velocity is a vector quantity) of either the aerofoil, the actual or the “relative wind”. Note that while the length of the aerofoil and actual wind arrows stay the same, the length and hence the speed of the relative wind changes.



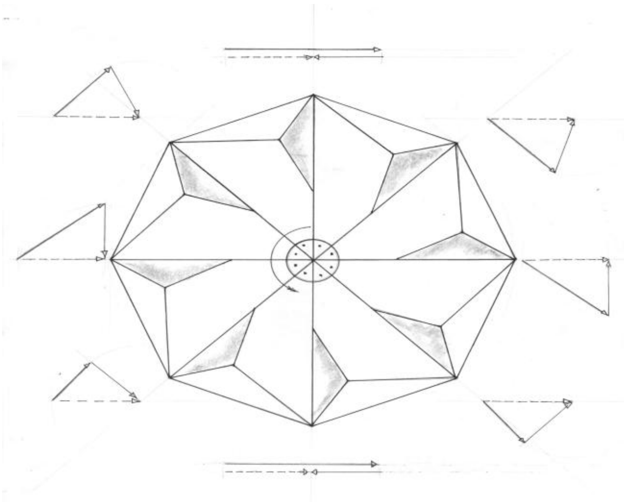
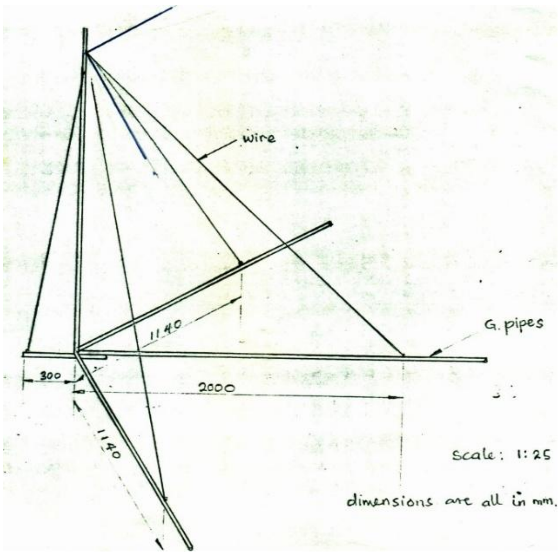


Fig 2. a. Rotor assembly b. Rotor



c. Reinforcement of the Rotor Frame

3.2 SAILS

The guiding principle in the setting of the sails is that it is important for the spent air to be able to leave the wind wheel without obstructing their flow to the following sails. It is also important to note that the main turning effect is due to the difference in drag between the concave and convex faces of the cups. The sails are made of tarpaulin. They are cut or shaped into right-angle triangles of perpendicular sides of about 2. 3m x 2.5m. The edges are sewn to prevent the sails from tearing prematurely. The sails are riveted at the edges and their centroids. Each sail has about 22 rivets in all. The sails are to be tied to the rotor by nylon cords and shaped in the form of a cup by means of three nylon cords radiating and passing through the centroid to the corners as shown in fig. 3

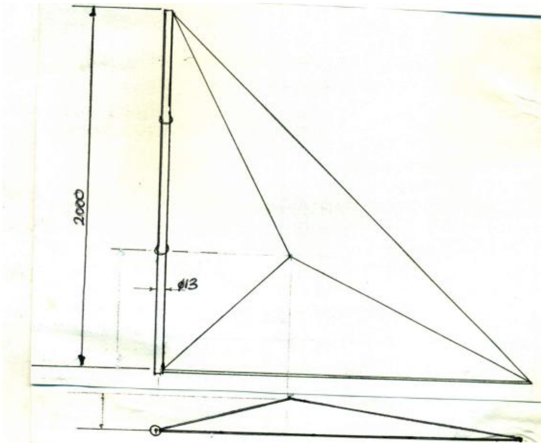


Fig.3 Sail configuration

To set the sails in position, the following steps were followed:

1. Cut three cords and tie one end of the cords at one point such that the three cords radiate from a common point.
2. Tie the sails onto the poles.
3. Tie the nylon cord to the corners of the poles such that it radiates from the centroid. They must be under tension. (Note: this has no effect on the sails at this stage.)
4. Pass a cord through the centroid of the tarpaulin and tie one of the ends of the cord to the nut or joint at the common point of (3).
5. Now tie the other end of the cord to the foot of the next pole. Tensioning this cord causes the sails to be shaped in the form of a cup.

3.3 The Tower (Supporting Frame)

It serves as a point of attachment for various components such as the main shaft, transmission, bearings, etc. The Rotor is usually placed on a tower to. Regardless of the platform type there are several possible tower forms that can be used. Essentially these are: Lattice steel (truss) tower (3 or 4 legs); Single column (steel or concrete) and multiple column (3 or 4 legs).

The supporting frame is made up of galvanized steel pipes of diameter 60mm. These are joined together by welding to attain a height of 10m above ground level. The initial height which has been constructed for test purposes is about 2.5m. There is a platform about 1m from the top of the supporting frame. This consist of a rectangular frame of angle bars, on which mahogany boards are placed (Fig. 4). The platform is a little over 1m below the rotor hub at the top of the supporting frame, a seat is provided for attachment of the bearing housing.

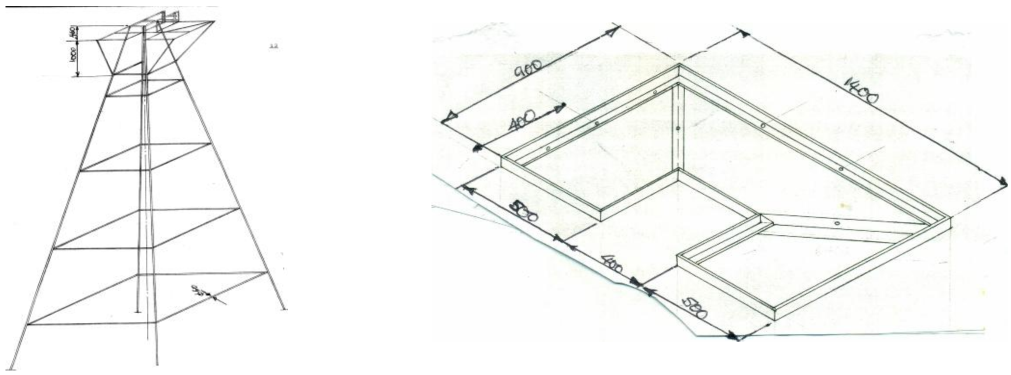


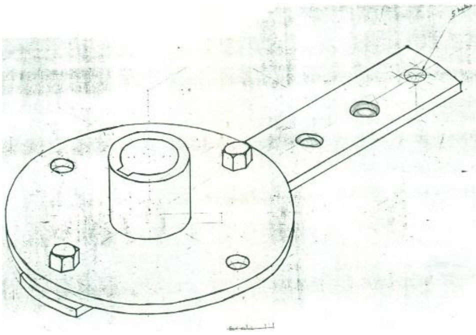
Fig 4. a.The windmill tower b. Platform

3.4 The Transmission

The transmission is made up of a chain and sprocket to step up the speed and the bell crank mechanism to change the rotational motion to reciprocating motion. The speed ratio is about 1:10. 2.1.3.1. The connecting rod connects the transmission hub to the bell crank by means of ball and socket joints at both sides.

3.5 The Transmission Hub

The hub is keyed and machined to make its walls as thin as possible and has an inner diameter of 30mm. A bar is bolted to the hub (as shown) to extend its flange and prevent the machining of an exceptionally large hub.



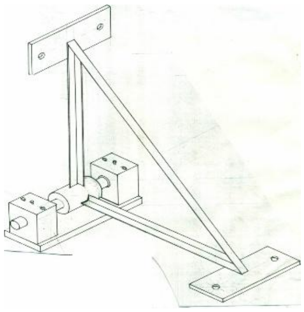


Fig 5 a. Transmission Hub b. The Bell Crank Mechanism

The bell crank mechanism consists of angle bars, 20mm x 3mm, welded to a crank which passes through two wooden bearings. The wooden bearings are bolted bars 50mm x 50mm which are also to be bolted, to the sliding seat. This mechanism helps produce the reciprocating motion at the pump handle fig.5.

3.6 Pump Handle Connection

The handle of the pump was spring loaded so that the spring provide the down stroke whilst the windmill took care of the up stroke. Two eye bolts of size M15 are used to hold the spring in position. One of the bolts is screwed to the pump and the other to a tapped plate. The force in the spring can be adjusted by screwing or unscrewing the bolt in the plate. The tapped plate is welded to two galvanised pipes whose lower portion is also welded to another plate which will be fixed to the slab. Another spring connected directly to the bell crank helps return both the bell crank and the pump handle to their equilibrium position .This works against gravity and reduces the extra work the mill would have done against gravity.

3.7The Main Bearing Housing

This is a four legged structure made from mild steel. A hollow shaft which is flanged at the top runs through two bearings - a roller bearing at the top and a taper bearing at the bottom. The flange is about 300mm in diameter and has holes for coupling the rotor. The feet of the bearing housing are bolted to the seat of the supporting frame.

3.8 Power Shaft/Driven Shaft

The forces on the shaft include: a) Thrust forces due to the wind on the sails b) The tension in the chain c) Reaction at the bearings and d) The thrust forces due to the weight of the rotor. The power shaft has a diameter of 30mm. It also has two keyways at one end for keying to the rotor and one at the other end for a flange and the bigger sprocket Fig. 6. The driven shaft is of diameter 35mm. One end takes a tapper bearing and a flange as part of the transmission hub and also acts as a point of attachment to a rotary pump and the other end takes the smaller sprocket and a pulley for possible generation of electricity.

Fig 6. Power shaft

3.9 The Breaking Device (Manual)

The device consists of a bar, on which an old brake shoe is bolted. The bar is pivoted at the middle. A force is applied at the side opposite the break shoe which causes it to engage with a hub on the rotor, stopping it by friction. The whole mechanism is a first class lever. It consist of 60mm x 10mm metal bars being part of a long lever connection welded to opposite sides of a hollow shaft as shown (fig.7). A square plate, 100mm x 100mm, is welded to the ends of one of the bars. The plate has four holes so that the break shoe can be bolted to it.

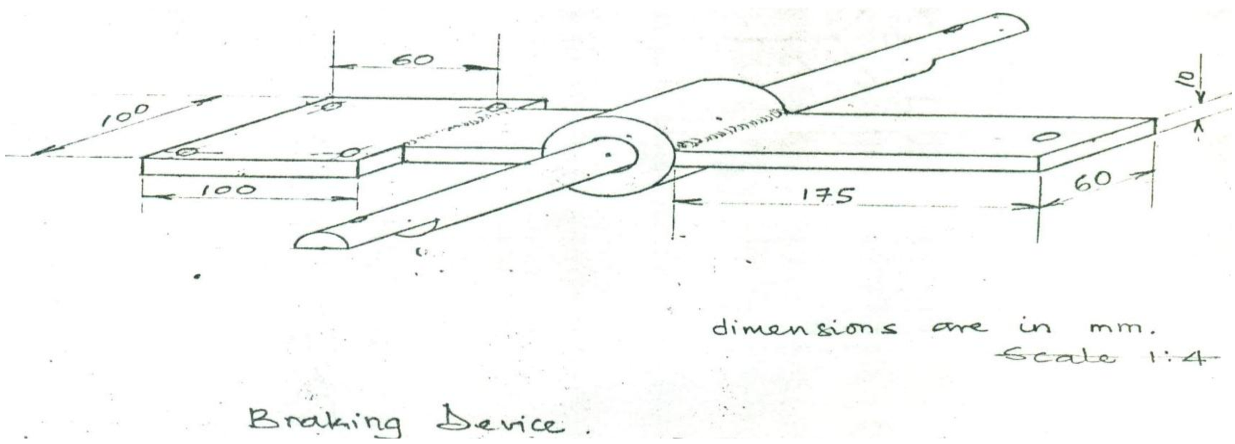


Fig 7. Braking device

4.0 The Strap Holder

This is a rod of 10mm diameter rolled into an arc subtending an angle of 270'. Four square plates, 50mm x 50mm containing holes of diameter 13mm at their centres are welded to the arc at 90' from each other. This enables it to be secured firmly on four different parts on the supporting frame fig 8

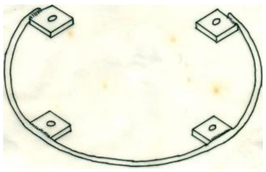


Fig 8.Safety Device-Strap Holder

4.1 Sliding Seat

It is intended that the rotor would be slid up on one side of the supporting frame by means of pulleys. To this side of the frame the platform does not extend, however the bell crank mechanism protrudes so a sliding seat is provided so that when the rotor is about to be mounted, it can be slid onto the central part of the supporting frame to prevent obstruction. The sliding seat consists of a flat metal bar of thickness 10mm fixed to two U-bars by welding. The U-bars were shaped to fit into two pipes of diameter 60mm as shown in fig.9

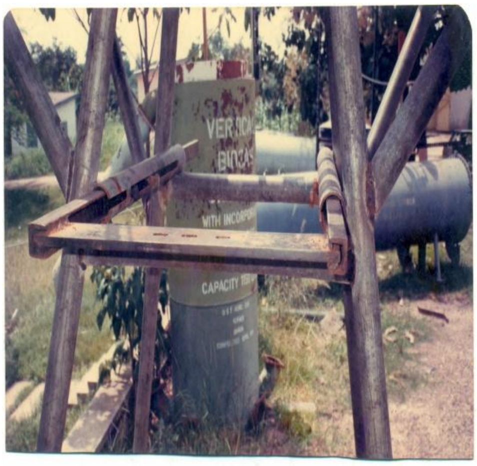


Fig 9. a. Sliding seat b. Constructed windmill

Conclusion

Wind energy is one of the options of renewable energy resources which can be strategically exploited as a supplement to traditional energy. The escalating costs for hydroelectric.power, fossil, nuclear fuelled systems calls for the use, of alternative source of energy in developing countries like Ghana. The present construction makes use of the locally available materials and energies. It is a simple technology which every layman can understand. The entire know-how is within the country and since everything is locally made spare parts can be obtained in the country. Raw materials are reliable and cheap. It is also important to note that there is no need for well equipped workshops with qualified personnel or specialists. The new design is independent of any other technology available at the site. The operational and maintenance costs during its complete service life is also minimised. The utilization of low wind velocities (which occur far more often than higher velocities), for example for pumping water for irrigation purposes which is so important for developing countries is significant. The rotor has been design to deliver a high starting torque and to begin running at very low wind speeds.

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