CONSTRUCTION OF SAILWING ROTOR (VERTICAL) FOR PUMPING WATER IN BANGLADESH

A THESIS SUBMITTED TO THE DEPARTMENT OF "MECHANICAL ENGINEERING" IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGRE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

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CERTIFICATION

This thesis paper entitled "**CONSTRUCTION OF SAILWING ROTOR (VERTICAL) FOR PUMPING WATER IN BANGLADESH**" submitted by under mentioned group has been accepted satisfactory as required for partial fulfillment for completion of 'Bachelor of Science Degree in Mechanical Engineering' for Level-4 (Term-I and Term-II; Course No.- ME-400) on 13 December, 2017.

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DECLARATION

We hereby solemnly declare that, the contents of this thesis are results of works earnestly carried out by the undersigned students, supervised by Dr. Md. Quamrul Islam, Professor; Mechanical Engineering Department, Military Institute of Science & Technology (MIST), Mirpur Cantonment, Dhaka- 1216, Bangladesh.

We also declare, neither this paper nor any of its parts of it have been submitted elsewhere for award of any other degree.

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ABSTRACT

From the Recent years perceptions, obviously Fossil fuels are going to either be gone or they will turn out to be excessively costly, making it impossible to sensibly utilize and furthermore, the atmosphere is changing and that non-renewable energy source emissions are contributing enormously to that change. Improvement of wind energy used in urban situations is of developing enthusiasm to industry and local governments as a alternative option to utility-based and non-renewable types of energy creation and also wind turbines produce zero outflows in their generation of power. To lessen the present utilization of power for pumping water and to guarantee of drawing water in the territory where transmission of power is too exorbitant, development of sailwing rotor (vertical) is valued. To use the accessible wind energy a vertical axis sailwing rotor having six sails combined with a diaphragm pump is created utilizing locally accessible material and innovation which works even at low and variable air speed.

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NOMENCLATURE

P- air density (kg/m^3)

A-area swept by the rotor blades (m^3)

v_α – undisturbed wind velocity

d- diameter of rotor

U-wind velocity through the rotor

V-wind velocity for behind the rotor

α-angle of attack

Q = water discharge rate, m^3/s p,,, = water density, kg/m^3

H = total static pressure head, m pa = air density, kg/m^3

1.1 General

The increase in costs of fossil fuels has greatly lead to the development of alternative sources of Green Energy that are environmental friendly and cheaper to produce. The major resource in this category is wind energy.

Energy consumption is the prime concern of people of the world now a days. To meet up the demand of growing population importance on conversion of energy is given.

Energy from natural sources has always been a great appeal. Barrels of oil, lumps of coal, even uranium comes from nature but the possibilities of all almost limitless power from the atmosphere and the atmosphere and the oceans seem to have special attraction.

The massive increase on fuel price over the last decades has compelled us to investigate and find out the new means of sources from where energy can be extracted. From that point of view renewable energy sources come to the scenario. Six main sources of renewable energy are Solar power, Wind Power, Hydroelectricity, geothermal, ocean tidal and biomass.

our thesis project is based on the wind power as we are interested to extract energy from wind. Wind power can be utilized in many ways, generation of electricity has become the most useful one for recent years. Wind power is growing at the rate of 17% annually, with a worldwide installed capacity of 432,883 megawatts (MW) at the end of 2015.

The simplest and undoubtedly economic means of extracting wind energy by sailwing rotor (vertical) for pumping water is our present concern.

1.2 Objectives of Study:

The main objectives of the thesis are-

- To seek suitable means of extracting energy from natural sources by altering or modifying the existing ways and ingredients.
- To extract wind power through sailwing rotor (vertical) for driving diaphragm pump.
- To construct the project in such a way so that it would be economical as well as effective
- To observe and performance of the same under the available wind in this country.
- To know about the Darrius rotor as it is said to be the most efficient vertical axis rotor.

  But we cannot construct it as it is very difficult to maintain the perfect airfoil shape of the rotor blade and it also needs costly materials, high staring velocity and it needs pilot rotor.

2.1 DEFINITIONS

Wind

This is air in movement and it is a characteristic asset that is unreservedly accessible in space and moves at different velocities relying upon the geological area.

Wind energy

Wind energy originates from solar energy where the sun heats the atmosphere unevenly causing some parts to be warmer than others. The warmer patches of air rise and other air patches blow into replace them. Thus, alternating air flow which results in wind.

Windmill

Windmills are machines that are used to harness the kinetic energy of the wind which blows over the blades rotor assembly causing it to rotate on a shaft. The resulting shaft power is then used to provide mechanical work for pumping water.

2.2 Wind Energy And Sailwing Rotor For Pumping Water

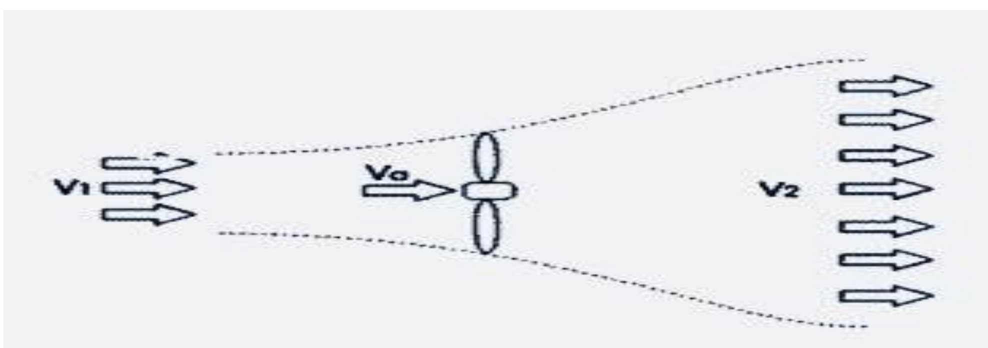

Figure 2.1 : flow of air through a rotor of windmill

Sailwing rotor works on the principle of converting kinetic energy of the wind to mechanical energy. Air mass flowing with a velocity v_α through an area A represents a mass flow rate m of

$m=\rho A v_\alpha$ (kg/s)

thus for a flow kinetic energy per second or kinetic power P_{kin} is given by

$P_{kin}=1/2 * m * v_\alpha^2$

$=1/2 *(\rho A v_\alpha) * v_\alpha^2$

$=1/2 * \rho * (\pi/4 * d^2) * v_\alpha^3$

$P_{max}= 16/27 *1/2 * m * v_\alpha^3$

Where,

P- air density (kg/m^3)

A-area swept by the rotor blades (m^3)

v_α – undisturbed wind velocity

d- diameter of rotor

U-wind velocity through the rotor

V-wind velocity for behind the rotor

At the point when the air in motion strikes the sails, it takes up the state of an aero foil with a concave surface looking into the wind, after half revolution the inward surface of the sailwing changes to opposite side naturally.

So a positive torque is developed for all the position of the rotor. The shaft power is transmitted to the pump in several ways. If a reciprocating pump is used, rotary motion of the main shaft is converted to reciprocating motion either by an eccentric wheel mounted on the wheel or a crack mechanism. If a rotary pump is used motion is transmitted to a pulley on the pump shaft by an endless belt.

The overall efficiency of the system, is plotted against the water discharge rate, Q Overall efficiency is defined as

$$\eta = Q\rho_w \, gH / ½\rho_a AV^3$$

Where

Q = water discharge rate, m^3/s p,,, = water density, kg/m^3

H = total static pressure head, m pa = air density, kg/m^3

V = wind speed m/s

2.3.Types of Wind Mill (According to Axis)

a) Horizontal axis wind mill
b) Vertical axis wind mill

A horizontal axis wind mill has its rotor oriented normal to the wind direction. its design is complicated because the mechanical energy is transmitted over a distance and secondly it needs to be mounted on a turn table or like for orienting it to change wind direction.as a result vertical axis wind mill is preferred over horizontal axis wind mill.

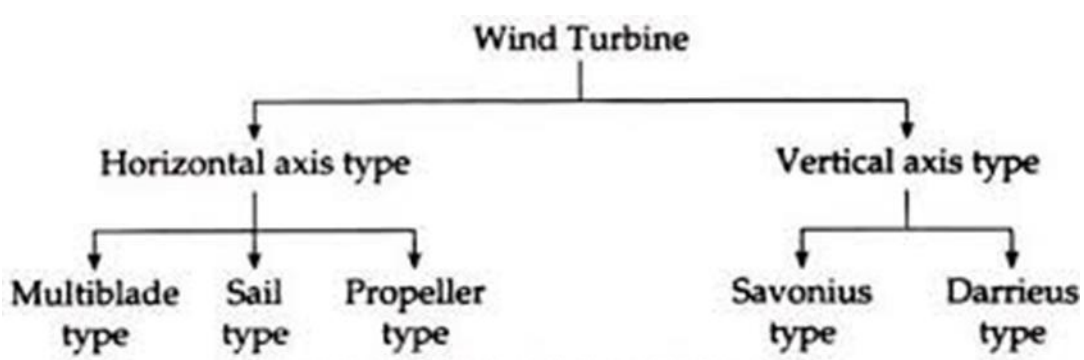

Figure 2.2 : Wind Turbine Classification

2.4Feature of Vertical Axis Wind Mill:

i. It has its rotor moving in the same direction as the wind.
ii. Delivers mechanical power at ground level.
iii. No pitch control is required for synchronous application.
iv. Turbine01 is omni directional in its acceptance of the wind.
v. Simple support tower construction.
vi. Eliminates yawn control due to vertical symmetry.
vii. No gyroscopically induced stresses.
viii. Reduced sailwing fabrication cost.
ix. Versatility and simplicity afforded by the vertical main shaft in mounting driven devices.

2.5 Flow Over an airfoil: (definitions)

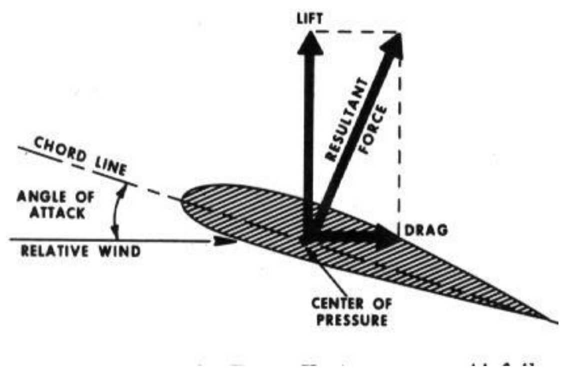

Figure 2.3: Force vectors on an airfoil

An airfoil is a surface over which air flows. This flow results in two forces: LIFT and Drag.

LIFT- The lift force is the force measured perpendicular to the air flow.

DRAG-The Drag is the force measured parallel to the flow.

Angle of Attack- All airfoils require some angle to the air flow in order to produce lift. The angle required for lift is called angle of attack (α).the angle is measured between the chord line and the direction of air flow.

2.6 Pump Selection For Wind Mill

For selecting possible pump types for low or high head requirements at three different capacity levels the initial classification is to be known. Reciprocating Diaphragm pump is used. Because of the nature of the crank mechanism and rate of discharge.

2.7 Wind Data Collection

For installation of a wind turbine analysis of wind date for a certain region is very important. The following points will be considered for the analysis of wind data:

i. Daily, monthly and annual wind pattern of the region.
ii. Duration of low wind speed and high wind speed.
iii. Maximum gust speed.
iv. Wind speed of the place of location.
v. Probable energy that can be produced per month and per year.

A set of hourly data from a meteorological station may be available. However short time measurements are necessary at the location where a new wind mill is planned. If no data are available at all, then judgement is limited to inquiries of local population and analysis of the vegetation.

Reliability of data depends on the following factors:

i. Actual position of the Anemometer.
ii. Distance and height of nearby buildings.

iii. Type and quality of the Anemometer.
iv. Method of reading for recording the data.
v. Make sure whether m/s, knots, miles/hr. or other units of measurement are employed.

2.8 Location of the Plant

The power output of a wind turbine increases with the cube of the wind speed. This means that the site for a wind mill must be chosen very carefully to ensure that the location with the highest wind speed in the area is selected.

Number of effects to be considered:

i. Wind Shear: the wind slows down near the ground due to surface roughness.
ii. Turbulence: due to buildings, trees, ridges etc.
iii. Acceleration (or retardation): on the top of hills ridges etc.

Following factors are considered for plant location:

i. Availability of the wind energy.
ii. Degree of utility of wind power.
iii. Requirements of power.
iv. Cost of competitive power.
v. Geographical location and environment.
vi. Project visibility to assess public reaction.

History and Construction of Sailwing Rotor

3.1 History

Vertical axis sailwing rotor was designed and constructed for the first time by the Australian Wind Energy Association. The basic theme of the design of this inexpensive and versatile windmill is the development of a vertical axis sailwing rotor supported by a rigid frame, in which the wind itself is used to shape the wings.

Encouraging results were obtained by Brin Hurley who pointed out that rotor might be constructed with three to eight sails. As increase in the number of sails help the rotor to start at low wind speed. However, the maximum power doesn't vary significantly with the number of sails.

3.2Main Components of Sailwing Rotor

The sailwing rotor consists of following components:

a) Rotor
b) Tower
c) Baseplate
d) Guyes
e) Sail frame
f) Rotor arms
g) Sail
h) Bearings
i) Diaphragm pump

Description of the Components

a) **Rotor:** the rotor consists of six sailwings mounted vertically at equal distance from the vertical axis. The rotor has the following elements- (also shown in the fig.)

   i. Hollow steel pipe
   ii. Rotor arms
   iii. Two steel plate

The two-steel plate is welded to the rotor i.e. to the hollow steel pipe. The rotor arms are screwed with two 5 mm diameter bolt to the steel plate.

The dimension of the elements is given below:

   i. Hollow M.S Pipe-

      External dia – 1.5’’

      Internal dia – 1.4”

      Length – 20”

   ii. Rotor arms are made of steel conduit pipe-

      External dia – .585”

      Internal dia – .475’’

      Length – 5’

   iii. Two circular steel plates-

      Diameter – 12’’

      Thickness – .4’’

      Hole Diameter – 8mm

The rotor rotates about the vertical axis. Each sailwing is formed a rigid span which is positioned at the leading edge of the sail. To this span two or more rigid ribs are attached at right angles. The trailing edge of the sailwing is held in tension in between the end of spans. The surface of the sailwing is made from parachute fiber canvas.

At the point when the air encroaches on the sailwing it takes up the state of an airfoil with concave surface looking into the air. Amid revolution the sailwing acts like an airfoil with continually changing approach. Amid one finish revolution of the rotor the sailwing switches the concave surface starting with one side then onto the next naturally. This empowers the rotor to build up a positive torque even at low rpm for essentially all places of the rotor.it is self starting not at all like the Darrius rotor to which it is comparable in same other perspective. An element which is of vital is that the trailing edge of the sail moves its position with respect to the main edge of the sail moves its position in respect to the main edge amid turn. The trailing edge is redirected to the side far from the air because of the belly created by the sail. This has the impact on decreasing the approach of the relative air. This tends to postpone the slowing down of the sail.

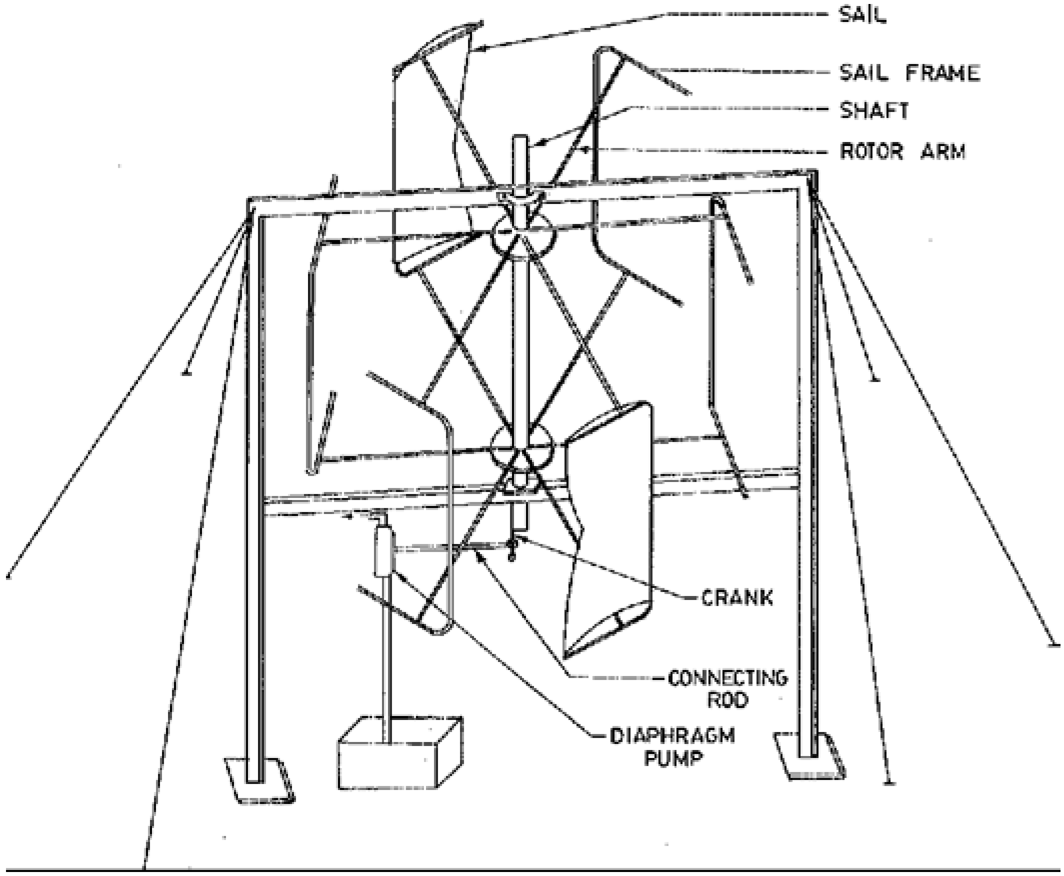

Figure 3.1 : Construction of Sailwing Rotor

b)**Tower**:

The Frame structure is made by two 4*2" C section vertical and 2 horizontal channel joined together forming a frame structure.

c)**Baseplate**:

The base is also made of 4"*2" C-section channel.

- Quantity of channels-4
- Length of channel (each)-2'

d)**Guys**:

Guys wires are used for holding the structure tightly to the exact place and also to hold the crank mechanism straight.

e**) Sail frame**:

The sail frame is made of steel conduit pipe and the sail is made of flexible material such as cloth(parachute fiber canvas) .the main components are –

i) Sail frame

ii) Parachute fiber sail

Six sails are made of parachute fiber canvas and their dimension is 4’ X 40’’ .the sail frame is constructed by bending the conduit pipe to the shape using a bending machine.

The sail is made from canvas or polythene. The pocket through which the sail frame is inserted is made by turning back the front edge and switching the doubled-up canvas or polythene. The two corners of the sail need extra reinforcing. The sails are secured at the corners to the ends of the sail frame by cord which is sufficiently strong to with-stand normal working tension but which should snap under storm conditions. It is better to make the cord too light than too strong. We can easily repair the broken cords after a storm, an wrecked windmill is another matter.

f) The Bearing

There are blocks which are fastened to the tower cross pieces with bolts each and a ball bearing and thrust bearing was placed on it to make sure that they can be loaded vertically to take the weight of rotor and its components. Wood bearings could be used if made from hard wood, although the vertical loading might present some problem. The thrust bearing takes all the vertical load of the rotor. The dimensions of the bearing are given below:

i. Ball Bearing-

Size, external dia = 1.75’’

Internal dia = 1.49’’

ii. Thrust Bearing-

Size, external dia = 1.75’’

Internal dia = 1.49’’

g) Diaphragm Pump

A diaphragm pump manufactured locally is connected to the crank by a mild steel rod. A circular metal piece made of 6.52 cm diameter and 1.12 mm thick plate, having a 1.11 cm diameter hole at the Centre is fitted at one end of the connecting rod. The rotary motion of sailwing rotor is converted into reciprocating motion in the pump. The pump has the following components –

i. Delivery pipe

ii. Leather diaphragm

iii. Flange

iv. Connecting rod

v. Circular metal piece

vi. Suction pipe

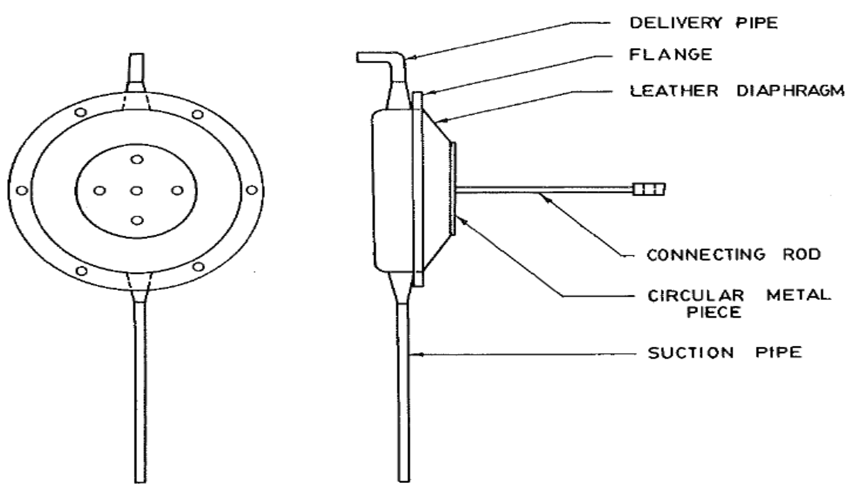

figure 3.2: Schematic diagram of diaphragm pump

4.1Feasibility of the Project

The venture in light of the wind energy use was for the most part kept with the development of the vertical sailwing rotor for directing water in Bangladesh. This was finished by utilizing locally accessible materials and innovation. The development was observed to be exceptionally straightforward and generally financial.

The current ground in this nation in wide zones with rapid air renders its application prudent satisfactory. The possibility ponder demonstrates that this sort of windmill will be best for this nation as it needs low beginning wind speed (1.5m/s). It is likewise expected that this methods for pumping water will work more effectively during the time in the beach front region, slope tracks and town sides.

Every one of these contemplations demonstrate a promising future for the improvement of windmill framework in Bangladesh and its developing commitment to the national energy generation.

5.1 Design & Construction

The vertical axis sailwing rotor, the most economic one was first designed and developed by the Australian Wind Energy Association (AUSWEA). But in this work we have made some variations in both materials and design to fulfil the material availability, its economic and the production (fabrication) facilities.

The rotor consists of:

i. Mild steel shaft

ii. Two mild steel circular plates (hubs)

iii. Six sail frames with twelve rotor arms made of conduit pipe

iv . Six sailwings having the size 1.22 m * 0.76 m and having two reinforced corners each.

5.2Construction procedure:

The vertical axis wind turbine is mainly a combination of two parts. Namely –

1. Holding STRUCTURE
2. The turbine

HOLDING STRUCTURE

The structure consists of mainly two parts

1. The frame (Tower)
2. The base

Frame: The Frame structure is made by two 4*2" C section vertical and 2 horizontal channel joined together forming a frame structure. The vertical channel is kept at a height of 20 feet from the ground to get good turbulence of air. The vertical channels are kept apart at a distance of 14 feet from each other by the horizontal channels. The purpose of the frame is to support and hold the turbine while it rotates 20 fts above from the ground.

The vertical and the horizontal channels are joined together by nuts and bolts through the welded plates and triangular brackets.

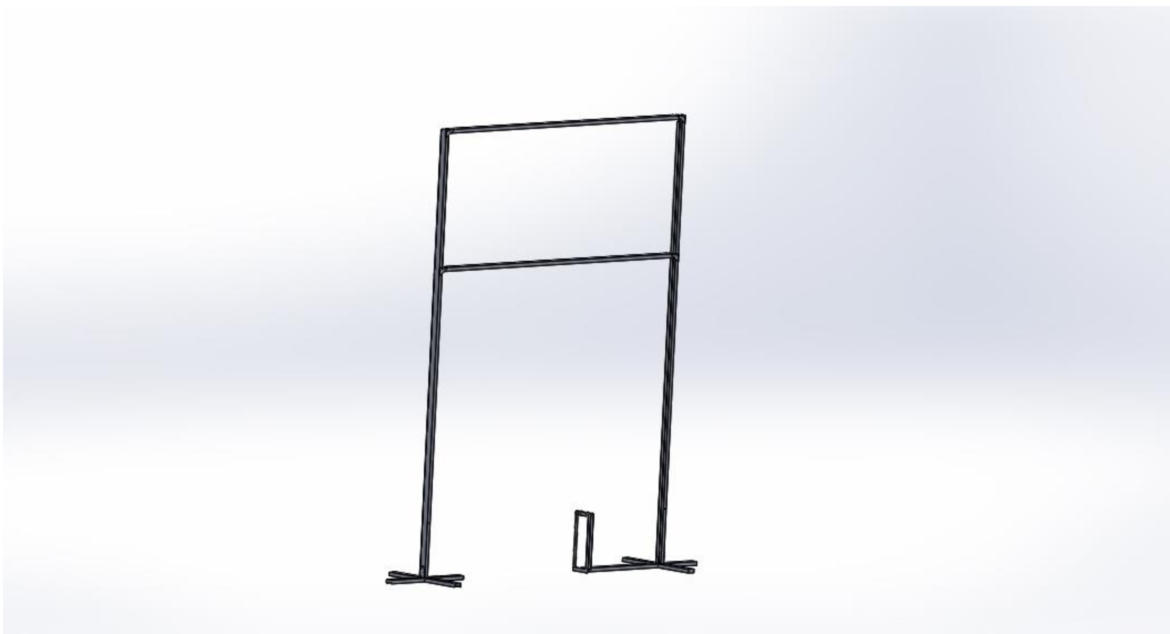

Figure 5.1: 3D-view of the frame

WELDED PLATES

Two plates are welded on the upper sides of each of the vertical channels which resist the downward axial force of the horizontal channels. Similarly two plates are welded to each of the vertical channels which are located 6 feet below the upper welded plates and it supports the lower horizontal bars. The plates are .2” thick and 6” in length.

The first hole is drilled at a distance of 3” from the welded side of the plate. The center of the second hole is taken at 2” apart from the center of the first hole in the longitudinal direction. The lateral distance of the third and fourth hole from the center of the first and second hole is 2.5”. The diameter of the hole is taken to fit a 12mm nut and bolt.

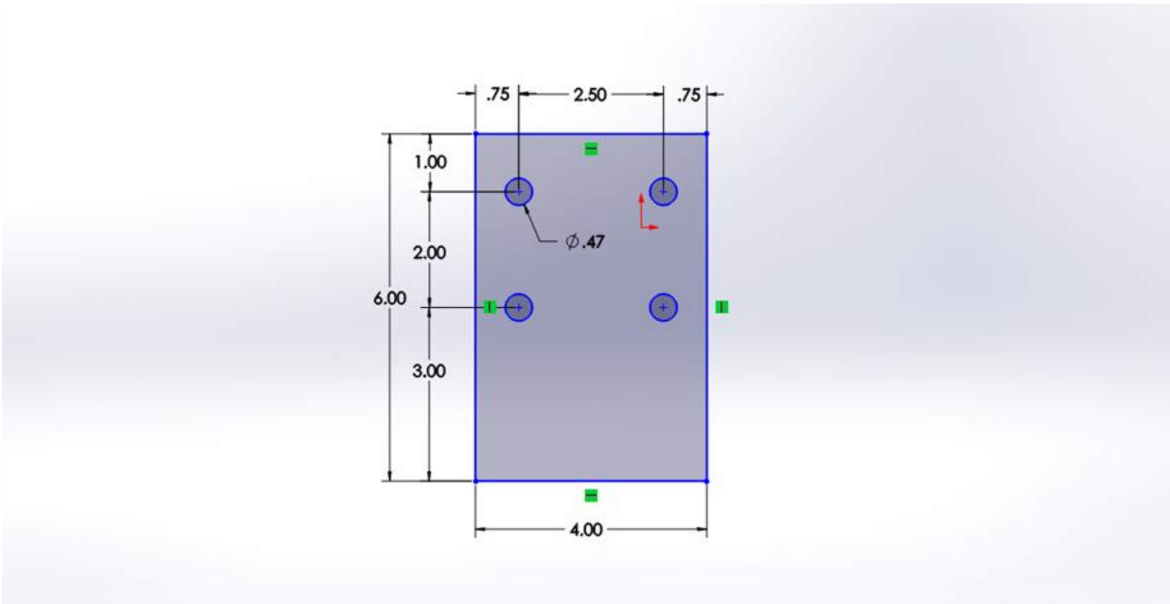

Figure 5.2: Schematic of Welded part (all dimensions are in inch)

BRACKETS

The brackets are basically a triangular plate of 0.2” thick which is used to restrict the lateral movement of the horizontal bar. Four holes are drilled in the plate so that it can be fixed with the vertical and horizontal channels with the help of 12mm nuts and bolts. Among the four holes two holes are drilled on the base side with a center distance of 3.5” and the other two holes are drilled on the perpendicular sides of the triangle with a Centre distance of 2” from each other.

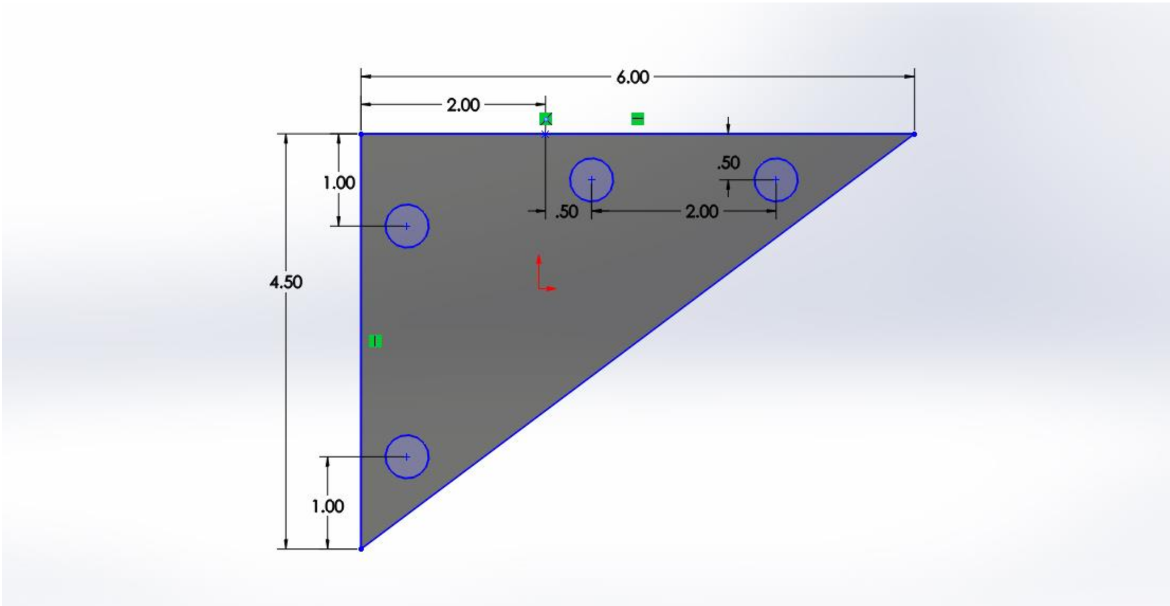

Figure 5.3: Schematic of Bracket (all dimensions are in inch)

BASE

The base is also made of 4”*2” C-section channel and it looks like the symbol plus ‘+’.4 piece of channels each having a length of 2’ are welded together to form the plus shape. A plate of 0.3“thick plate is welded vertically at the center of the plus. The plate is 6” in length and 4” in width. 6 holes having a diameter of 12mm is drilled into the plate. Three longitudinal holes are drilled at a center distance of 2” from each other and the lateral holes are drilled at a center distance of 2.5” from the longitudinal holes. This plate is used to lock the lower side of the vertical frame channels to the base by the means of nuts and bolts.

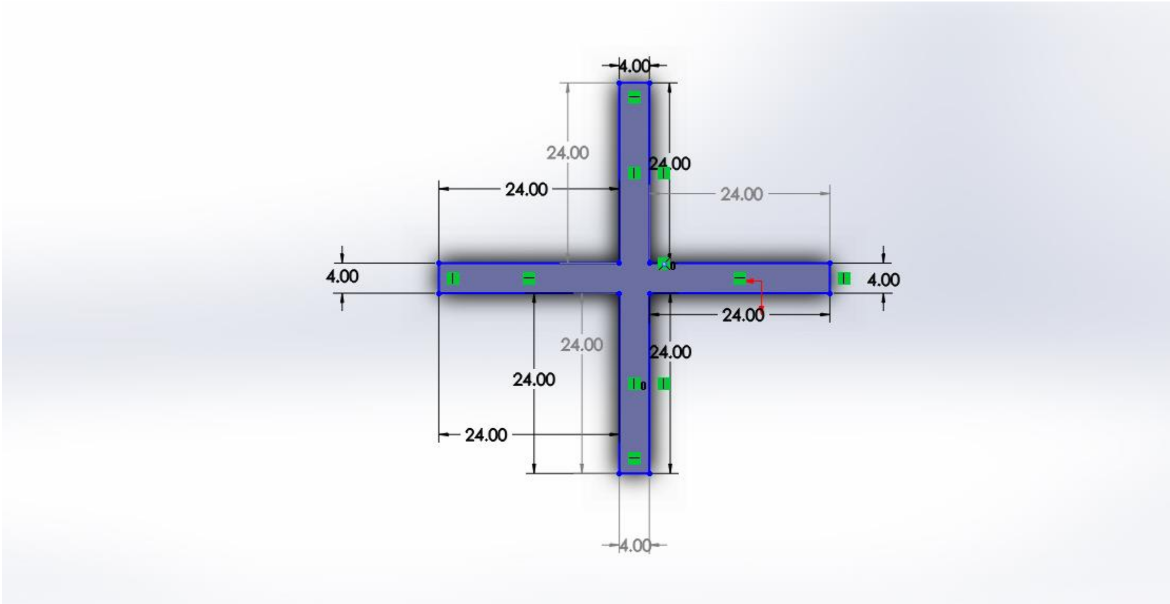

Figure 5.4: Left Base (Top view) (all dimensions are in inch)

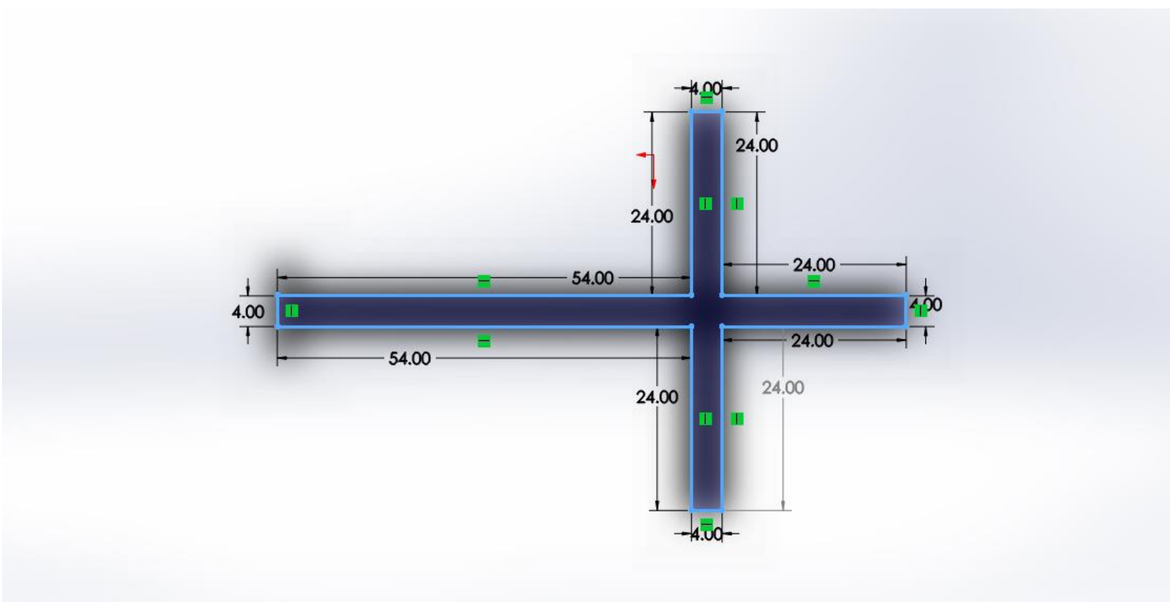

Figure 5.5: Right Base (Top view) (all dimensions are in inch)

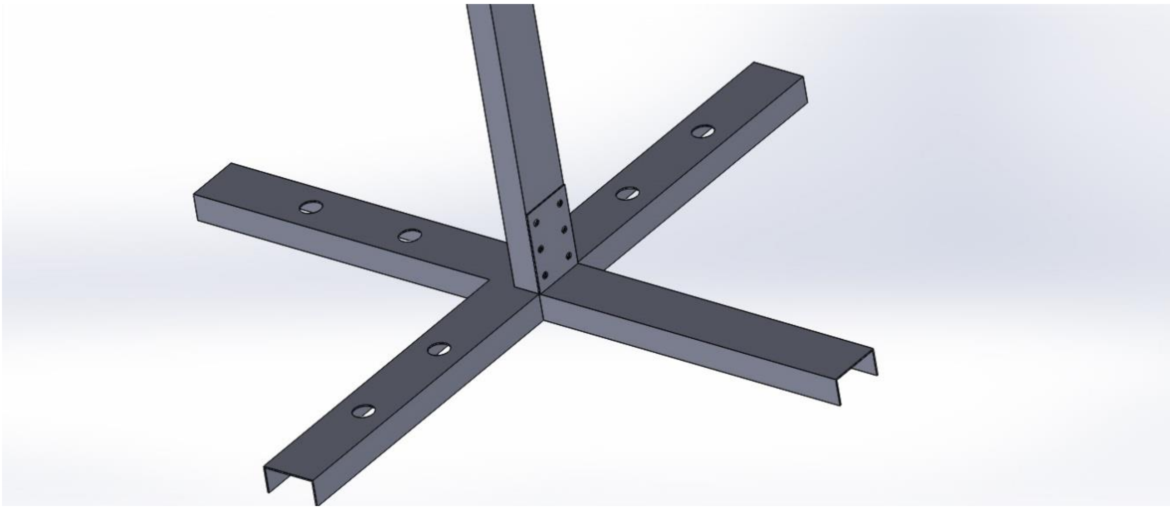

Figure 5.6 : Base joining (3D View)

ANGLE SUPPORT

3”*3” angles are used on four sides of the vertical frame channel to support it. One side of the angle is fixed with the base channel at a distance of 1.5’ and the other side is fixed with the vertical frame channel at a distance of 3.5’ with the help of nut and bolts forming the hypotenuse of a right angle triangle. The purpose of it is to reduce all lateral and longitudinal vibration.

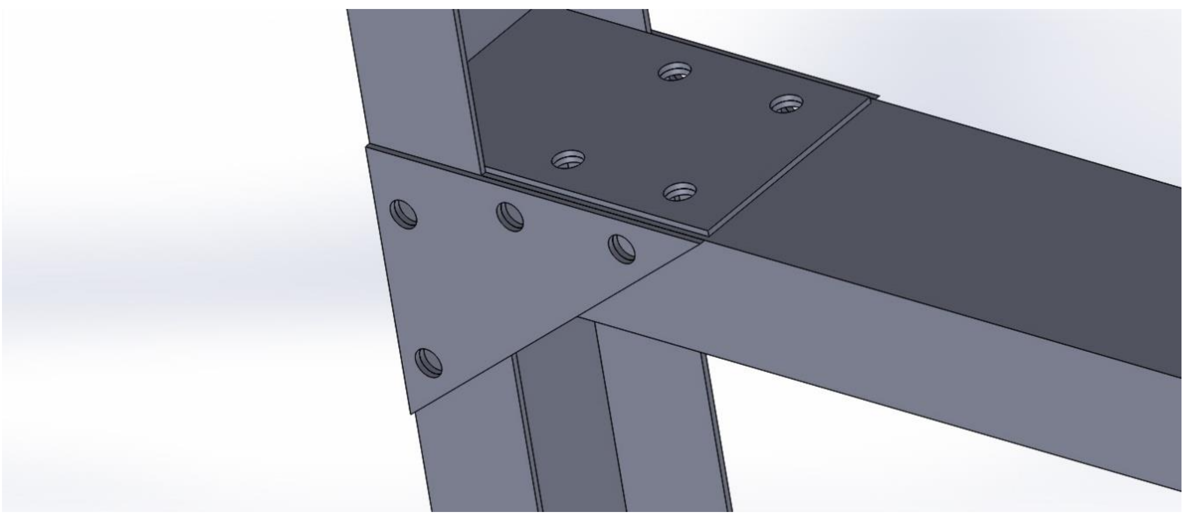

Figure 5.7: Angle (3D view)

Pump Bench

The pump bench to accommodate the pump is placed at one side of the base structure. On that side of the bench the channel closest to the rotor pipe is elongated 5'towards the rotor pipe. The bench is given a height of 2.5' from the base with the help of two 3"*3" two angles each kept at a distance of 8" from each other and they are welded at the edge of the 5' elongated welded channel. A horizontal angle is again welded on the top side of the vertical angles. Two holes are drilled at a center distance of 4" from each other with a diameter of 10mm to accommodate the pumps nuts.

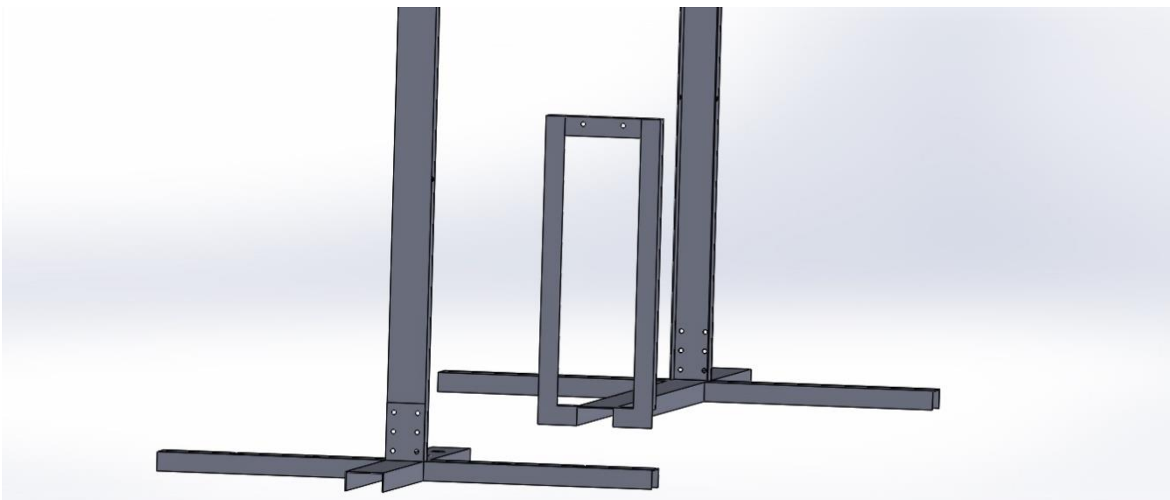

Figure:5.8: Pump Bench (3D view)

THE TURBINE

The turbine is basically a vertical axis sailwing rotor which rotates using the velocity of atmospheric wind. Structurally the turbine can mainly have divided into two parts

a. THE ROTOR

b. THE SAILWING FRAME AND SAIL

THE ROTOR

The rotor or the rotating shaft is basically a hollow steel pipe which is being rotated with the help of two steel plates and rotating arms when the sailwing gets deflected due to the wind velocity. The rotor is a summation of mainly three elements

1) Hollow steel pipe

2) rotor arms

3) Two circular steel plates

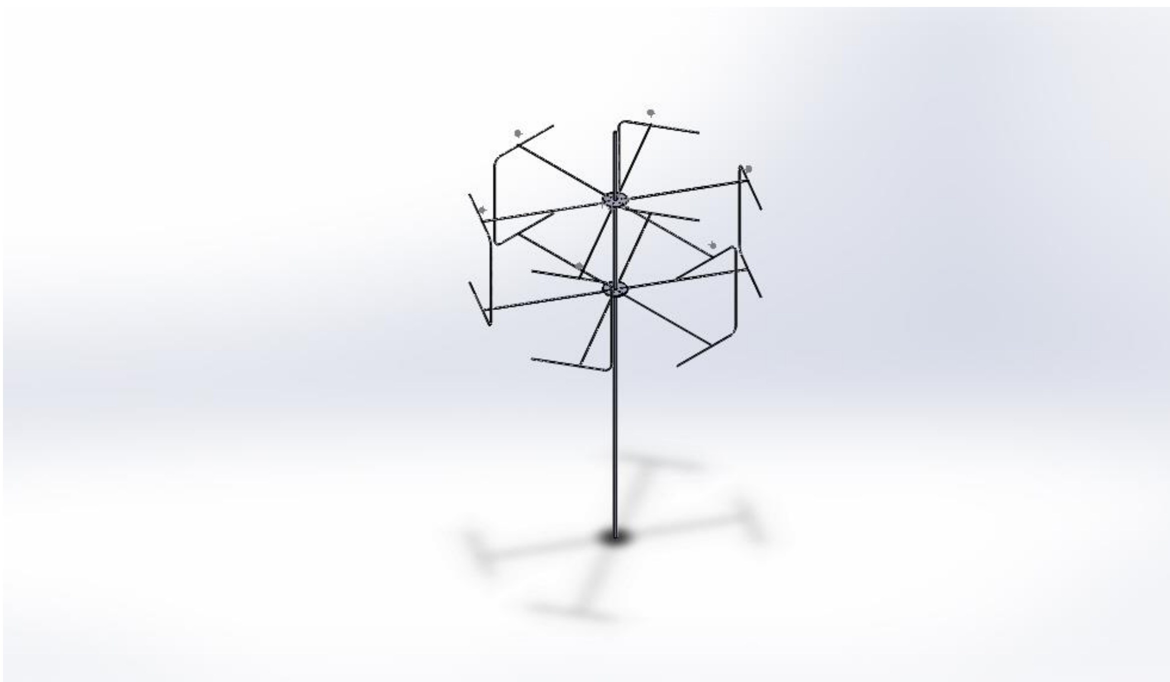

Figure 5.9: the rotor (3D View)|

1)HOLLOW STEEL PIPE:

The hollow MS pipe is used as the rotating shaft having an external diameter of 1.5" and a internal diameter of 1.4".The length of the pipe is taken 19 feet considering a structural advantage

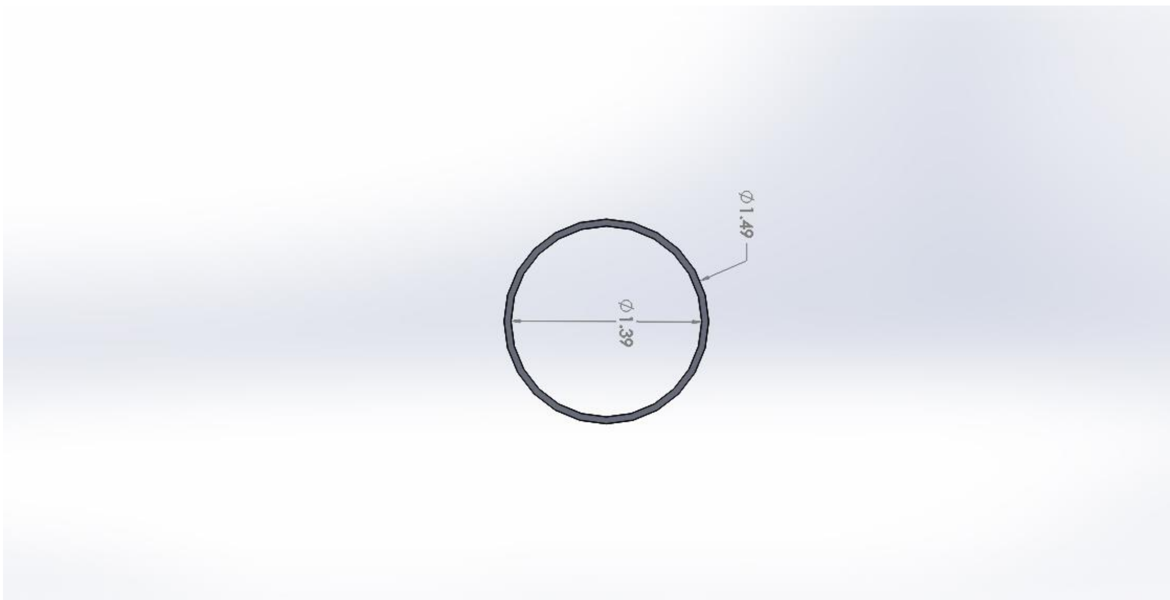

Figure 5.10: Hollow Steel Pipe (all dimensions in inch)

2)TWO STEEL PLATES

Two circular steel plates to hold the rotating shafts or pipes with the help of rotor arms two circular steel plates having a thickness of 0.4" is used.The plate is also made of ms .The diameter of both of the plates is taken as 12" each.To accommodate six rotor arms the plate is equally divided into six parts by taking six lines to represent six rotor arm axis.Each of the line is taken at interval of 60 deg to give equal spacing.Along each line two holes are taken. Front the center of the the plate the first holes center is taken at 3' and the second hole is taken at a distance of 2.25"from the first hole.The diametr of the holes drilled through the center is taken to house 8mm nut and bolt.

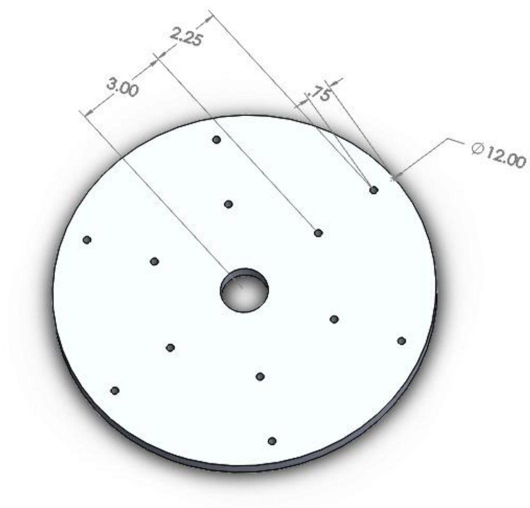

Figure 5.11: Steel plate (all dimensions are in inch)

3)THE ROTOR ARMS

The rotor arms are made of hollow steel conduit pipes with an external diameter of .585" and a internal diameter of .478".The rotor arm is taken 5 feet long and one edge of the pipe is tapered to house two holes with a center distance of 2.5 and 8mm in diameter for fixing it with the circular steel plates. At The other edge of the conduit pipe a hole is drilled having a diameter of 6mm to fix it with the sail wing frame. When the rotor arm is fixed with the circular plates and the sailwing frames usung nuts and bolts the three parts works as a single unit to transmit the kinetic motion of the sail to the rotor or rotating shaft.

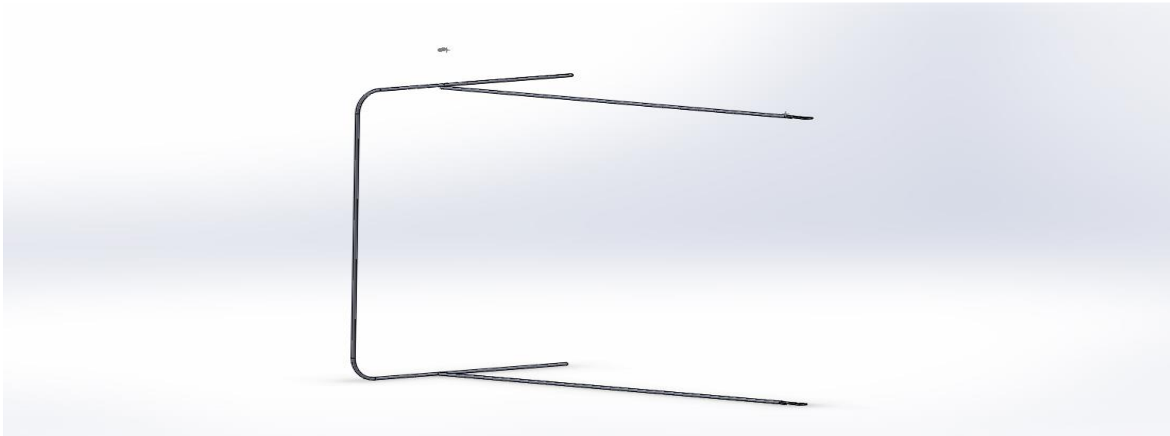

Figure 5.12: Rotor Arm with Sail frame (3D view)

Figure 5.13: Single Rotor Arm with Dimension (dimensions in inch)

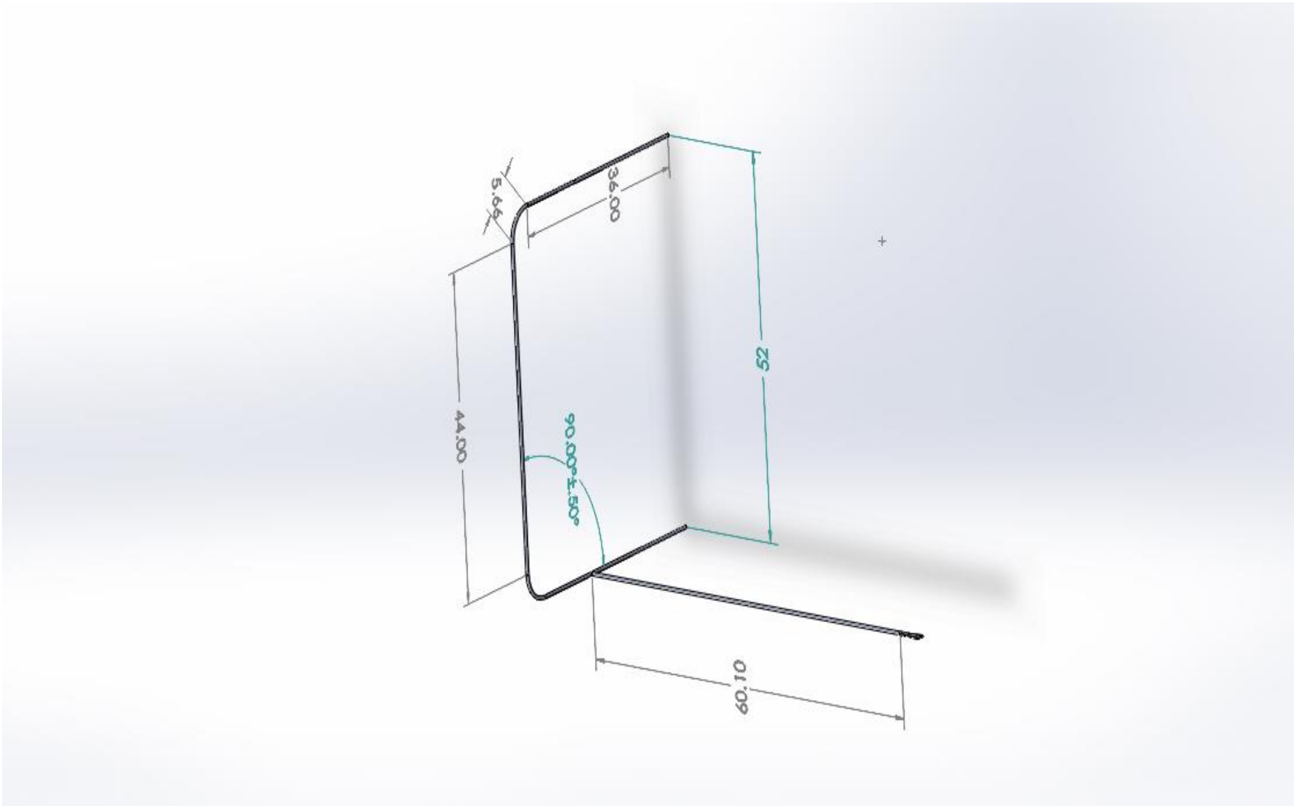

Figure 5.14: Sail Frame with screwed arm (3d view) (all dimensions are in inch)

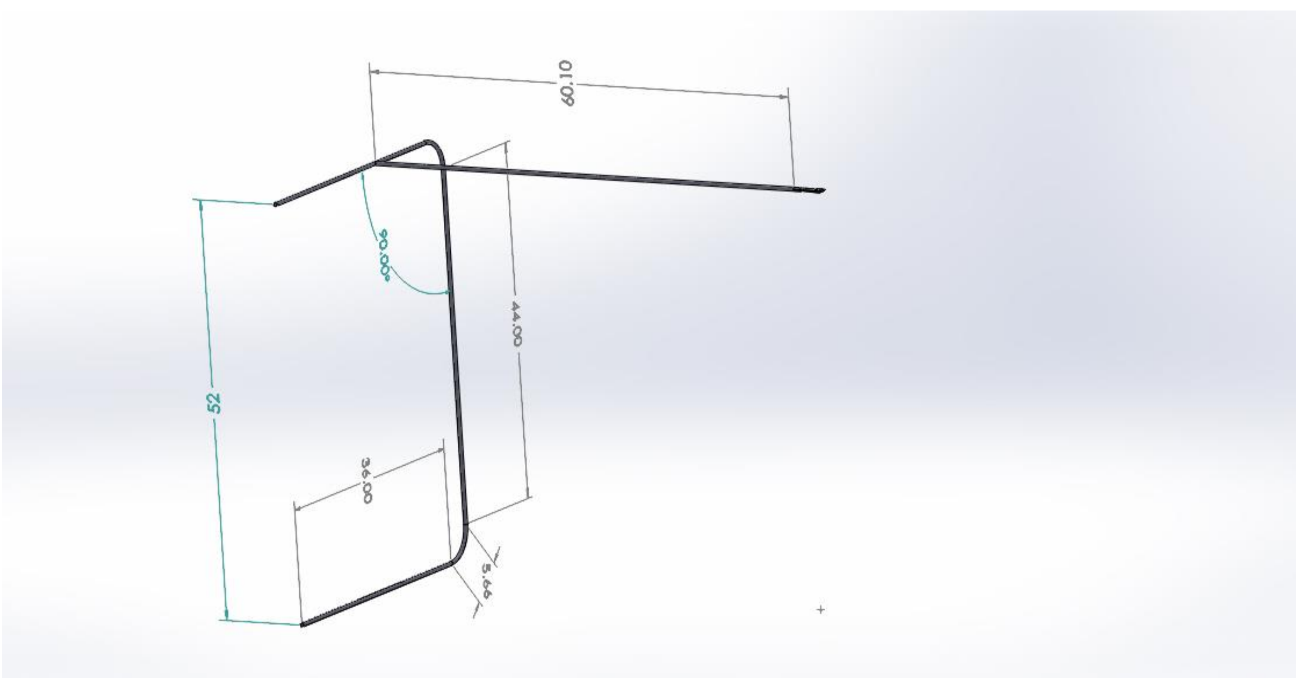

Figure 5.15: Sail Frame with welded arm (3d view) (all dimensions are in inch)

SAILWING FRAME AND THE SAIL

The sailwing frame is also made of steel conduit pipe having the same structural properties as of the rotor arms. 10’ conduit pipe is required for making each of the sailwing frame. The frame is constructed by bending the conduit pipe at a 90 degree angle to a length of 3’ from both of the edges. The bends on the both sides takes up a length of 5.66” and the distance of the bends from each other is taken 3.67’. The frame is then connected to the circular steel plates with the help of the rotor arms. The rotor arm connecting the upper circular plate with the help of nuts and bolts on one side is welded to the sailwing frame on the other side. The rotor arm of the lower side connects the frame to lower circular plate by the means of nuts and bolts on the both sides. One rotor arm is welded and the other kept connected to the sailwing frame so that it becomes easy to insert the sail into the frame just by removing a nut.

The sail is nothing but a flexible canvas or cloth like substance which can be made of polythene, jute cloths, silk or nylon. All of these fabrics are very light but very strong in nature and is less porous so shows a good resistivity to the flow of air through it. The sail has a length of 3.5’ and a width of 3.04’. The pocket through which the sail frame is inserted is made by turning back the front edge and switching the doubled up canvas. The two corner of the sail requires extra strengthening. The sails are secured at the corners to the end of the sail frame by cord which strong enough to bear the normal working tension but it should tear under strong storm conditions. The cord is fastened to the hole provided in the sailwing frame at the outer most corner. It is better to fasten the cord loosely for the purpose of better air foil development. The cords are also made too light than too strong. The broken cords can easily be repaired after a storm

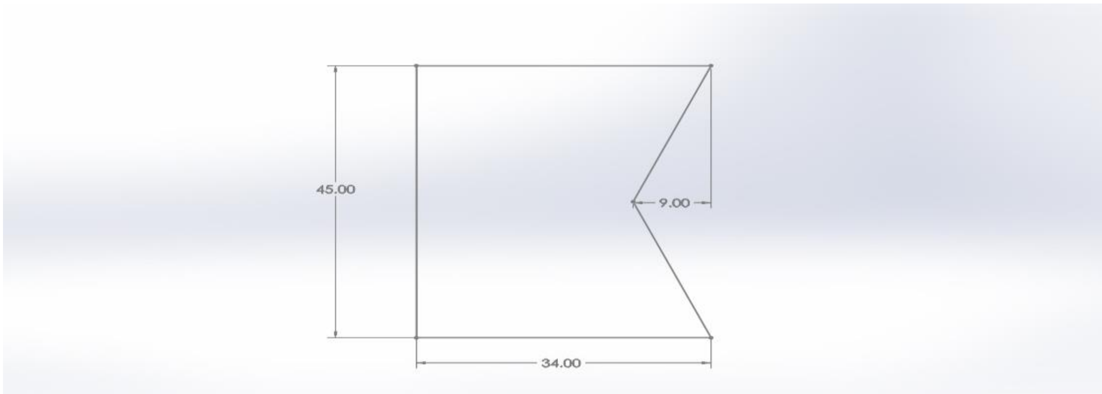

Fig 5.16: Sail Wing (all dimension are in inch)

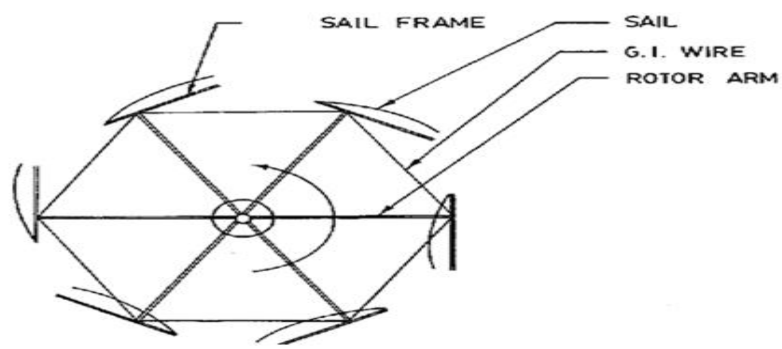

Figure 5.17: Changing position of sail

6.1 Results and Discussion:

RPM(N)	Discharge (Q),Lit/min
8	10.2
10	12
14	16.5
16	18

Table 1: Rpm VS Discharge

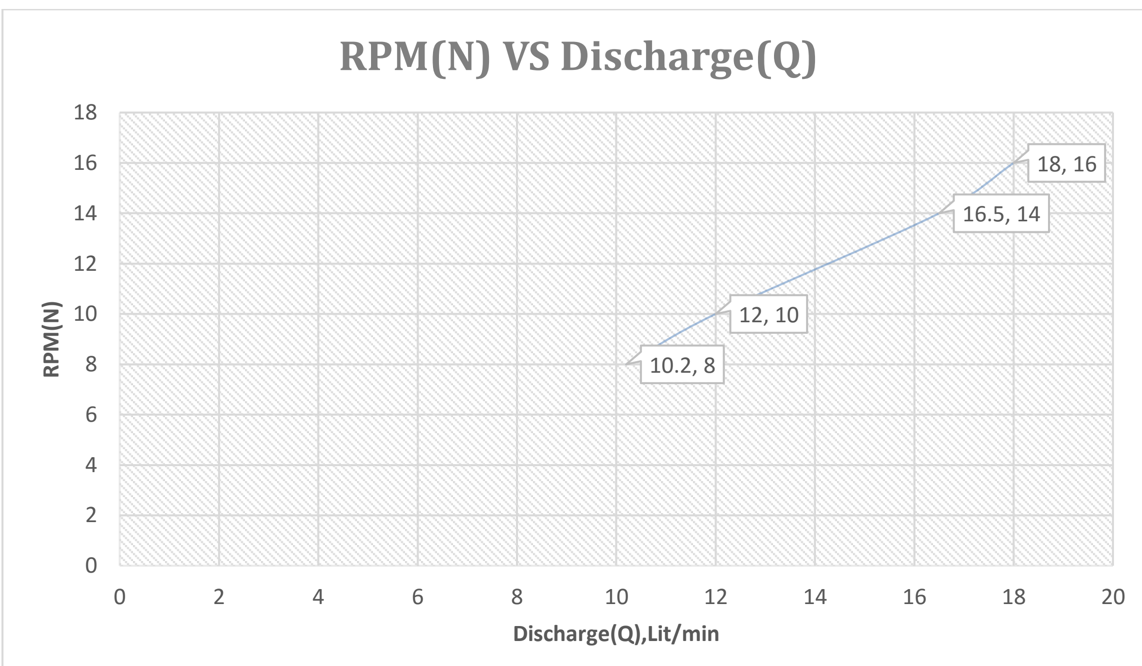

Figure 6.1: RPM vs Discharge

The trial was done on the side of Pump Testing Bench, Military Institute of Science and Technology(MIST). The varieties in the release of the diaphragm pump with wind speed are appeared in Fig. 5. It was watched that for this framework the beginning wind speed is around 1.5 m/s (3.35 mph). Results show that discharge increases with the increase in RPM. This will be true up to a certain limit. Then the increase in RPM will not increase the discharge so by an experiment we shall have to set an optimum RPM to get higher discharge. If double acting reciprocating pump is used then the discharge will be double theoretically but practically discharge will increase more or less 1.8 times of the single acting pump.in the result there is a linear relationship between RPM and Discharge but is all the possible error can be reduced then there may not exist linear relationship. This is empowering from the perspective that most zones of Bangladesh, particularly the regions far from the drift, for the most part have low wind speed.

Wind velocity(vα),m/sec	Discharge(Q), Lit/min
1.6	10.2
1.7	12
2	16.5
2.3	18

Table 2: Wind Velocity Vs Discharge

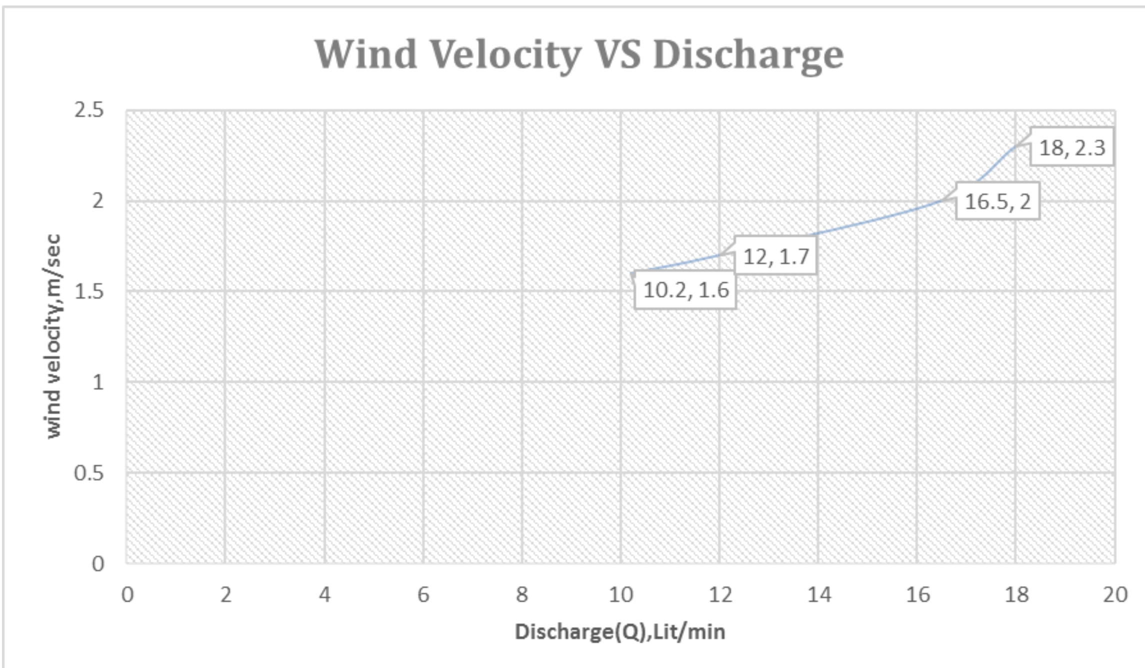

Figure 6.2:Wind Velocity vs Discharge

Discharge of water is completely dependent on the wind velocity. The more the velocity, the more the discharge rate should be. Even the rotor needs a starting velocity. The relation of this two parameters are proportional. The setup and construction of pump bench and crank mechanism are designed in such a way that it gives the best possible discharge at the most possible wind speed at the site. The speed of wind were taken with the help of anemometer.it showed 1.5 m/s velocity at which point the rotor starts to rotate. By measuring we got a value of around 1.2 liters water in per revolution of rotor. That's why when the wind velocity was recorded as 1.6 m/s for one minutes we got a discharge of water amount of 10.2 liters.in this way with the increase of wind velocity recorded till 2.3 m/s we got discharge about 18 liters.

Discharge	**Efficiency**
10.2	**21.34**
12	**20.94**
16.5	**17.68**
18	**12.68**

Table 3: Efficiency Vs Discharge

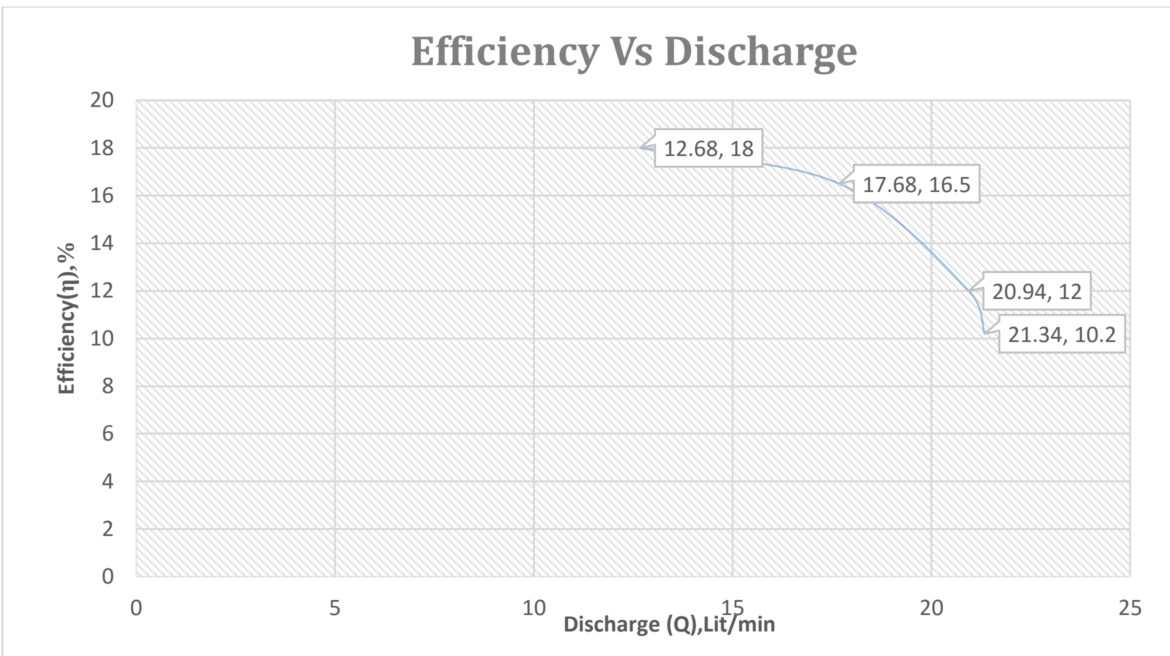

Figure 6.3: Efficiency Vs Discharge curve

Efficiency also depends on the discharge rate of water.as the discharge rate goes higher, efficiency curve goes lower (asymptotic). It is because of more work done due to pumping the water more as well as more loss occurred. Hats why at 10.2 liters discharge we got 21.34 % of efficiency. But in case of the 18 liters of discharge we got only12.68% of efficiency.

Wind velocity	Power
1.6	6.03
1.8	7.233
2	11.777
2.3	17.91

Table 4: Wind Velocity Vs Discharge

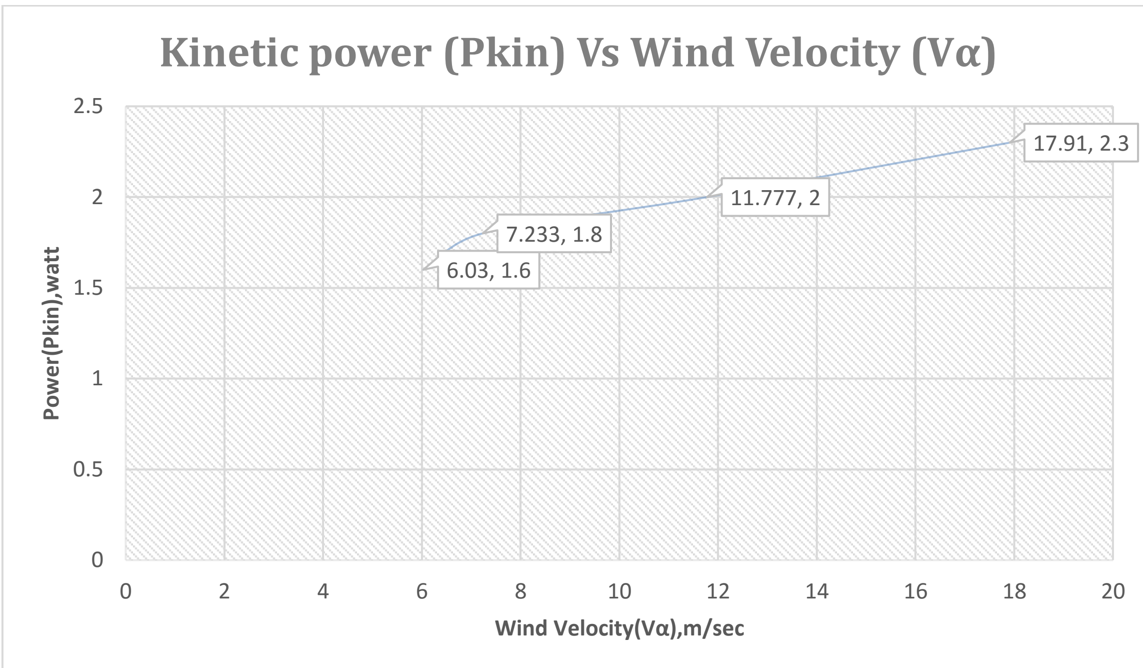

Figure 6.4: Kinetic Power Vs Wind Velocity Curve

Kinetic power also depends on the wind velocity as like as the discharge rate. Kinetic power and wind velocity has a proportional relationship.the more the velocity,the more the kinetic power should be.

7.1 Future Prospect

Energy crisis exists all over the world. Specially in the developing countries like Bangladesh, it is very important and will be of ever increasing in future. The lack of energy for this country is tremendous.

We can not solely rely on petroleum, electricity, natural gas due to higher cost and lack of appropriate technology and limited stock. Hence a diaphragm pump driven by small-wing rotor may keep an important contribution to the economy of the country, specially in the field of agriculture.

Since the sailwing rotor (vertical) for pumping water is easy to manufacture, most economical, it will keep a major contribution in gathering power from natural source to meet the demand of energy of over populated Bangladesh in future.

Incase of Prawn Pisciculture this design can be used for maintain the oxygen level in water.

8.1 Conclusion

Bangladesh is an agricultural country and about ninety percent of her total population live directly and indirectly on income derived from agriculture. Our agriculture will be very prosperous that will lead us to be self-reliant if proper and most economic irrigation system can be introduced.

Since the sailwing rotor coupled with diaphragm pump can be manufactured at a very low cost by utilizing locally available materials and technology, it will be an effective means of irrigation if properly utilized throughout the country during dry season. Our cultivators should be made aware of this suitable and most economic irrigation system to ensure better future of our Bangladesh.

8.2 Recommendation

- To make the system most economic bamboo poles and old used up cloth should be used.
- To have higher discharge the entire system should be made proportionately large.
- To reduce the starting speed to a minimum value sub-sails in between the sails should be introduced.
- Crank mechanism can be developed from the present arrangement
- Another bearing can be used for the easier rotation of the rotor
- Diaphragm can be made of thick leather
- Rotor arm can be built more longer for getting more power
- For security purpose LED lights can be attached to the structure which can be driven from the power generated from the windmill rotation.

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