

Design of Water Pumping Mechanism using Wind Energy (Analysis Study)

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Abstract: In the past, the main sources of energy were coal, oil, natural gas, nuclear energy and wood. All of these sources are limited in quantities and depleted. Moreover, they are considered the main cause of environmental pollution. Due to their limitations and their negative effects on health and environment, attention was turned to alternative energy sources and their uses in various applications. One of those sources is wind energy which is clean and available throughout Earth's geography and today. Wind energy is used in many applications where it can be converted into electrical energy, stored and transmitted, and it can also be converted into a mechanical form that is used directly in machines like water pumps. The main objective of this study is to design a wind-powered water pumping turbine. One of the most important results of the study is the design of a pump to raise water from a well using wind energy to irrigate farms with an area of (2.5) hectares. A two-piston pump was designed, the first to withdraw water from the well and the second to Push the water into the reserve tank. (Irrigation occurs during periods of unavailability of rain water). Use Programmes in study is matlab for analysis and solidworks for 3d pump. place of work is Iraq, Almousel.

Keywords: Wind turbine; Renewable energy; Water irrigation.

1. Introduction

The global trend towards renewable sources of energy arose as a result of the energy crisis that occurred in the seventies of the last century. It should be noted that even if fossil fuel sources are abundant, the use of renewable sources of energy is better for the environment. Those sources of energy are usually called "green technologies" or "clean technologies" because in most cases they do not produce polluting substances or emissions that are harmful to the environment [1].

Some people resorted to wind turbines to extract energy from wind and to generate electrical energy from it because wind energy is used to produce mechanical energy in the so-called windmills [2]. So, approximately 2% of the sunlight that falls on the surface of the globe is converted into kinetic energy of the wind [3]. This is a huge amount of energy, which exceeds the world's need for consumption in any year.

Wind energy is one of the main components for solving the issue of global warming because it is clean and free energy and it is not subjected to the traditional global monopoly of energy [4]. It is also used to generate electricity which makes it necessary to be included in applications. This research comes to study the use of wind energy in water pumping applications to present a design study. The facility includes the pump, air fan, and associated equipment suitable for the system's default production capacity [5].

Water pumping is extremely vital, most elementary widespread energy wanted in rural areas of the globe. Water supplies like wells, dugouts, rivers can often be used for agricultural fields. However, due to limited availability of power supplies or resources, some alternate form of energy has to be used to supply water from the source to the point of consumption. Wind energy is an important source of renewable energy that can be used for pumping water in far-off locations. A wind pump is nothing but a windmill used for pumping water, either as a source of fresh water or wells. It is one of the earliest strategies of utilizing the energy of the wind to pump water [6].

Among the renewable energy resources, the generations of electrical energy and mechanical energy by windmills have emerged as a feasible and cost-effective option [7].

Today, it is very important to depend on renewable energies which are sources of clean, inexhaustible and increasingly competitive energy. Those energies differ from fossil fuels principally in their diversity, abundance and potential for use anywhere on the planet, but above all in that they produce neither greenhouse gas – which cause climate change – nor polluting emissions. Their costs are also falling and at a sustainable rate, whereas the general cost trend for fossil fuels is in the opposite direction in spite of their present volatility.

One of those energies is wind energy which offers many advantages, and explains why it is one of the fastest-growing energy sources in the world. It is also expected to be the main way in which industry responds to the government's targets, so it will be an important source of electricity and water pumping in years to come.

2. General Review

Wind energy has been in use for thousands of years, but only in the late last century was it used to generate electric power [8], and only in recent decades has it become economical for use in electric power generation. Denmark was the leading country in the world in terms of generating electricity by wind [9].

In July 1887, the first windmill to produce electric power was built in Scotland by Professor James Blyth of the Anderson Institute. The windmill was 10 meters high, and its fan blades were made of canvas, and it was working on charging batteries developed by the French Camille Alphonse Faure to light a hut that went down in history as the first house to be lit by wind electricity [10].

On the other side of the Atlantic, Charles Brach built a larger electric windmill in 1888, which was used to produce electric power until 1900 [11]. It was erected on a pole 18 meters high, and its bed was 17 meters in diameter, and its capacity was 12 kilowatts, and batteries were charged with electricity [12].

For the past four or five decades, the use of wind energy in generating electricity has evolved. Wind energy has met about 20% of global electricity needs [13].

Wind pumps: Wind has been a traditional source of energy for several centuries and is still used and widely spread in several developed countries. It has been used to and to grind grain or spices, pump water, saw wood and sail boats. Modern wind power machines are used to create electricity. These are called wind turbines by engineers or wind mills by the average person. Before modern times, windmills were most commonly used to grind grain into flour for making bread, but since the beginning of the thirteenth century the wind has been used to pump water and to drain water from reclaimed lands in Holland [11].

Small wind pumps made of wood were used in France, Portugal, and Spain to pump seawater to produce salt [14], and later American wind pumps made of steel with multi-blade propeller-like rotors became the most common technology for pumping water in order to provide water for the population [15].

At the end of the nineteenth century wind pumps were used for watering livestock in the wide plains of North America, and for the last hundred years it has manufactured more than eight million windmills in the United States, and the design has proven a great success and spread around the world [16].

Today, there are more than one million wind mills in practical use, most of which are installed in the United States, Argentina and Australia [17]. Wind pumps are fans which operate a piston reciprocating pump connected to a speed reducer. Conventional air is less efficient than modern wind turbines and Fig. 1 shows the old wind fans used to water the flocks on large farms.



Fig. 1 Old air fans used for watering flocks [1]

Electric wind turbines that can generate two types of current, alternating current (AC) and direct current (DC) were developed at the end of the twenties of the last century [18]. Very few (micro turbines), which produce a few Watts, can be installed and dismantled by one person, and are mainly used to charge batteries in sailing boats [19].

The water pumping system using a wind turbine was studied by P Jagadeesh [20] and the core calculations of the turbine and flow rate were carried out, development of wind-powered water pump by I.F Odesola, L.G Adinoyi, a HAWT with three rotor balance with a maximum pump head of 0.3m to reduce other obstructions to motion just like friction. A three performed evaluation test was carried at every 20 minutes' time sections. Performed test of the development wind pump revealed an ample discharge flow rate in the range of 3.4 to 6.44 l/min for irrigation purpose. In another research, renewable and sustainable energy reviews, wind powered utilization for water pumping using small wind turbines in Saudi Arabia, annually there is 30,000m³ total water pumping capacity and is done from a depth of total dynamic head of 50m, hub height 15 -40 m, at all three sites with total cost of water pump in and the results were, Total torque = 106.4572 Nm flow rate = 0.1736×10³ m³/sec.

A wind-powered water pump was developed [21] and the relationship of wind speed with water rate was studied, and the study concluded that the more the wind speed increases the more the water discharge increases. The performance of a small wind-powered pump was studied [22] and concluded that the pumping performance measured was very good at demonstrating an ability to pump enough water at 50m pumping depth to water 120 cattle and at a 100m pumping depth to water 60 cattle.

Modern wind energy applications do not require high wind speeds because its peak production does not usually coincide with peak consumption, which does not contribute to reducing the burden on traditional electricity production plants during peak consumption. As for homes, its biggest drawback is that wind turbines production is not sustainable. To avoid this, it is possible to benefit from production by connecting it directly to the public electricity network or installing batteries to store that energy and use it throughout the day.

3. Basic Principle

3.1 Wind energy

In many parts of the world, wind energy is a promising source of renewable energy, and the energy that can be captured by wind turbines depends largely on the average local wind speed [23]. The areas with the greatest wind potential are located near coasts, inland areas with open terrain, or at the edge of water bodies [24]. The mountainous regions also have good potential. There is extensive terrain in most regions of the world to supply a large part of the local electricity needs with wind energy projects [25].

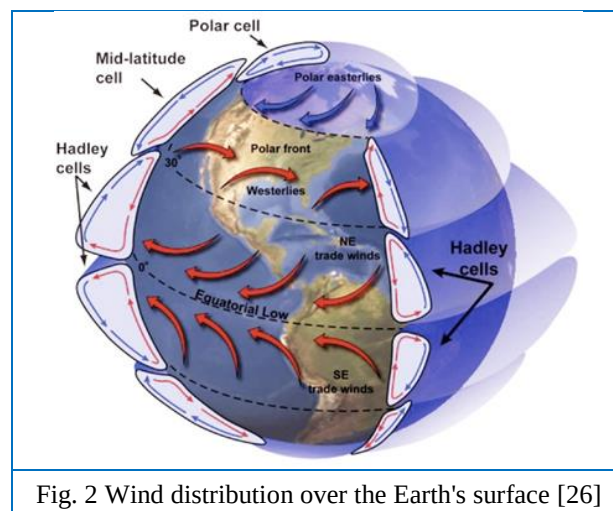


Fig. 2 Wind distribution over the Earth's surface [26]

3.2 Pumping system measurements

Once the appropriate power source model is determined, the amount of water required and the total pumping height determine the dimensions of the system, and these are the two main criteria in standardizing any water pumping system. The daily water need and the peak hour water need are estimated based on the number of the population, the area of the land on which it is cultivated, or the number of livestock required to be watered [27]. The need for water used for irrigation is estimated based on the area of land that will be irrigated and on the amount of water required to grow the crop [16]

The water consumption per person in the case of (domestic) water supply is limited to (1000-10 litre/day) for each person depending on the available capabilities, climate and population habits.

In isolated villages of Africa, for example, water consumption can be less than (10liter/day) per person, while in California it is higher (1000liter/day) per person.

3.3 Total pumping pressure

It is the total pressure required to pump water from the water source to the tank, that is, it is the sum of the pumping pressure, friction and discharge height.

3.4 Drainage height

It is the height from the surface of the earth to the outlet of the tank pipe.

3.5 Pumping pressure

In the case of surface water, it is the level of still water plus the amount of water immersion of the pipe.

3.6 Frictional pressure

The loss of energy in pipes and their accessories. These terms are shown in schematic diagrams of electrical and mechanical wind pumps in Fig. 3.

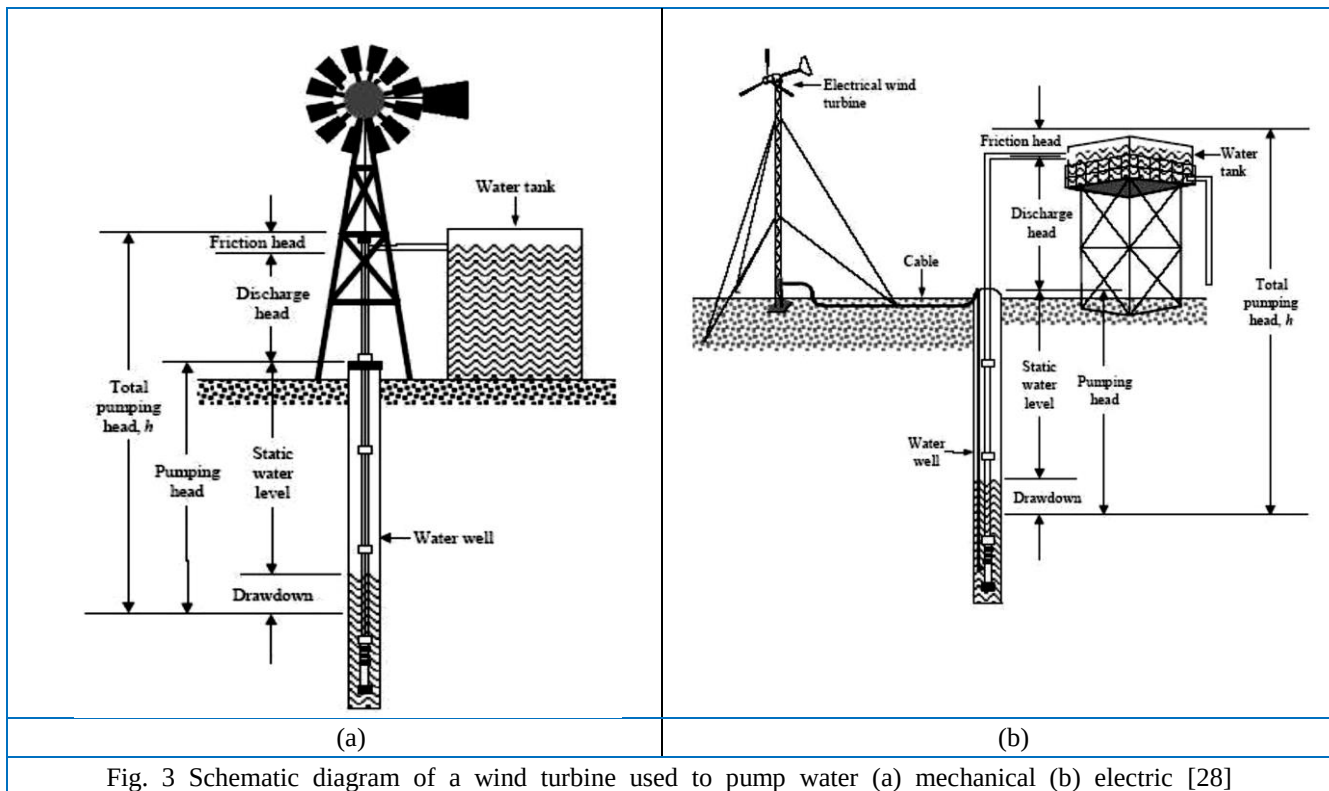


Fig. 3 Schematic diagram of a wind turbine used to pump water (a) mechanical (b) electric [28]

Therefore, it is required to know the long-term weather data in order to design the system, and from these necessary data [29], the following must be determined:

- Determining the worst continuity of solar radiation and wind availability times and estimate the total amount of water that can be pumped during these estimated times.
- Determining the total need for water during periods of unavailability of wind or solar radiation throughout the year, which exactly determines the size of the required reserve water tank [30].

4. Knowledge requirements before working on the project and some suppositions

- The type of services and what kind of infrastructure that is available at the site.
- The physical possibility of the population in return for ensuring a continuous supply of water.
- To what extent they can withstand the periodic shortage of water.
- In the event of a system failure, how many days can the tank alone provide for the subscribers' needs until it is repaired?
- Extent of warranty of maintenance work and insurance of spare parts [31].

Simple charts can be used by anyone interested in determining the measurement of a PV pump, an electrical or mechanical wind pump, and these charts are prepared based on the mechanical relationships of energy available from the solar or wind source and from hydraulic energy, and they can also be used to determine the measurement of the group of PV and the wind machine in order to determine the capabilities and size of the engine and pump and vice versa, and it does not help us in estimating the volume of water tanks, and this is mainly due to the fact that the size of the tank depends on the availability and continuity of work of renewable energy sources [32]

Then the chart shown in Fig. 4 has been developed to estimate the standardization of the PT pump at air temperature $t_a = 25^\circ\text{C}$, and this chart can be used either to determine the measurement of the PV group required for the desired pumping pressure and water needed, or to estimate the quantity of production. Daily water for the pumping pressure and volume of the PF group are given. If the hydraulic

power changes from month to month due to the change in water levels or the change in the need for water, it is necessary to specify the month that will be the intensity and period of solar radiation as well as the speed and period of wind blowing as low as possible while the water consumption increases, it is the month of design. The need for water must be determined from the number of people that will be served and the total pumping pressure [33]. Then the line will be drawn on the scheme either clockwise or counter clockwise using the appropriate values for the efficiency of the partial systems and the average solar radiation to reach the required group size.

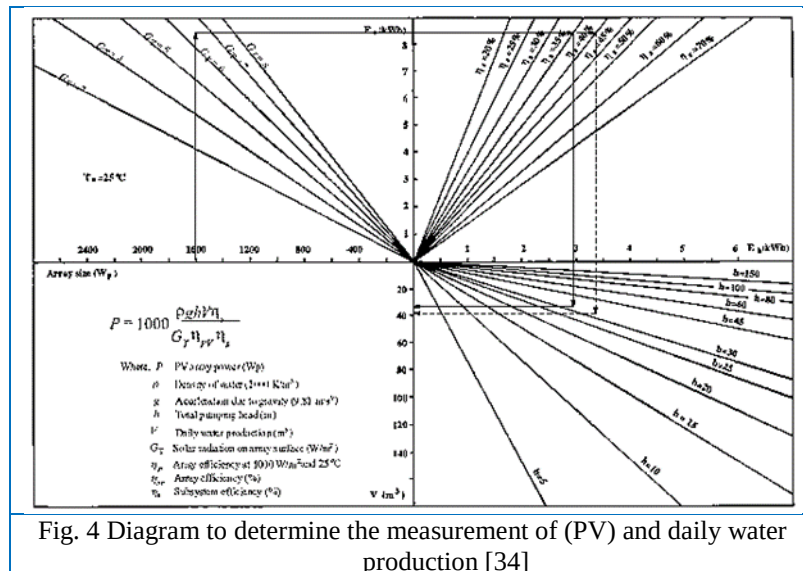


Fig. 4 Diagram to determine the measurement of (PV) and daily water production [34]

The daily required amount of water (i.e. the water needed) is calculated from the measurement of the area of land that must be irrigated and the type of crop desired, and then the water source is determined. The amount of water available in the well has been determined by examining the well.

Symbols used in the search

ρ : density of water [kg/m^3],
 g : acceleration due to gravity [m/sec^2],
 H : cloud height
 Q the intensity of the pump [m^3/sec],
 P : the pressure generated by the pump [$kg.f/m^2$],
 η : the yield of the pump.
 ρ : air density [kg/m^3],
 V_1 : wind speed [m/sec],
 A : rotor surface area facing the wind [m^2]
 S : pump stroke [m],
 n : number of pump revolutions [$r.p.m$]
 P : piston pressure [N/m^2],
 F : piston force [N].

5. Practical section and suppositions

5.1 Choosing the pump (analysing its work and determining its dimensions)

The use of piston pumps for pumping water in wind energy facilities is common, due to the availability of the following specifications:

1. Working with a small number of cycles fits well with the number of cycles of the slow-rotating and high-torque pneumatic facility.
2. Possibility of obtaining pumping heights of up to 100 m and more.
3. The high efficiency of the piston pump, with a value of $0.9 - 0.8 = \eta$
4. Mechanical simplicity in addition to the possibility of easy construction and assimilation of its technology.

Assuming that the area of land to be irrigated by the wind power facility is (2.5 hectares) and the crop is citrus, we find that the largest consumption of water for irrigation per day is during the month of July with a value of up to (27.3 hectares / m^3), Table (1) shows the consumption Water for citrus in a farm, so the amount of water needed to irrigate the total area during one day:

$$2.5 \times 93.1 = 232.75 \text{ } m^3 \quad (1)$$

Below is a table of the monthly water needs of fruit trees and plants.

Table 1 The net monthly water requirement of citrus trees in the studied farms

Title	May	June	July	August	September
The maximum amount of evaporation (m^3/ha)	886.6	1131	1228	1188.85	975
The net water requirement of mature trees (m^3/ha)	425.75	734.5	940	851.5	529.75
The net water requirement of the planting (m^3/ha)	250.25	507	625	555.75	286
Total (m^3/ha)	1562.6	2372.5	2793	2596.1	1790.75

Assuming that the pump is running on day 10[h], the required volume of the pump is:

$$\frac{232.75}{10} = 23.275 \text{ } m^3/hr \quad (2)$$

As for the reserve water tank, a tank with a capacity of $200 \text{ } m^3$ is chosen so that it can be used for different purposes such as irrigation and others in the case of energy stillness. So that, this tank is filled with water at times when the wind is blowing and we do not need water in it or with water in excess of the required need, and by studying the reality of water basins in the studied area, the levels of water from wells available in summer range between $3 - 7 \text{ } m$. This makes way for the choice of a pump with large dimensions (diameter, stroke).

When the maximum intensity [$23.275 \text{ } m^3/hr$] is needed, the pump can be operated on suction only, assuming that:

$$losses + pumping \text{ height} = 5 \text{ } m \quad (3)$$

The thrust at the pump is calculated from the relationship:

$$P = \rho . g . H [N/m^3]$$

where : ρ : density of water [kg/m^3], g : acceleration due to gravity [m/sec^2], H : cloud height

$$P = 1000 \times 9.81 \times 5 = 49050 [N/m^3]$$

Assuming that the pump yield is $\eta = 0.8$, the pump capacity is calculated from the relationship:

$$N = \frac{Q.P}{102\eta} \quad (4)$$

Where: Q : the intensity of the pump [m^3/sec], P : the pressure generated by the pump [$kg.f/m^2$], η : the yield of the pump.

$$N = \frac{25 \times 49050}{3600 \times 102 \times 9.81 \times 0.8} = 425.5 \text{ W} \quad (5)$$

5.2 Finding the diameter of the air fan

By equating the power of the pump with the power of the generated wind energy, and this is contained in a specific field, considering the loss in the transmission mechanism, we can find the diameter of the wind fan as follows:

Assuming the return of the transmission system $\eta + r = 0.9$, the power generated from wind energy is equal to [473 W] and from the relationship:

$$P = (0.10.3) \frac{\rho}{2} \cdot V_1^3 \quad (6)$$

Where: ρ : air density [kg/m^3], V_1 : wind speed [m/sec], A : rotor surface area facing the wind [m^2]. If the average wind speed is [5.8 m/sec], the surface of the fan is calculated from the relationship:

$$A = \frac{2 \times 473}{0.2 \times 1.29 \times 5.8^3} = 18.8 m^2 \quad (7)$$

From it we find the diameter of the fan $d = 4.84$ [m]

5.3 Calculating the dimensions of the piston

The main dimensions of the piston are related to the diameter of the piston and the cylinder and the length of its stroke, and since the equation used is multi-unknown and unsolvable, so it must be based on assumptions and here we must start by finding the ratio between the two main dimensions S/D , the greater the value of the piston diameter D when knowing the flowing quantity and the higher the pumping, the smaller the value of the stroke length S , so that the number of revolutions is constant, the average piston speed is:

$$C_m = S \frac{n}{30} \quad (8)$$

Where: S : pump stroke[m], n : number of pump revolutions [$r.p.m$]. But the piston force increases, which is given by the relationship:

$$F = \frac{D^2 \cdot \pi}{4} P \quad (9)$$

Where: P : piston pressure [N/m^2], F : piston force [N]. Thus, the dimensions of the crankshaft parts increase. At large pumping heights, small diameters D of the piston are usually chosen, meaning that the ratio $X_\pi = \frac{S}{D}$ is large, otherwise the force acting on the connecting rod will be very large.

$$X_\pi = \frac{S}{D} (0.6 \div 6) \quad (10)$$

The maximum value is 6 when the pressure value $P = 600 \text{ atm}$

For the previously selected pump, we can choose the ratio $X_\pi = 4$

The number of revolutions of the piston pump is in the range of $n = (40 \div 190)$ *r.p.m* and in pumps with high cycles this value reaches $n = 500$ *r.p.m* in order to obtain small piston diameters that can be tightened more easily.

Although a large number of revolutions helps in obtaining small dimensions, its important disadvantages are rapid wear of valves and parts of the crankshaft, as well as large acceleration, and inertia losses.

$n = 40 - 60$ *r.p.m* *Slow rotation*

$n = 60 - 160$ *r.p.m* *Normal rotation*

$n > 160$ *r.p.m* *Fast rotation*

And we choose for the pump in question the number of normal cycles $n = 90$ *r.p.m*

As for the piston speed in piston pumps, it should not exceed the following value:

$$C_m = S \frac{n}{30} = (1.5 \div 2) \text{ m/S} \quad (11)$$

For the previous pump, we choose $C_m = 1.5$ [m/S]

This is because the value of the piston's average speed is usually taken as a measure of the life (life) of the pump. In pumps where lubrication of the piston and cylinder surface is difficult or impossible (except with the fluid being pumped). The average speed of the piston should be as small as possible.

When calculating the main dimensions, a distinction must be made between a single-acting or double-acting pump. For single-acting pumps:

$$Q_{th} = \frac{Q'}{\eta_H} = \frac{F.S.n}{60} = \frac{D^2 \pi S n}{4 \times 60} \text{ [m}^3/\text{S]} \quad (12)$$

When the length of the piston stroke is known (or assumed) as well as the average number of revolutions (n), then the piston diameter or the cylinder diameter is calculated as follows, where we have assumed $S = 40$ *cm*.

$$D = \sqrt{\frac{4 \times 60 \times Q'}{\pi S n \eta_H}} = \sqrt{\frac{4 \times 60 \times 25}{3600 \times \pi \times 0.4 \times 90 \times 0.8}} = 9 \text{ cm} \quad (13)$$

When calculating the diameter based on the stroke ratio $X_\pi = \frac{S}{D}$, it is:

$$\frac{Q'}{\eta_H} = \frac{D^2 \pi X_\pi D n}{4 \times 60} \quad (14)$$

$$D = \sqrt[3]{\frac{4 \times 60 \times Q'}{\pi X_\pi n \eta_H}} \quad (15)$$

$$D = \sqrt[3]{\frac{4 \times 60 \times 25}{3600 \times \pi \times 2 \times 90 \times 0.8}} = 15.4 \text{ cm} = 16 \text{ cm}$$

From the above we choose the diameter of the piston $D' = 20 \text{ cm}$.
In order to calculate the relationship:

$$D = \frac{S}{X_{\pi}} = \frac{40}{2} = 20 \text{ cm} \quad (16)$$

In the case of single-acting pumps, the connecting rod does not enter the pumping chamber, and therefore the section of this arm does not affect the approved piston surface. In the case of double acting pumps:

$$Q_{th} = \frac{Q'}{\eta_H} = \frac{2F.S.n}{60} = \frac{2D^2\pi.S.n}{4 \times 60} \text{ [m}^3/\text{S]} \quad (17)$$

When knowing the length of the stroke and the number of revolutions, the diameter of the piston (without the connecting rod) is calculated as follows:

$$D = \sqrt{\frac{4 \times 60 \times Q'}{2\pi.S.n.\eta_H}} \text{ [m]} \quad (18)$$

When the stroke ratio X_H is known, the piston diameter (without the connecting rod) is calculated as follows:

$$D = \sqrt{\frac{4 \times 60 \times Q'}{2\pi.X_H.n.\eta_H}} \text{ [m]} \quad (19)$$

The length of the run is calculated from the relationship:

$$S = X_H \cdot D \quad (20)$$

The piston diameter calculated in this way is used only when the connecting rod (piston rod) is considered not to be present in the pumping chamber and when taking into account the diameter of the connecting rod d' [m], the theoretical piston diameter D should increase to the actual diameter D_1 .

5.4 The model used in the study

We will use a two-piston pump, the first one to draw water from the well to the second cylinder, where the second piston will push it to the reserve tank, and our professions are:

$$Q = i \times \frac{\pi}{4} \times D^2 \times S \times \frac{n}{60} \quad (21)$$

Where: i is the number of cylinders.

Here we will use two different cylinders and thus the following relationship:

$$Q = \frac{\pi}{4} \times \frac{n}{60} (D_1^2 \times S_1 + D_2^2 \times S_2) \quad (22)$$

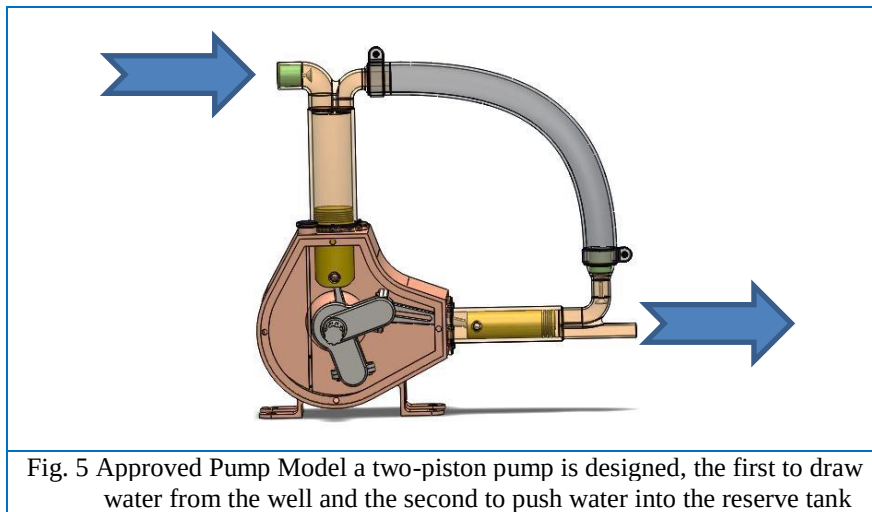
Here we will choose the pistons according to the following dimensions:

$$S_1 = 32.4 \text{ cm}, S_2 = 31.05 \text{ cm}, d_1 = 10.8 \text{ cm}, d_2 = 7.56 \text{ cm}$$

To make sure of the choice, we find the flow that this pump delivers according to the relationship:

$$23.45 = \frac{\pi}{4} \times \frac{90}{60} (0.08^2 \times 0.24 + 0.056^2 \times 0.23) \times 3600$$

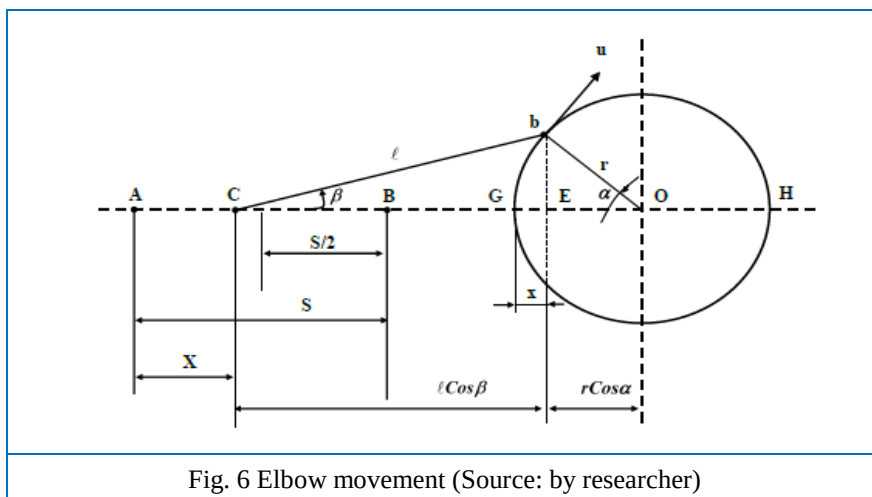
It is sufficient to secure the required volume. The approved pump model is shown in Fig. 5.



5.5 Elbow movement

In the wind power facility used to operate a reciprocating piston pump, the rotational motion of the fan is converted into a reciprocating straight motion by means of an elbow and a connecting rod, as shown in Fig. 6. Usually, the motion and force resulting from the cranked motion can be calculated structurally or mathematically.

This construction process already needs information about the nature of the movement of the cranked unit, and there are standard methods to calculate it.



5.6 Calculation of piston path

In Fig. 6, the piston path is calculated from the following relationship:

$$X = r(1 - \cos \alpha + \frac{1}{2} \lambda \sin^2 \alpha) \quad (23)$$

Where: r : radius and equal to [0.135 m], l : length of the connecting arm equal to [0.27 m], λ :

As for the return path of the piston from point B to point A, it is taken in Fig. 7 in terms of the angle α_1 .


$$X = r(1 - \cos \alpha_1 + \frac{1}{2} \lambda \sin^2 \alpha_1) \quad (24)$$
$$v = \frac{dS}{dt} \quad (25)$$
$$v = \frac{dX}{dt} \quad (26)$$
$$DG = u.t = r.\alpha \quad (27)$$
$$v = \frac{u}{r} \frac{dX}{d\alpha} \quad (28)$$
$$v = \frac{u}{r} \frac{d[r(1 - \cos \alpha_1 + \frac{1}{2} \lambda \sin 2\alpha)]}{d\alpha} \quad (29)$$

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$$v = r \cdot w \left(\sin \alpha + \frac{1}{2} \lambda \sin 2\alpha \right) \quad (30)$$

Calculation of piston acceleration:

$$a = \frac{dv}{dt} \quad (31)$$

Acceleration is:

$$dt = \frac{r}{u} d\alpha \quad (32)$$

$$a = \frac{r}{u} \frac{dv}{d\alpha} = \frac{r}{u} u \frac{d\left(\sin \alpha + \frac{1}{2} \lambda \sin 2\alpha\right)}{d\alpha} \quad (33)$$

And from it:

$$a = \frac{u^2}{r} (\cos \alpha + \lambda \sin 2\alpha) \quad (34)$$

$$a = r \cdot w^2 (\cos \alpha + \lambda \cos 2\alpha) \quad (35)$$

The exact mathematical relationships of the piston path, velocity and acceleration are given below when using normal cranked motion.

Piston path:

$$X = r + l - u \cos \alpha - l \sqrt{1 - \lambda^2 \sin^2 \alpha} \quad (36)$$

Piston speed:

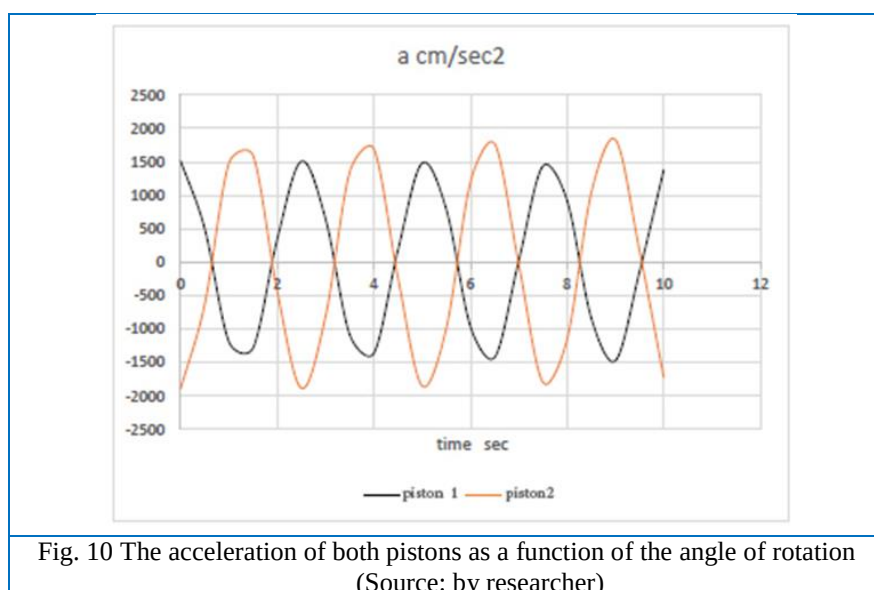
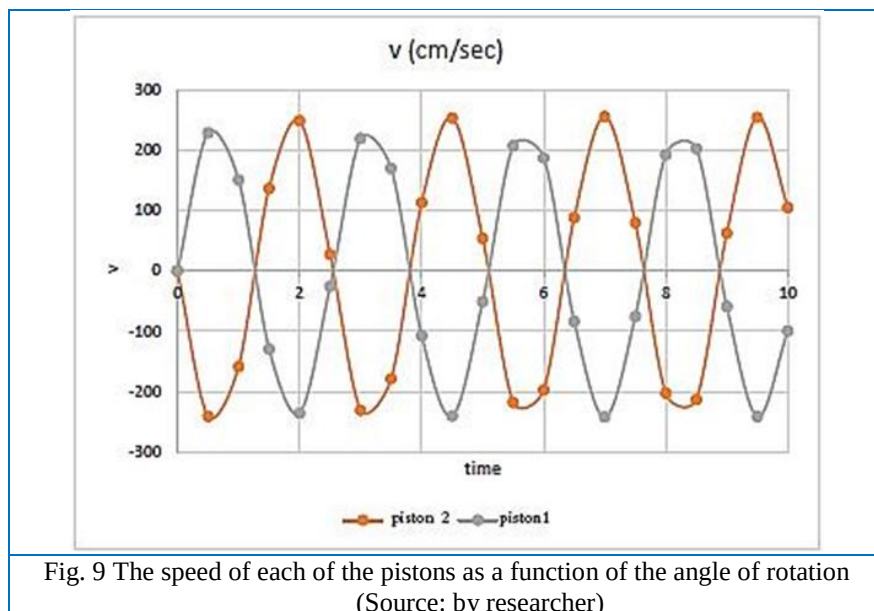
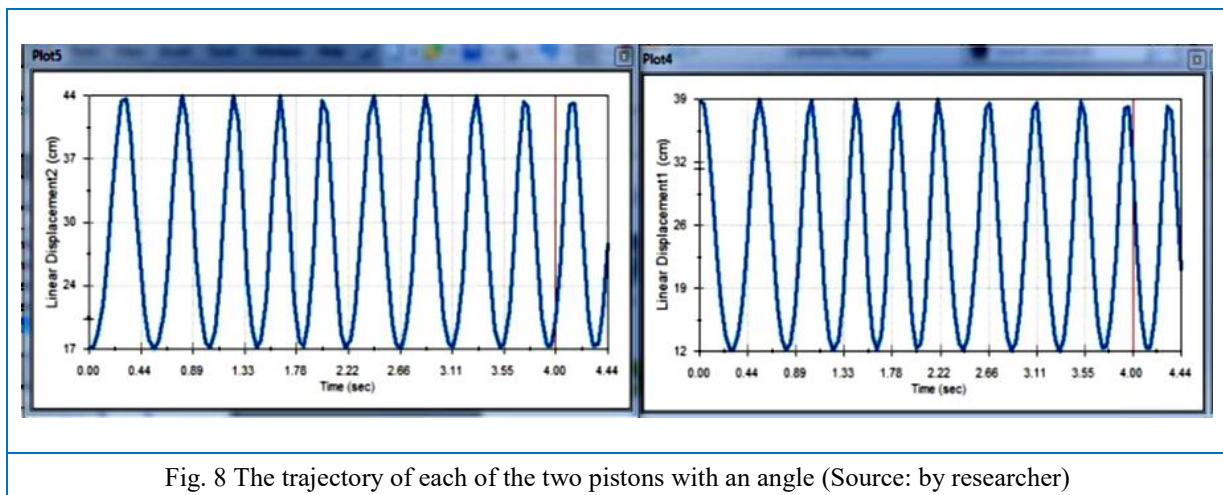
$$v = rw \left[\sin \alpha + \left(\frac{\lambda}{2} + \frac{\lambda^3}{8} + \frac{15\lambda^5}{256} \right) \sin 2\alpha - \left(\frac{\lambda^3}{15} + \frac{3\lambda^5}{64} \right) \sin 4\alpha + \frac{3\lambda^3}{256} \sin 6\alpha \right] \quad (37)$$

Piston acceleration:

$$a = rw^2 \left[\cos \alpha + \left(\lambda + \frac{\lambda^3}{4} + \frac{15\lambda^5}{128} \right) \cos 2\alpha - \left(\frac{\lambda^3}{4} + \frac{3\lambda^5}{16} \right) \cos 4\alpha + \frac{4\lambda^3}{128} \cos 6\alpha \right] \quad (38)$$

Figure 8 shows the linear displacement relationship with time, where we notice that the relationship is non-linear and changes over small time intervals. We notice the speed relationship in Figure 9, where there is a wave relationship around the value of zero speed, and the maximum value of the speed is 250 and the minimum is -250. As for the acceleration in Figure 10, it also has a wave relationship between the maximum value of 1750 and the minimum value of -1750.

Figures 8, 9 and 10 represent the graphs of the path, velocity and acceleration in terms of angle α .



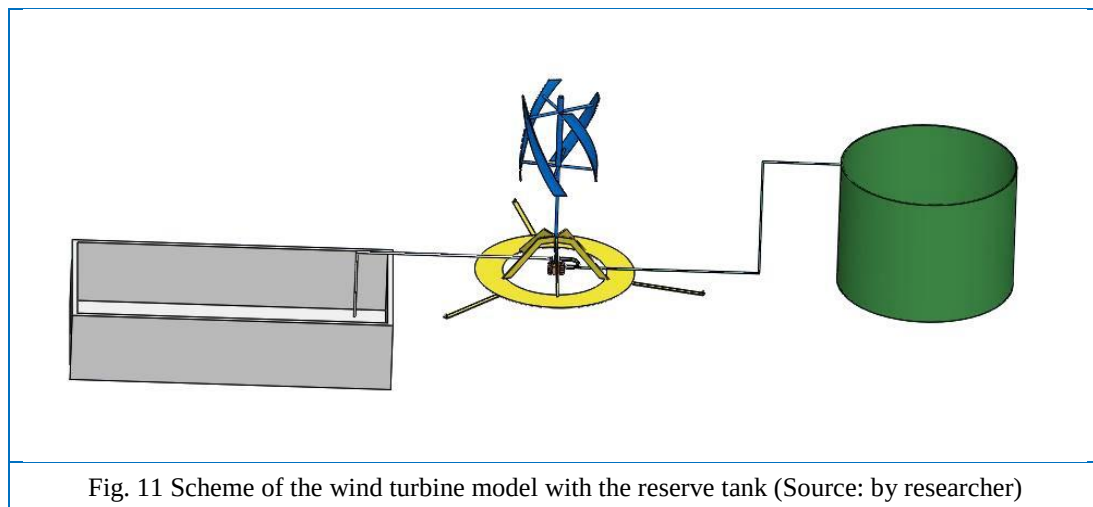


Fig. 11 Scheme of the wind turbine model with the reserve tank (Source: by researcher)

6. Conclusion and recommendations

Wind energy has received a lot of attention by researchers and designers in order to use it in energy-saving and environmentally friendly applications. One of the applications of wind energy exploitation is using wind turbines to pump water by wind, the subject of this study in which, a pump was designed to raise water from a well using wind energy to irrigate farms with an area of (2.5) hectares, a two-piston pump is designed, the first to draw water from the well and the second to push water into the reserve tank. (Irrigation occurs during periods of unavailability of rain water).

Finally, we recommend the following:

1. Attention must be turned to techniques related to wind energy and focus must be maintained on those techniques because of their actual contribution to the fields of clean energy.
2. Heading to use the techniques for obtaining electrical energy by using wind energy to be used in agricultural applications such as grinding grains and hydraulically pressing fruit.
3. Attempting to design a water pump that relies on the energy of the wind tree because it is a modern wind energy application that does not require high wind speeds.

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