Design and Development of Wind Power Water Lifting Pump Mechanism

Hayder Kadhim Khashan
PG Student
Department of Mechanical Engineering
VIT PUNE

Abstract

As an energy source, wind is free and does not need to be imported from other countries. Currently the popularity of wind power is still increasing world-wide. Denmark is one of many countries who are continually planning ahead in the development of wind power. Today, 25% of their electrical power is generated from wind with a goal of 50% for the year 2020. A windmill is a machine that converts the energy of wind into rotational energy by means of vanes called sails. Originally, windmills were developed for milling grain for food production. In the course of history, the windmill machinery was adapted to many other industrial uses. An important non-milling use is to pump water, either for land drainage or to extract groundwater. A wind pump is a windmill used for pumping water, either as a source of fresh water from wells, or for draining low-lying areas of land. Wind pumps are used when electricity is not available. In this paper, it is described the detail design and development, experimentation of wind power water pump mechanism which is today’s need for rural development. In further paper, the objective is to implement the design concept for the rural development.

Keywords: Windmill, water-pump, electricity

I. INTRODUCTION

Today, wind power has the potential to reduce the amount of carbon dioxide and related greenhouse gases that contribute to global warming. As an energy source, wind is free and does not need to be imported from other countries. This is an extremely important advantage of wind power since many countries are dependent upon foreign providers for a large present of their fossil fuels. New and renewable sources of energy can make an increasing contribution to the energy supply mix of the developing country in view of favourable renewable energy resource endowments, limitations and uncertainties of fossil fuel supplies, adverse balance of payments, and the increasing pressure on environment from conventional energy generation. Among the renewable energy technologies, the generation of mechanical and electrical power by wind machines has emerged as a technoeconomical viable and cost-effective option. The use of wind pumps declined dramatically from the 1920s due to the economic depression and the use of electric motors or petrol and diesel engines to drive water pumps. Soaring energy prices in the 1970s and growing interest in renewable energy sources led to their reconsideration, particularly in Sudan, although the take-up of the technology is still slow in this field. This paper work handled the developments of i) to attempts to disseminate wind pumps and ii) Adoption of modern engineering analysis and design methods; and iii) A new generation of low cost modern wind pumps has evolved but, it has not reached the level of reliability of the old classical wind pumps yet. In the past 20 years, there have been major innovations in wind energy development. From 2008 to 2009 alone, wind powered electricity generation increased 20% worldwide. Still, wind energy only accounted for 1% of the world’s electricity use. Many countries have recently seen significant strides in wind technology implementation as wind turbines, both on and offshore, have been installed, wind maps displaying wind patterns from around the world created, and innovative advancements in wind technology researched.

There has also been an increase of wind power use in developing nations as a source of electric power, or as mechanical energy to pump fresh water from wells. Due to the strides taken in high-strength fibre material technology, variable-speed electric generators, and the experience gained through continued development of wind technology, the cost and difficulty of construction of wind power has significantly decreased to provide more feasible and affordable wind powered machinery. Currently the popularity of wind power is still increasing world-wide. Denmark is one of many countries who are continually planning ahead in the development of wind power. Today, 25% of their electrical power is generated from wind with a goal of 50% for the year 2020. This paper work based on fully design and development and their experimentation in order to develop the rural backward area.

The main principle of this concept adopted is to convert Kinetic energy into the Mechanical energy to pump the water. In order to properly estimate the anticipated power generation for a wind turbine, certain factors about the area needs to be calculated. For example, in order for a wind turbine to be economically viable, there needs to be enough wind at the site to power the turbine. This is referred to as the specific power of a site. The specific power is calculated as follows: \( P = \frac{1}{2} \rho V^3 \) Where \( P \) is the specific power, \( \rho \) is the air density (in kilograms per cubic meter), and \( V \) is the air velocity (in meters per second), and the specific wind power is measured in watts per square meter swept out by the rotating blades. This can be thought of as the amount of power that could be extracted from the wind by a 100% efficient turbine. However, no wind turbine can extract all of the power from the
wind. The turbine output power, in watts, can be calculated \[ P_o = \frac{1}{2} \rho A V^3 C_p \] Where \( P_o \) is the output power of the turbine, \( \rho \) is the air density, \( A \) is the swept area of the rotor blades, \( V \) is the upstream wind velocity, and \( C_p \) is a variable known as the power coefficient. This coefficient, also known as the rotor efficiency, is the “fraction of upstream wind power that is extracted by the rotor blades and fed to the generator (Patel, 2006).” The power coefficient can be calculated as follows \[ C_p = (1 + \frac{V_o}{V}) \left[ 1 - \left( \frac{V_o}{V} \right) \right], \] the power coefficient is calculated using the upstream wind velocity, \( V_o \), and the downstream wind velocity, \( V \). The maximum theoretical value for \( C_p \) is 0.593; this value is known as the Betz coefficient. In practice, however, a realistic estimation for the maximum value for \( C_p \) is closer to 0.5.

The power coefficient is closely related to another coefficient, which is known as the tip speed ratio of the rotor. The tip speed ratio, \( \lambda \), is defined as \[ \lambda = \frac{\omega r}{v} \] Where \( \omega \) is the rotational speed of the turbine (in radians per second), \( r \) is the turbine radius, and \( V \) is the wind speed. This dimensionless coefficient, along with the power coefficient, can be related to the efficiency of the turbine. Fig. 1 shows the relationship between the power coefficient and the tip speed ratio for different turbine types. There are multiple different curves which represent different types of turbines. Each curve represents the power coefficient as a function of the tip speed ratio. Each curve (except for the ideal power coefficient curve) has a certain tip speed ratio that will give a maximum power coefficient, and therefore a maximum power. It is advantageous to ensure that the tip speed ratio is such that it maximizes the power coefficient.

![Fig. 1: A chart comparing rotor power coefficients and tip speed ratios](image)

**II. LITERATURE REVIEW RELATED WIND POWER MILL**

Windmills were used to pump water since at least the 9th century in what is now Afghanistan, Iran and Pakistan. The use of windmills became widespread across the Muslim world and later spread to China and India as well. Windmills were later used extensively in Europe, particularly in the Netherlands and the East Anglia area of Great Britain, from the late Ages onwards, to drain land for agricultural or building purposes. Early immigrants to the New World brought with them the technology of windmills from Europe. On US farms, particularly on the Great Plains, wind pumps were used to pump water from farm wells for cattle.
In early California and some other states the windmill was part of a self-contained domestic water system including a hand-dug well and a redwood water tower supporting a redwood tank and enclosed by redwood siding (tank house). The self-regulating farm wind pump was invented by Daniel Holladay in 1854. Eventually steel blades and steel towers replaced wooden construction, and at their peak in 1930, an estimated 600,000 units were in use, with capacity equivalent to 150 megawatts. Early wind pumps directly operated the pump shaft from a crank attached to the rotor of the windmill; the installation of back gearing between wind rotor and pump crank allowed the pump to function at lower wind speeds. The multi-bladed wind turbine atop a lattice tower made of wood or steel hence became, for many years, a fixture of the landscape throughout rural America. These mills, made by a variety of manufacturers, featured a large number of blades so that they would turn slowly with considerable torque in low winds and be self-regulating in high winds. A tower-top gearbox and crankshaft converted the rotary motion into reciprocating strokes carried downward through a rod to the pump cylinder below. Rising energy costs and improved pumping technology are increasing interest in the use of this once declining technology.

III. DESIGN METHODOLOGY

The detail construction of concept developed is shown in fig. 3. The different components of concept developed are base stand, T-shaped, rotating foils and cycle disc plate UPVC pipe and N-R Valve and cycle wheel. When wind energy strike on foils, the foils produced rotating motion and hence it’s also rotating the cycle rims. But horizontal gear attached to the cycle rim (Axle) hence its rotate the vertical gear because horizontal gear and vertical gear mesh with each
The connecting rod is connecting to the vertical gear and piston rod. Hence the rotary motion of gear is converted into the linear motion of piston. The piston is reciprocating in the cylinder and piston suck the water from reservoir and discharge is created.

A. Design Methodology and Fabrication Adopted for Wind Power Water Pump

1) Part – I Design
To find velocity for rotation of rim as input for this mechanism \( \omega = \frac{2\pi n}{60} \)
\( \omega = 0.04188 \text{ rps} \)
\( V = r \times \omega \)
\( V = 0.753 \text{ m/s} \), the input velocity acting on the rim is about 0.753 m/s as shown in fig. 5
To find the Force acting on the rim \( a = \frac{\omega}{t} = 6.98 \times 10^{-4} \text{ m/s}^2 \)
\( F = ma = 39.2 \times 6.98 \times 10^{-4} \)
\( F = 0.029 \text{ N} \), the force acting on the rim is 0.029 N
To find the Torque acting on the disc \( T = F \times R = 0.029 \times 1800 \)
\( T = 52.94 \text{ N-mm} \), the torque acting on the disk plate is 52.94 N-mm

Design of hollow pipe for the purpose of reciprocating pump

To find the torque acting on disc \( T = \pi \times \tau \times do^3/16 \), \( do = 42.01 \text{ mm} \), \( di = di/2, di = 21.005 \text{ mm} \), the diameter of reciprocating pump is 42.01 mm and 21.005 mm respectively.

To find Discharge of the reciprocating pump \( A = \pi/4 \times d^2 = 276.11 \text{ mm}^2 \), \( Q = LAN/60, Q = 17.67 \times 10^3 \text{ m}^3/\text{min} \) The discharge of the reciprocating pump is nearly 17.67 \( \times 10^3 \text{ m}^3/\text{min} \)

2) Part – II Fabrication
The different fabrication steps shown below for the parts developed in workshop
- Cutting Process: As per the design Foils are cut by the cutting process.
- Drilling Process: On metal strips and foils for mounting the drilling process is used.
- Welding Process: Two rims are joined together with the help of metal strips by welding process.
- Threading Process: Used for threading of stand pipes.
- Hammering Process: Bearing are mounted by the process of hammering.
- Filing Process: This process is used for filing of supporting stand.
- Polishing Process: By polishing process pipe and elbow are polished.
- Painting: For painting of stand and tee.
IV. CONCLUSION

There has also been an increase of wind power use in developing nations as a source of electric power, or as mechanical energy to pump fresh water from wells. Due to the strides taken in high-strength fibre material technology, variable-speed electric generators, and the experience gained through continued development of wind technology, the cost and difficulty of construction of wind power has significantly decreased to provide more feasible and affordable wind powered machinery. Currently the popularity of wind power is still increasing worldwide with improved design for wind turbines, financial package, political will to support large-scale wind projects through public sector undertakings, and a remunerative price for wind generated electricity, it is hoped that wind energy will play a supplementary role to meet the growing power demands in the country in general, so our design and experimentation is to meet the standard for the development of rural area field.

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