



Wind Machine for Wastewater Treatment

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Abstract

This paper presents the study of using wind turbine for wastewater treatment application. Wind energy is clean power resource that can be applied into many useful works. And the wind turbine is a machine which converts the power in the wind into many forms of energy such as electricity, hydraulics or air pressures etc. However, most of the wind turbine nowadays is using for electricity generation purpose, while others are not applicable and world wide uses especially, in low wind speed areas. In this paper, others application of wind machine was studied and investigated. As in many applications and areas, the electricity is not the main requirement but the need of air and oxygen is required. Especially, in agriculture areas and some industrial sites, the water pollution is a big issue to be solved. Therefore, the used of wind machine for oxygen generation was studied and presented in this paper. This research shown that the prototype was generates 3 bar of air pressure circulates of $1.3101 \times 10^{-3} \text{ m}^3/\text{s}$ volumetric at wind speed of 5 m/s average into the wastewater pond. Additionally the suitable engineering design using Computational Fluid Dynamics (CFD) indicated that high performance airfoils could be applied in wind turbine rotor for wastewater treatment at low wind speed areas.

Keywords : Wind turbine, Wind Energy, Air-Pressed Turbine, Air pump

1. INTRODUCTION

Wind is one source of energy that is prevalent in most areas of the world. Because of this fact harnessing wind energy makes sense in many cities where pollution is already a factor and issued. Like the solar power, power production from wind is an alternative to coal, oil, nuclear and other fossil sources due to the following:

- It is a renewable and infinite resource.
- It is free of any emissions, including

carbon dioxide (greenhouse gas).

- It is a free resource after capital cost of installation (excluding maintenance).
- Energy production with wind power prevents significant water usage associated with coal, nuclear and combined cycle sources.

In fact, wind energy is a converted form of solar energy. The sun's radiation heats different parts of the earth at different rates — most notably during the day and night, but also when different surfaces



(for example, water and land) absorb or reflect at different rates. This in turn causes portions of the atmosphere to warm differently. Hot air rises, reducing the atmospheric pressure at the earth's surface, and cooler air is drawn in to replace it. The result is blowing in the wind.

Air has mass, and when it is in motion, it contains the energy of that motion — "kinetic energy." Some portion of that energy can be converted into other forms — mechanical or useful torque or electricity — that we can use to perform many works.

Most wind machines nowadays were designed and constructed for generating electricity based on megawatt size wind machines. However, small wind machines can

be applied to other applications as shown in this paper. The benefit of using wind machines for water treatment is significant to the results of renewable energy uses. The objective of wastewater treatment is to increase the leveling of oxygen, which is not electricity generation. Therefore, most of the wastewater treatment process uses wind machines to generate electricity and then convert to air or other devices to force the air to the wastewater. In those processes the energy loss from a conversion of each step results in low efficiency of the system. Because in the energy conservation shown that if we convert the energy form to others will lose some energy on the process. Additionally, the energy from fossil is not the right energy source for wastewater treatment. Because the original resource is not clean and that the process of water treatment could use the energy source by clean or natural resource.

On this study the process works like a natural treatment without pollution by using the wind machine. Because the wind machine rotor would generate the useful torque by using working fluid of the air passing through the airfoil and therefore convert to the air pressure by using the air piston pump. The study investigates some parameters for the design process.

- Air piston pump starting torque
- The lift force generated by the turbine blade
- The revolution required of the piston pump
- The volumetric of the cylinder
- The cut-in and rated rpm of the wind turbine rotor.
- The solidity of wind turbine blade
- The maintenance process of the piston pump
- Number of blade

Those factors are to be used for minimum parameters could be effected to the machine power output.

2. THEORY OF LOW WIND SPEED DESIGN CONCEPT

Thailand and some other parts of the world have low wind speed resource. Therefore to design the air-pressure turbine that will be used for low wind resource is special topics and design. Because the wind speed of the wind class III is too low for using from high speed wind turbine designed. Additionally, we could not control the speed of the wind, therefore low speed wind machines need to concern about the high power output at low wind speed. Unfortunately, increasing the length of wind turbine blade will reduce the speed of the rotor rotational.



Additionally it's would not possible to modify the original wind machine that design for high wind by replacing the longer blade. And also from the studies results we don't think any change of alternator is going to give high wind machine the wattage we're trying for. The only thing that can think and design of increasing output is increasing input. Since we can't increase the wind's speed, therefore the studied suppose this will mean increasing and selecting the size of your airfoil blades and shapes. Catching more wind at the same speed will increase the energy that is being input into the low wind speed system. At eventually the 400 Watt wind machine that was using for constructed of wind turbine for pressing the air to water is constructed and investigated and specifications are in as the following:

Rotor Diameter: 2.8 meter

Cut in wind speed: 2.5 m/s

Rated wind speed: 7 m/s

Cut out wind speed: 15 m/s

Working rpm: 100- 250 rpm

Weight of Nacelle: 15 kg

Blade material: Fiber glass Rein forced

Sound level at 50 m distance: <30 DB

2.1 Air-foil and blade design

In the design process of the airfoil for making the wind turbine rotor, the aerodynamics deals with the motion of air and with the forces acting on objects moving through air or remaining stationary in a current of air. The same principles of aerodynamics apply to both rotary-wing and fixed-wing aircraft. Four forces that affect a wind turbine at all times are weight, lift, thrust, and drag:

- Weight is the force exerted on a wind turbine nacelle by gravity. The pull of gravity acts through the wind turbine rotor of the center of gravity, which is the point at which wind turbine would balance if suspended.

The magnitude of this force changes only with a change in wind turbine blade weight.

- Lift is produced by air passing over the wing of a blade or over the rotor blades. Lift is the force that overcomes the weight rotor itself and all the friction and nacelle weight that it can still continues to generates useful torque

-Thrust is the force that moves a wind turbine rotor generates power when revolution through the air. In a conventional fixed-rotor wind machine, thrust provided by the wind turbine rotor and also generates lift force. In a wind turbine rotor both thrust and lift are produce from the moving fluid (air).

- Drag is the force of resistance by the air to the passage of rotor blade and nacelle through it. Thrust force sets a generator to generate power when wind turbine blade is and keeps it in motion against drag force.

The amount of lift that an airfoil can develop depends on five major factors:

- Area (size or surface area of the airfoil).
- Shape (shape or design of the airfoil sections).
- Speed (velocity of the air passing over the airfoil).
- Angle of attack (angle at which the air strikes the airfoil).



- Air density (amount of air in a given space).

Area and Shape

The specific shape and surface area of an airfoil are determined by wind machine designed engineer in manufacturer. An airfoil may be symmetrical or unsymmetrical, depending on specific requirements. A symmetrical airfoil is designed with an equal amount of camber above and below the airfoil chord line. An unsymmetrical airfoil has a greater amount of camber above the chord line. An airfoil with a smooth surface produces more lift than one with a rough surface. A rough surface creates turbulence, which reduces lift and increases drag.

Speed

The speed of an airfoil can be controlled and changed by the speed of incoming air and control system that caused the changes of the angle of the blade to the air.

The lift developed by an airfoil increases as speed increases. However, there is a limit to the amount of lift because the drag (resistance) of the airfoil also increases as speed increases.

Angle of Attack

The angle of attack is the angle between the airfoil chord and the direction of relative wind. Direction of airflow in relation to the airfoil is called relative wind. Lift increases as the angle of attack increases up to a certain point. If the angle of attack becomes too great, airflow over the top of the airfoil tends to lose its streamlined path and break away from the contoured surface to form

eddies (burbles) near the trailing edge. When this happens, the airfoil loses its lift, and it stalls. The angle of attack at which burbling takes place is called the critical angle of attack that would have to be serious concern in wind machine design and design process.

Air Density

The density (thickness) of the air plays an important part in the amount of lift an airfoil is able to make. The air nearest the earth's surface is much denser than air at higher altitudes. Therefore, wind turbine working can achieve more energy if the air density is high and keeping at the same speed and angle of attack, a wind turbine will slow down of making energy and less power as lower density of the air. \

3. DESIGN PROCEDURES

In the design process of low speed wind machine, the airfoil profile is the most important factor to be concerned. And as we know that for wind turbine engineering, the most important parameters influencing to the efficiency of the wind machine is the shape of the wind turbine. The airfoil characteristics is the performance of generates lift and drag coefficients C_l and C_d . The lift and drag force is generated when the wind passes through an airfoil cross section. When the wind flow passes through the different areas or shapes, the velocity is also altered. It passes more rapidly over the longer (upper) side of the airfoil (see Fig.1), creating a lower- pressure area above the airfoil. From the pressure difference resulting in a force called aerodynamic lift –the drag force is always perpendicular to the lift force.

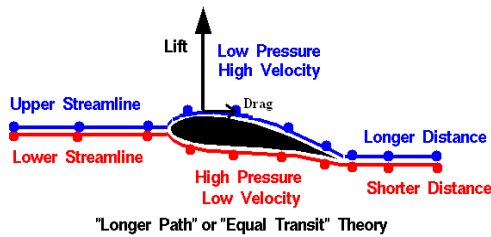


Fig.1 Lift and drag forces when the fluid passes through the airfoil section [1].

In the wind turbine design process, we have to maintain high performance in low wind speed, a higher value of lift and drag ratio is needed and requires a longer period of angle of wind attack α . The higher the lift to drag ratio is, the more efficient the airfoil. Good airfoil is capable of producing high lift at a small drag penalty. The lift and drag coefficients can be found using equations:

$$C_l = \frac{2L}{\rho V^2 A} \quad C_d = \frac{2D}{\rho V^2 A}$$

Where L and D represent the lift and drag force (N) respectively. A is the cross section area of selected airfoil area (m^2), V is coming wind velocity (m/sec) and ρ represents the density of the air (kg/m^3). The airfoil characteristics will affect the wind turbine rotor performances and suitable for design wind turbine characteristics. The theory of wing sections has been well researched and studied [1-3], and various airfoil sections suitable for low speed wind machine have also been investigated and studied. Most published studies on airfoils characteristics presented today are usually obtained from tests in wind tunnels. The usual tests are carried out over a range of Reynolds number (Re), depending on the goal of

the study. The Re may range from 3 to 9 million and at Mach numbers less than 0.17 [1]. In this study, the selected airfoil section for low wind speed has been investigated using special airfoil design for low Reynolds number used.

In the design process of diameter of wind turbine rotor using for air-pump turbine of low speed wind turbine blade shown that a high lift airfoil section becomes a manufacturing of rotor blade. The machine was designed with the C_p of 0.3 to 0.35 is recommended from experimental tested. With drive train efficiency, η_d and the air piston pump efficiency, η_g then the power output of the wind machine prototype becomes:

$$P_{out} = \frac{1}{2} \rho A C_p \eta_d \eta_g V_0^3 \quad (1)$$

In order to find the rotor swept area, A would come from the relation

$$A = \frac{2P_{out}}{(\rho C_p \eta_d \eta_g V_0^3)} \quad (2)$$

The prototypes low wind speed wind machine produces 400 watt for driving about 250 watts air-piston pump and the wind machine furling away from the maximum wind speed of 12 m/s to avoid over speed. The rotor sizing of wind rotor to generate 400 watt in operating area wind speed 7 m/s at altitude of 12 m was proposed. Assume that a drive train efficiency of 0.8, rotor power coefficient of 0.35 and air piston pump efficiency of 0.85[3].

Firstly, find the air density at altitude 12m.

Assuming

$$\rho = 1.255 \exp[(-0.297)(12) / 3048] = 1.181 kg/m^3$$

Then, calculate the swept rotor area, A from



$$A = 2(400) / [(1.18)(0.35)(0.8)(0.85)(7^3)]$$

$$A = 8.30 \text{ m}^2 = \pi r^2; r \sim 1.6\text{m.}$$

Thus, the rotor diameter would be 1.6 m.

The twisted airfoil S1223- C is selected for the purpose of air-pump turbine blade prototypes. The Computational Fluid dynamics was used to investigate and studied the aerodynamics performance of this airfoils section. The results of this study was shown in Table 1. The result of CFD shown that the model blade of twisted angle of 8 degree at root to 2 degree of tip of wind turbine rotor was higher performance to be selected of in this project.

Table1. CFD results of investigated wind turbine blade for air-pressed turbine

Mode I Confi gurati on	Tor que N.m	Lif t Fo rc e	Dra g For ce	C D	C L	Ra tio L/ D
8°-8°	598	0.0 6	0.0 4	0. 4 6	0. 3 0	1.5
8°-2°	615	0.0 9	0.0 3	0. 2 3	0. 6 9	3

3. INSTALATION AND SITE TEST

The model was constructed and tested its performance with data logger to record and investigation process. The model was installed at

wastewater testing pond at Pathumthani province. The installation process and wastewater testing of the water treatment process working shown in Fig. 2



Fig.2. Site test and installation process of Wastewater treatment pond

4. THE RESULTS AND DESCUSSION

In this study the porous plates was connected to the end of air pipe to diffuse the water increasing the oxygen to the wastewater treatment process. After designed, constructed and installation to the site test some data were recorded and could be specify characteristics of the wind machine and operating results was shown. The results of the study showed the following configuration. - Maximum rpm of 400 rpm at wind speed of 8 m/s - Rate of oxygen press to the air of 1.83 kg/ hr -Cut in wind speed of 2.5 m/s – None cut out wind speed using auto furling system for mechanical safety at 12 m/s. The data of air press to the water at variable wind speed as shown in Table 2 and 3



Table2. The wind speed versus the air volume

Wind speed V(m/s)	Air Volumetric ,Q (m ³ /s)
2	4.1549x10 ⁻⁴
2.3	4.6617x10 ⁻⁴
2.8	5.0671x10 ⁻⁴
3	5.2022x10 ⁻⁴
3.5	7.4317x10 ⁻⁴
3.8	8.2424 x10 ⁻⁴
4	8.7154x10 ⁻⁴
5	1.2465x10 ⁻³
5.2	1.3101x10 ⁻³

Table 3 shows the average air volumetric and the mass of the oxygen dissolved to the wastewater

Average air volumetric (m ³ /s)	Mass of the oxygen (kg/s)
4.1549x10 ⁻⁴	5.0897 x10 ⁻⁴
4.6617x10 ⁻⁴	5.7106 x10 ⁻⁴
5.0671x10 ⁻⁴	6.2072 x10 ⁻⁴
5.2022x10 ⁻⁴	6.3727 x10 ⁻⁴
7.4317x10 ⁻⁴	9.1038 x10 ⁻⁴
8.2424 x10 ⁻⁴	1.0097 x10 ⁻³
8.7154x10 ⁻⁴	1.0676 x10 ⁻³
1.2465x10 ⁻³	1.5270 x10 ⁻³
1.3101x10 ⁻³	1.6049 x10 ⁻³

The wind machine prototype was 3 m. diameter with design tip speed ratio of 8, special for low wind speed areas. The main shaft from turbine hub connected direct to the air compressor shaft of ½ HP piston pump. From the results of this

study, the prototype was starting up at 2.5 m/s with maximum rotation speed of 250 rpm at 5.5 m/s wind velocity. The system generates 3 bar pressure average to compress the air into the waste water pond with maximum air volumetric of 1.3101x10⁻³.

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