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# COMPARISON OF HINT WIND TINES OF AIRFOIL TYPE NACA 4412, NACA 23012, and NACA 16-212 USING QBLADE SOFTWARE

**Nurcholish Arifin Handoyono[1], Abdul Ghofur Syamdatu Wardhana[1]**
[1]Mechanical Engineering Education, Teacher Training and Education Faculty, Sarjanawiyata Tamansiswa University

*Corresponding author: Abdulghofur271196@gmail.com*

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## ABSTRACT

Wind energy as one of the new renewable energies that has considerable potential in Indonesia is known by the rapid development of wind power plants in Indonesia. The windmill blade which is one of the main components of the windmill has a role as the conversion of wind potential energy into motion energy to eventually become electrical energy that is influenced by the shape of the windmill blade of the windmill. NACA (National Aeronautical Committee Advisory) in charge of aeronautics has standards regarding varying airfoil shapes. A comparison of variations of 4-digit type airfoils (NACA 4412), 5 digits (NACA 23012) and series 16 (NACA 16-212) to determine the value of Cl / Cd from the variation of NACA airfoil types. The results of simulations carried out using Qblade software showed that the value of Cl / Cd to the highest alpha of the three types of airfoils was NACA 4412 with a value of 134, alpha 6 and the Cp value for the highest TSR was 0.44 at TSR 5.5. Furthermore, the NACA 4412 airfoil blades can be developed by making lighter material variations so that the windmill blades are easier to spin so that the resulting power becomes more maximal.

**Keywords**: NACA, HAWT, Qblade, Wind Beam, Airfoil

## INTRODUCTION

The available wind potential energy can be utilized and converted into electrical energy with windmills. To do this, there are several things to support it, namely the windmill as a means of converting wind energy into mechanical energy which is then passed on to the generator which is a means of converting mechanical motion energy into electrical energy. Coupled with the electrical energy through the controller as a voltage stabilizer and also as a controller of incoming electricity. During the process, the monitoring activities are very much needed as input data to further evaluate and develop the process. Therefore, the need for a data loger as a means of conversion of all activities that take place into data that can be presented and can be processed as development material. The electricity produced must have a place for storing energy, that is the battery so that the electrical energy stored in this battery can be used when needed. Some important things that should be reviewed are the windmill blade, Horizontal Axis Wind Turbine, and Airfoil.

Windmill blades are the very first objects dealing directly with the wind as a means of converting wind's potential energy into mechanical motion energy. To carry out their duties as a conversion tool, the blades must have a design that is suitable for the wind conditions where the windmills operate. The part of the blade that most influences the result of rotation and the torque produced is the airfoil section. The international institution recognized as a reference and standard is NACA (National Aeronautica Committee Advisory). Based on NACA standards used to form windmill designs, there are many types of airfoils so it is interesting to do research on the comparison of HAWT Windmill Blades Type Airfoil NACA 4412, NACA 23012, and NACA 16-212 using Qblade Software. The purpose of writing this article is to find out what type of airfoil with an efficient model is used somewhere that will serve as the development of new renewable energy, especially in wind energy.

The Horizontal Axis Wind Turbine (HAWT) has a main rotor shaft and an electric generator at the top of the tower. Small turbines are driven by a simple wind vane (weather vane), while large turbines generally use a wind sensor that is coupled to a servo motor. Most have a gearbox that changes the slow turning of the wheel to be faster. Because a tower produces turbulence behind it, turbines are usually directed against the wind direction of the tower. Turbine blades are rigid so they are not pushed towards the tower by high-speed winds. In addition, the blades are placed in front of the tower at a certain distance and tilted slightly.

Because turbulence causes damage to tower structures, and reliability is so important, most HAWTs are upwind machines. Even though they have turbulence issues, downwind engines (according to wind majors) are made because they do not require additional mechanisms so that they remain in line with the wind. In addition, when the wind blows very hard, the blades can be bent so as to reduce their blowing area and thus also reduce the wind resistance from the blades.

Airfoil is a form of geometry. When placed in a fluid flow will produce a lift force (lift) greater than the drag force (drag). Lift force occurs on the airfoil because the velocity of air flow at the upper surface of the airfoil is lower than the velocity of air flow at the lower surface. One of the geometric parameters that determines the amount of lift force produced by an airfoil is the location of its maximum thickness. The farther the location of the maximum thickness with the initial tip will result in an increase in the velocity of the flow of air that passes through the surface of the airfoil so that it will be one of the factors causing the average velocity along the surface to be lower. If this happens on the upper surface of the airfoil it will cause greater lift. But besides these factors there are still other factors that determine the magnitude of the average velocity of air flow both on the upper surface and on the lower surface of the airfoil, namely the magnitude of the angle of attack and the magnitude of the velocity of the air flow. To determine the combination of the effects of the two factors above on lift coefficient and airfoil inhibitory coefficient, it is necessary to study so that the use of airfoil in various fields of application can be done more optimally. On the airfoil there are sections as follows:

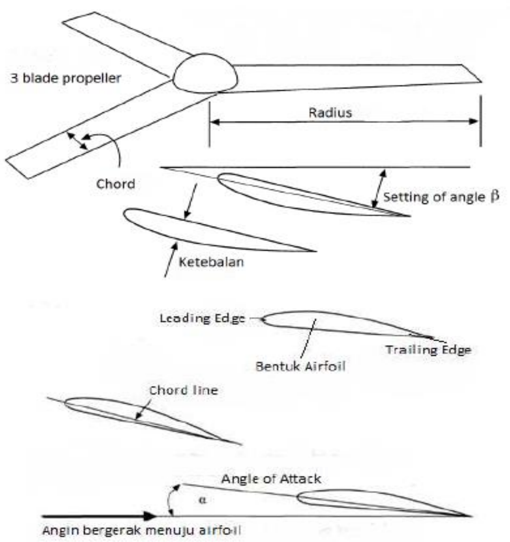



Figure 1. Windmill blades

1. Leading Edge is the very front of an airfoil
2. Trailing Edge is the very back of an airfoil.
3. Chamber line is a line that divides equally between the upper and lower surfaces of the airfoil mean chamber line.
4. Chord line is a straight line connecting the leading edge with the trailing edge.
5. Chord (c) is the distance between the leading edge and the trailling edge.
6. Maximum chamber is the maximum distance between the mean chamber line and the chord line. The maximum position of the chamber is measured from the leading edge in the form of a chord percentage.

7. Maximum thickness is the maximum distance between the upper surface and the lower surface of the airfoil which is also measured perpendicular to the chord line

QBlade is an open source wind turbine counting software, distributed under the GPL (General Public License). The integration of the XFOIL / XFLR5 function allows users to quickly design special airfoil and calculate their performance poles and directly integrate them into the design and simulation of wind turbine rotors. This software is very adequate for teaching, because it provides a 'hands on' design and simulation capability for the design of the HAWT and VAWT rotors and shows all the fundamental relationships of turbine design concepts and performance in an easy and intuitive way. QBlade also includes extensive post processing functionality for rotor and turbine simulations and provides insight into all relevant blade and rotor variables. In addition, the resulting software is a very flexible and easy-to-use platform for the design of wind turbine blades.

This software uses the Blade Element Momentum (BEM), Double Multiple Stream tube (DMS) and Nonlinear Lifting Line Theory (LLT) Design and Simulation Software for Vertical and Horizontal Axis Wind Turbines. It also includes tools for regulating and simulating the internal blade structure and performing aeroelastic analysis of wind turbine rotors in turbulent flow conditions through rapid coupling from NREL (National Renewable Energy Laboratory)

Many research and experimental efforts have been made to develop airfoil designs. This work is mostly done by NACA (National Aeronautic Committee Advisory), now NASA (National Aeronautics and Space Administration). NACA has identified differences in the shape of the airfoil with a logical numbering system.

Around 1932, NACA tested several forms of airfoil known as the 4-digit NACA series. The distribution of curvature and thickness of series four NACA is given based on an equation. This distribution was not chosen based on theory, but was formulated based on the effective wing shape approach used at the time, as it was known as the Clark Y airfoil. In the NACA four-series airfoil, the first digit represents the maximum percent of chamber to the chord.

The second digit represents the tenth position of the maximum chamber in the chord of the leading edge. Whereas the last two digits represent the percent thickness of the airfoil to the chord. For example, the NACA 2412 airfoil has a maximum chamber of 0.02 located at 0.4c from the leading edge and has a maximum thickness of 12% chord or

0.12c. Airfoil that has no curvature, where the chamber line and chord coincide is called a symmetrical airfoil. An example is NACA 0015 which is a symmetric airfoil with a maximum thickness of 0.15c.

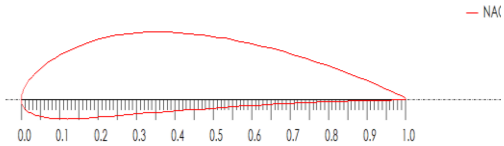



Figure 2. Airfoil NACA 4412

The development of the 5-digit NACA airfoil was carried out around 1935 using the same thickness distribution as the four-digit series. The average curvature of this series is different than the four-digit series. This change was made in order to shift the maximum chamber forward so as to increase Clmax. When compared to thickness and chamber, this series has a Clmax value of 0.1 to 0.2 higher than the four-digit series. This five-digit series numbering system is different from the four-digit series. In this series, the first digit multiplied by 3/2 then divided by ten gives the design value of the lift coefficient. Half of the next two digits are percent of the maximum position of the chamber with respect to the chord. The last two digits are the percent thickness / thickness of the chord. For example, airfoil 23012 has a Cl design of 0.3, the maximum position of the chamber at 15% chord from the leading edge and thickness or thickness of 12% chord.

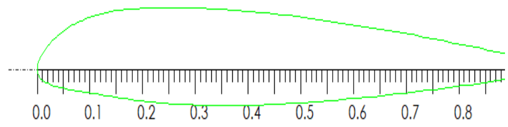
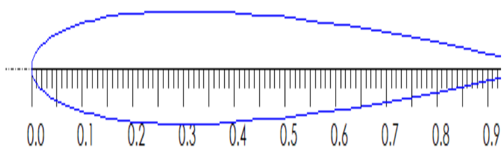



Figure 3. NACA 23012 airfoil

Airfoil NACA series 1 which was developed around 1939 is the first series that was developed based on theoretical calculations. The most commonly used Series 1 airfoil had a minimum pressure location at 0.6 chord, and came to be known as the 16-series airfoil. This airfoil line chamber is designed to produce pressure differences along a uniform chord. The naming of this series 1 airfoil uses five numbers. For example NACA 16-212. The first digit shows series 1. The second digit shows tenths of the position of minimum pressure against the chord. The number behind the hyphen: the first number is tenth of the Cl design and the last two numbers indicate the maximum percent thickness of the chord. So NACA 16-212 means that it is a series 1 airfoil with a minimum pressure location at 0.6 chord from the leading edge, with a design of Cl 0.2 and a maximum thickness of 0.12.




Gambar 4. *Airfoil* NACA 16-212

## RESEARCH METHODS

This study aims to study the HAWT (Horizontal Axis Wind Turbine) blades for Bayu Power Plants and compare the best type of airfoil based on Qblade Software simulation. which is located at PT. Lentera Bumi Nusantara is a renewable energy research area especially the use of wind energy. Located on Jalan Raya Ciheras RT 02 / RW 02 Kp. Sindang Asih, Dusun Lembur Tengah, Ciheras Village, Kec. Cipatujah, Tasikmalaya Regency, West Java. Data collection methods used were observation, interviews and literature studies.

## RESULTS AND DISCUSSION

In this section, simulation data are displayed from several types of NACA airfoils using Qblade software to compare NACA airfoil types. The following simulation data:Simulasi *airfoil* NACA 4 digit

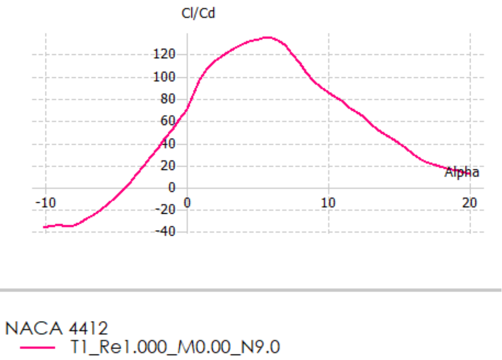



Figure 5. Cl / Cd graph of Alpha Airfoil NACA 4412

Simulation results as above, the maximum Cl / Cd value at alpha value 6 shows that the blades most easily rotate when the angle of attack against the wind is 6°.

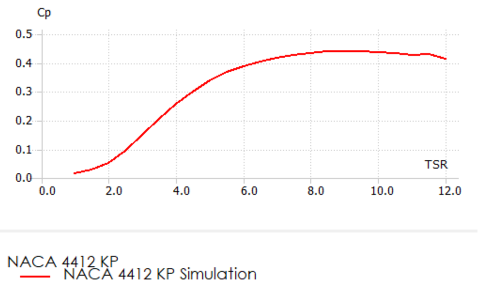



Figure 6. Graph of CP against TSR Airfoil NACA 4412

The graph above shows the value of Cp (Coefficient of Performance) produced from the blades with NACA 4412 airfoil. The optimum value of Cp that can be achieved is at TSR 8.0 with a CP value of 0.44.

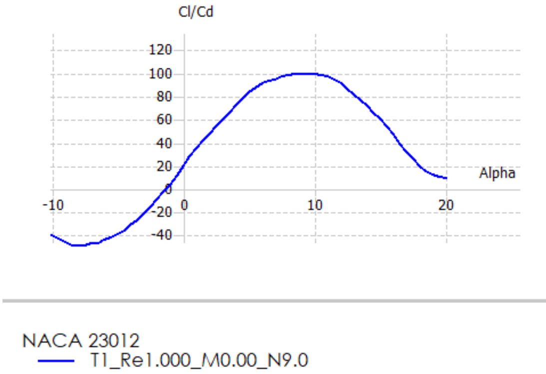



Figure 7. Cl / Cd graph of Alpha Airfoil NACA 23012

The simulation results as above, the maximum Cl / Cd value of 99 being at the angle of attack or alpha 9.5 shows that the bar rotates most easily when the angle of attack against the wind is 9.5.

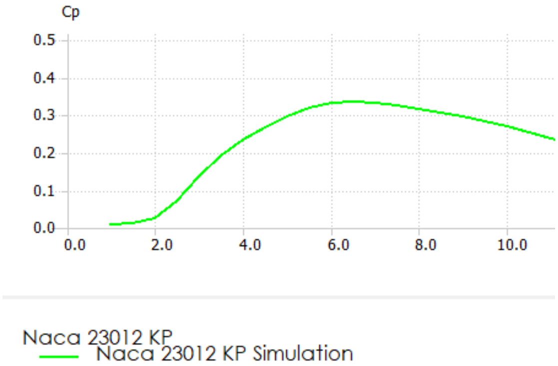



Figure 8. Graph of CP against TSR Airfoil NACA 23012

The graph above shows the value of Cp (Coefficient of Performance) produced from the slats with the NACA 23012 airfoil which is equal to 0.33. The optimum value of Cp that can be achieved is at TSR 6.5.

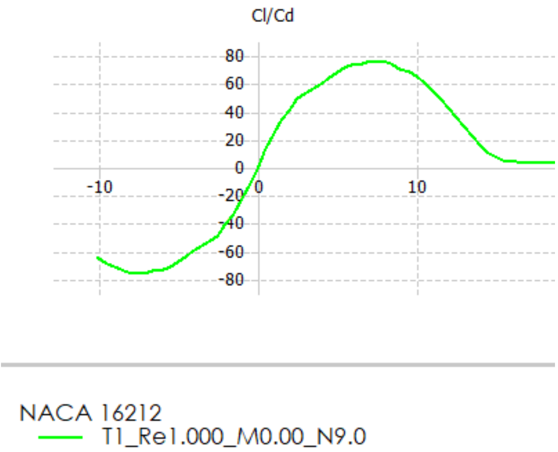



Figure 9. Cl / Cd graph of Alpha Airfoil NACA 16-212

The simulation results as above where the maximum Cl / Cd value of 75.5 is at an angle of attack value or alpha of 7.5 shows that the blades most easily rotate when the angle of attack against the wind is 7.5°.

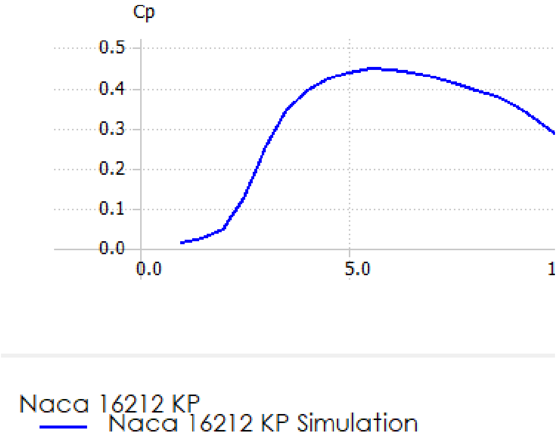



Figure 10. Graph of CP against TSR Airfoil NACA 16-212

Comparative analysis of 4-digit, 5-digit, and 16-digit NACA

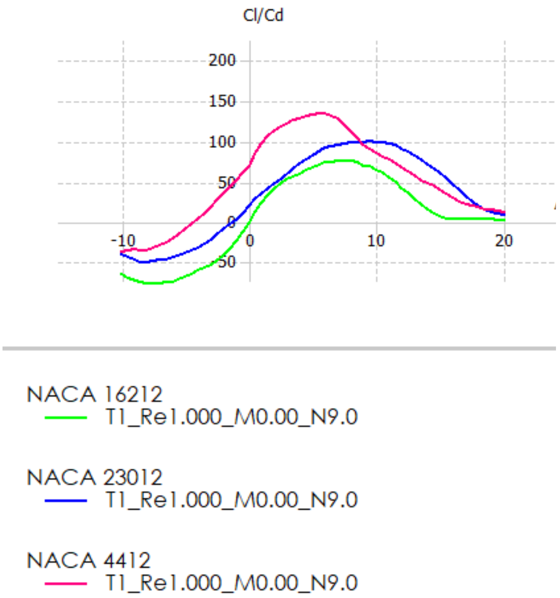



Figure 11. Cl / Cd graph of Alpha throughout the Airfoil simulation

The graph data shown is the result of simulation of three variations of NACA airfoil obtained the highest Cl / Cd value is the NACA 4412 airfoil design with Cl / Cd 134 values at an angle of attack $6^0$. In contrast to the other two types of NACA airfoils that get maximum Cl / Cd values of no more of 100. With the following simulation results the NACA 4412 airfoil has the highest lifting efficiency so that when implemented in the form of a blade airfoil, the windmill can rotate more easily than the two types of airfoil NACA 23012 and NACA 16-212

**CONCLUSION**

The utilization of wind energy in Indonesia is supported by the holding of wind power plants. For that efficient support of each component is something that must be considered. One of them is the windmill blade as the first component in direct contact with the wind. There are two types of blades based on the axis of rotation, namely the horizontal axis of rotation towards the wind direction and the axis of rotation of the vertical direction of the wind. Besides the type of airfoil as a cross section of the windmill blades have a varied shape. NACA (National Advisory Committee for Aeronautices) is an institution that issues standard forms of airfoil that have been used as a reference in the world.

Knowing the variations of NACA airfoil, it can be concluded that it needs comparative data between airfoils to find a good airfoil so that it can be implemented as a windmill blade. By using Qblade Software, it can be known the value of Lift Coefficient (Cl), Drag Coefficient (Cd), Coefficient of Performance (CP) which can then be used as a reference to determine the use of windmills with NACA airfoil types.

Three variations of NACA airfoil types, namely NACA 4412, NACA 23012, and NACA 16-212 aim to produce significant data from simulation results between the airfoils. The results obtained are the NACA 4412 airfoil has the highest Cl value than the two other NACA airfoil values with a value of 134 with Alpha 6. While for the NACA 16-212 airfoil the value of 75 and NACA 23012 obtain a Cl / Cd value of alpha of 99. In addition, the Cp value, Airfoil NACA 16-212 obtained the largest Cp value, which is 0.44 at TSR 5.5. Whereas the NACA 23012 Cp airfoil obtained was 0.33 and the NACA 4412 Airfoil obtained a Cp value of 0.43 at TSR 9.

Qblade software as a media analysis of windmill blades has variations in the NACA airfoil which has a relatively simple design that is easy to understand and use. HAWT windmill blades have strong and resilient properties. This is necessary because the placement of the windmill blades are far above the ground surface and face to face with the wind.

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