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COMPARISON OF AERODYNAMIC CHARACTERISTICS OF NACA4412, NACA 23012 AND SG6043 AIR FOILS AT VARIOUS REYNOLDS NUMBER USING X FOIL

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ABSTRACT

The effectiveness of the wind turbine and the use of wind energy are significantly impacted by the choice of the blade of air foil. The most widely used airfoils include NACA4412, NACA 23012 and SG6043. Lift and drag forces on an airfoil blade or wing are known to depend mainly on the airfoil geometry in addition to the angle of attack. XFOIL program is used to compare the lift coefficient, drag coefficient and lift to drag ratio for NACA4412, NACA 23012 and SG6043 air foils at Reynolds numbers 1.0x10^5 and 5.0x10^5. The results obtained were validated via comparison of the predicated data with published results in the literature. It's interesting to note that results like the drag and lift coefficients, lift to drag ratio vary with the Reynolds number and angle of attack which show that SG6043 air foils have better average performance criteria with higher lift to drag ratio.

KEYWORDS: *Air foil, X Foil, Lift Coefficient, Drag Coefficient, Angle of Attack*

Article History

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INTRODUCTION

The global warming and energy crisis have prompted a great deal of effort to learn more about renewable energy. Wind power is one type of renewable energy in which wind turbines capture wind energy and transform into fuel energy (1). Consequently, the overall performance of the turbine can be enhanced by the ideal wind blade geometry (2). The output metrics of the blade performance are reflected in the geometry of the blade, specifically distributions of airfoil types along the span, chord length and torsion angle distribution optimization and the ratio of blade thickness to chord length (3). The selection of the airfoil, a component of the wind turbine blade, is also a crucial element that needs to be taken into account during blade design.

The performance of the blade is characterized by the lift and drag forces that result from the motion of an airfoil-shaped body in a fluid. By adjusting the airfoil's shape and angle of attack, the lift can be maximized (4). A high lift to drag ratio is a general requirement for airfoil designs. Although it does not increase torque, raising the lift coefficient increases thrust, which lowers the drag coefficient and boosts aerodynamic efficiency (5). Using analytical equations that describe the camber (curvature) of the mean-line (geometric centre line) of the airfoil section as well as the thickness distribution of the section along its length, the early NACA airfoil series, the 4-digit, 5 digits and modified 4-/5-digit were created. The 6-

Series and later families are more complex shapes that are derived using theoretical methods rather than geometrical ones. Prior to the creation of these series by the National Advisory Committee for Aeronautics (NACA), the design of airfoils was largely up to the designer, with only prior knowledge of iconic shapes and experimentation with their modifications serving as a guide (6).

The airfoils chosen for this study are pertinent because the geometries are openly accessible and there is a wealth of experimental data that can be used to assess simulation results. The wind turbine database was used to choose various airfoil types recommended for small horizontal axis wind turbines. Current study compares NACA4412, NACA 23012 and SG6043 airfoils at Reynolds numbers 1.0x10^5 and 5.0x10^5 mainly using X FOIL program. For each airfoil, lift ratio, drag ratio, maximum lift to drag ratio and optimal attack angle were calculated.

METHODOLOGY

The efficiency of the wind turbine depends on the airfoil selection, which takes into consideration variables like manufacturing difficulty, blade quality, and aerodynamic performance. The NACA airfoil family is used as the research blade airfoil because it is the most widely used and representative traditional wind turbine airfoil according to pertinent data (7). Analysis and simulation of several low-wind HAWT airfoils currently in use were conducted using X-Foil software. In this case, the X-Foil software was used to compare and analyse the aerodynamic characteristics of NACA 4412, NACA 23012, SG6043 at Re100000 and 500000 and AOA between -15 and 20 degrees.

Of these, NACA4412 shows that the airfoil type has a maximum thickness of 12% at 30% chord and maximum camber of 4% at 40% chord length (Fig 1). NACA 23012 shows that the airfoil's maximum relative camber is 1.8%, in relation to the chord length 12.7% and maximum thickness (Fig 2). SG 6043 has a maximum thickness of 10% at 32.1% chord and maximum chamber of 5.1% at 53.35 chord length (Fig 3).

First digit indicates the maximum relative camber of the airfoil and the second digit indicates the position of the maximum relative camber relative to the chord length. The last three digits indicate the arc in the airfoil and its relative thickness (8).

The lift coefficient and drag coefficient are two crucial metrics that demonstrate the performance of the air foil. Drag force is the parasitic force, while lift force generates the blade's rotational action. Although the parameters of two forces are the same, their coefficients differ. The following equation (1) is a representation of the blade's Reynolds number (9)

$Re = \rho vC/T$

ρ = Density of air (KG/m^3),

v = Velocity of air (m/sec)

C=Chord length of blade (m)

T =Dynamic viscosity of air (N.Sec/m^2)

Glide ratio (GR), in addition to Re, is an important airfoil performance metric. Another name for it is the lift-to-drag ratio. Since it increases rotor torque and reduces bending moments on the rotor blade for a specific lift value, a higher lift to drag ratio is anticipated. Thus, the following equation (2) provides the glide ratio (10)

GR=L/D=CL/CD

L=Lift force(N)

D=Drag force (N)

RESULTS

The X Foil software is used to analyse and compare NACA 4412, NACA 23012 and SG6043 airfoils at Re 1.0x10^5, and 5.0x10^5 and the angle of attack from -10 to 20 degrees. At Re 1.0x10^5, the highest lift coefficient of 1.63 for SG6043 at angle of attack 14.75° is observed followed by 1.44 for NACA 4412 and 1.03 is noted for NACA 23012 at the same angle of attack. In contrast, the highest lift coefficient of 1.48 for NACA 4412 is recorded at an angle of attack of 14.25° and the highest of 1.27 for NACA 23012 is recorded at an angle of attack of 13° (Figure 4).

NACA 4412 has a drag coefficient of 0.028, NACA 23012 has a drag coefficient of 0.025, and SG6043 has the drag coefficient of 0.02 at angle of attack 6.75° at Re 1.0x10^5. On the other hand, NACA 4412 registers the drag coefficient of 0.017 at an angle of attack of 1.5°, while NACA 23012 records the drag coefficient of 0.0147 at an angle of attack of 1°. SG 6043 thus had least drag coefficient at highest angle of attack compared to other two foils (Figure 5).

Results also show that for SG 6043 the average maximum lift to drag ratio at Re of 1.0x10^5 is 66.46 with an angle of attack of 7°, while for NACA 4412 airfoils it is 54.09. It is also observed that, lift to drag ratio for NACA23012 is 35.64 at same angle of attack. This indicates that SG 6043 airfoils are more effective in areas with low wind speeds. Conversely, the NACA 4412 had a lift to drag ratio of 56.1 at an angle of attack of 6.2°, while the NACA 23012 lift to drag ratio is 36.38 at an angle of attack of 5.5° (Figure 6).

Figure 7 displays that, with an angle of attack of 15.5°, the highest lift coefficient of 1.7038 for SG6043, 1.517 for NACA 4412, and 1.40 for NACA 23012 at the same angle of attack are recorded at Re 5.0x10^5. While the highest lift coefficient of 1.43 for NACA 23012 is measured at an angle of attack of 14.25°.

At angle of attack 0.75° and Re 5.0x10^5, the drag coefficients of NACA 4412, NACA 23012 and SG6043 are 0.00693, 0.00723 and 0.00682 respectively. However, for NACA 4412 at angle of attack 0.25° the drag coefficient recorded was 0.05 (0.00681) whereas NACA 23012 has 0.05(0.00683) at angle of attack of 0.25° (Figure 8).

Figure 9 illustrates how the angle of attack affects the lift-to-drag coefficient ratio for the chosen airfoils at Re of 5.0x10^5. The highest ratio for SG 6043 reached at a 3.5 °angle of attack is 143, shows that lift is significantly higher than drag, which is ideal for small wind turbine design. The higher lift to drag ratio value of this airfoil indicating that the theoretical aerodynamic performance of this airfoil is superior to the other two. The lift-to-drag ratio has an impact on the rotor torque and power generation, particularly at low wind speeds. Results also show that, the average maximum lift to drag ratio for NACA 4412 airfoils is 100.7 and for NACA23012 is 60.3. Results also depicts that, the average maximum lift to drag ratio for NACA 4412 airfoils at angle of attack 6° is 108 and for NACA23012 is 77 at an angle of attack of 9°.

DISCUSSION

In wind turbine blade design, aerodynamic performance is crucial, and airfoil shape affects aerodynamics. It is crucial to make sure that the airfoil used to design wind turbine blades doesn't experience any operational instability. In particular, maintaining a relatively constant angle of attack is essential for pitch-controlled wind turbines in order to maintain full operability. The lift and drag coefficient describe the performance of airfoil. For all the selected airfoils of small horizontal wind turbine blades, as the angle of attack increases, the lift and drag coefficient increases till certain angle change. However, the rate of increment is much higher after a certain angle of attack due to flow separation (11). Increase in the thickness, camber and angle of attack of airfoil increases the lift coefficient (12). Controlling flow separation on an airfoil improves the airfoil's performance by raising the lift coefficient, lowering the drag coefficient, and raising the lift to drag ratio (13). The airfoil SG6043 has the highest lift coefficient and the flow separation occurs at the angle of attack 14.75°. Both the drag and lift coefficients account for the angle of attack (AoA). This angle of attack has a significant role in the magnitude of the lift and drag coefficient, which means that it also influences the amount of lift and drag force that is generated (14).

The operating Reynolds number of each airfoil is one of the key parameters. Reynolds number has a major impact on the airfoil's drag and lift characteristics and is a function of the airfoil's performance characteristics. As the Reynolds number decreases, the drag coefficient's overall level rises and additionally, the blade's Reynolds number tends to decrease as its length does (15). There was an increase in the drag coefficient for SG6043, NACA 4412, and NACA 23012 as the Reynolds number decreased from 5.0x10^5 to 1.0x10^5. However, at both Reynolds numbers, the drag coefficient values with SG6043 were the lowest. An increase in Reynolds number results in an increase in the airfoils lift curve slope, maximum lift coefficient, and critical attack angle. Mueller and Batill on a range of airfoils also concluded that maximum lift coefficient consistently increases with higher Reynolds numbers and that the minimum drag coefficient significantly decreases (16). For SG6043, NACA 4412, and NACA 23012, the lift coefficient increased as the Reynolds number increased from 1.0x10^5 to 5.0x10^5, with SG6043 recording the highest lift coefficient. Additionally, as the minimum drag coefficient falls, the lift to drag ratio increases (17).

CONCLUSIONS

Aerodynamic performance of the three different airfoils studied shows that SG6043 has the lowest drag coefficient value and highest lift coefficient at Reynolds number 1.0x10^5 and 5.0x10^5. SG6043 also depicted the highest lift to drag ratio at the same Reynolds number which increased with increase in in Reynolds number and also increase in angle of attack. After a detailed aerodynamic comparison, it was concluded that SG6043 is the most suitable airfoil for the small horizontal axis wind turbine operating at low wind speeds. Hence SG6043 can be suggested as the best performing airfoil among the compared airfoils for the given Re range

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FIGURES

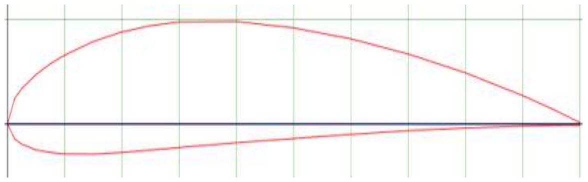

Figure 1: NACA 4412

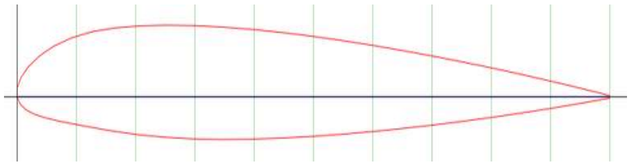

Figure 2: NACA 23012

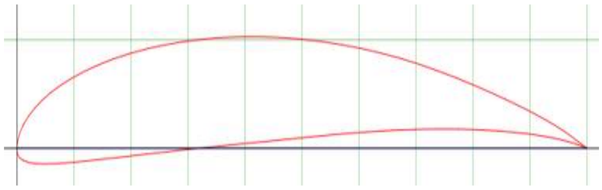

Figure 3: SG6043

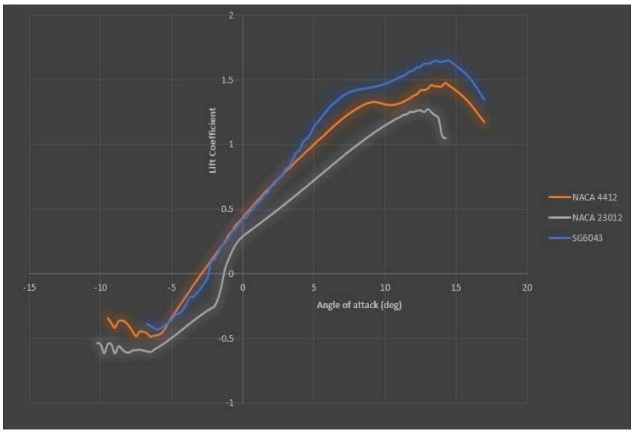

Figure 4: The Lift Coefficient Performance Curves for the NACA 4412, NACA 23012 and SG6043 Airfoils at Re=1.0x10^5

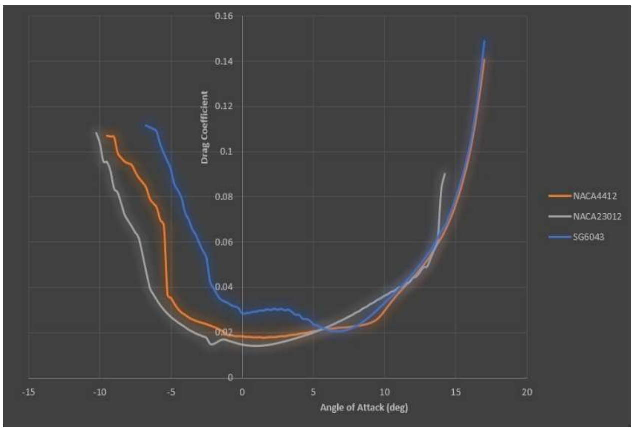

Figure 5: The Drag Coefficient Performance Curves for the NACA 4412, NACA 23012 and SG6043 Airfoils at Re=1.0x10^5

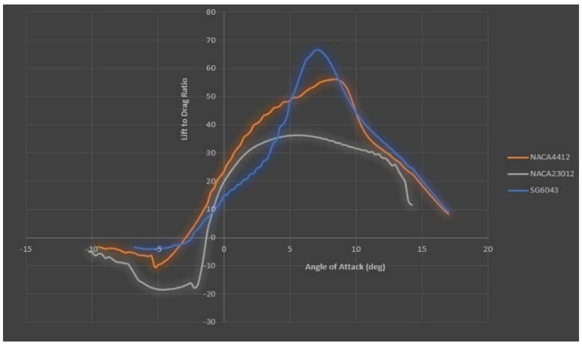

Figure 6: The Lift to Drag Coefficient Performance Curves for the NACA 4412, NACA 23012 and SG6043 Airfoils at Re=1.0x10^5

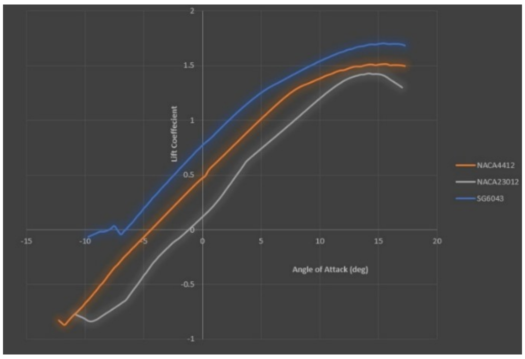

Figure 7: The Lift Coefficient Performance Curves for the NACA 4412, NACA 23012 and SG6043 Airfoils at Re=5.0x10^5

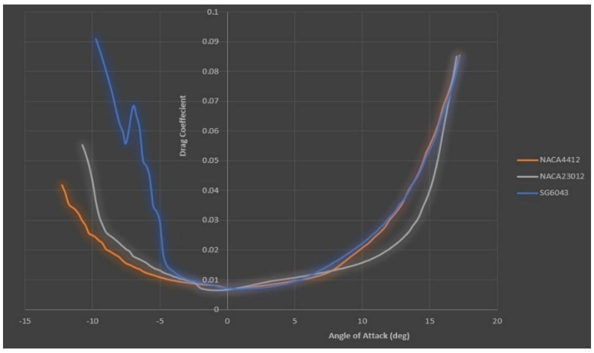

Figure 8: The Drag Coefficient Performance Curves for the NACA 4412, NACA 23012 and SG6043 Airfoils at Re=5.0x10^5

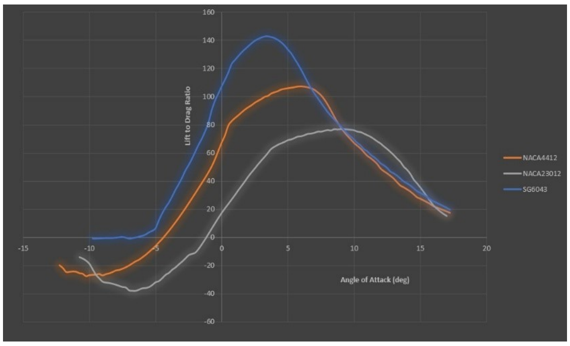

Figure 9: The Lift to Drag Coefficient Performance Curves for the NACA 4412, NACA 23012 and SG6043 Airfoils at Re=5.0x10^5