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Pitch Angle Analysis of NACA 2415 Airfoil

Ferit YILDIZ, Anil Can TURKMEN, Cenk CELIK, Halil Ibrahim SARAC

Abstract - In this study, the flow, pressure and velocity distribution analysis of NACA2415 profile is made according to the pitch angle. ANSYS was used for the analysis. Airfoil has a great importance in aeronautics. Profiles which are found in different types, was standardized by NACA codes. These profiles are selected depending on the application and aeordynamic properties of them increases the efficiency of wind turbine. This article will examine the advantages and disadvantages of different pitch angles.

Four different pitch angles were selected to observe clearly analysis results. Cross-section of a profile was studied in two dimensions, and comparisons were made in accordance to the results. 0º, 10º, 15º, 20º pitch angles were taken during the analysis. Thus, the advantages and disadvantages of the different pitch angles have been seen clearly.

***Index Terms* – Pitch angle, airfoil, naca 2415, CFD**

I. Introduction

ANY alternative energy resources are required instead of energy resources, which impair the world due to the increasing effects of the global warming. The science world addresses significance of the alternative energy resources, while power consumed even by a bulb is considered now. Using any alternative resources such sun, river, wind, etc., their negative effects on the world may be eliminated, and a more livable environment may be left for the future [2].

Attack angle is the angle that the wing falls on the wings and determines the pitch angle of the wings. A certain angle is applied to the wings to obtain best efficiency from the incoming wind and this angle varies depending both on attack angle and wind velocity. They are variable in others, while the pitch angles are constant in some wind turbines [1]. In general, the fixed pitch angles are used in the small turbines. The angles must be adjusted accurately in the turbines having the pitch angles. Otherwise, any non-controllable forces occur and the turbine is damaged. Given the cost of a wind turbine, a large volume of these damages may occur [4].

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The pitch angles are examined and three different characteristics like flow, pressure and velocity are considered in making a comparison. As a profile, NACA 2415 is used and the pitch angles are taken as 0º, 10º, 15º and 20º [11]. Comparisons shall be conducted in groups of 0º – 20º and 10º – 15º. Thus, it may be seen easily what happens in case of any major and minor changes in angles. Analyzes are conducted according to weather and wind conditions at an elevation of 1000m. Turbine entry velocity is taken as 37km/h, and turbine exit velocity is taken as 24.6km/h.

II. COMPARISON OF FLOW LINES

We may say that, when large values are reached beginning from the flow lines as we see in Figures 1 and 2, turbulences increase. Especially in a 20º analysis, wind is subject to a critical resistance. This resistance may cause turbulence in lower side of the wing as well as it creates an efficient force on the wing.

If we shall look at first flow line passing right under the profiles, this line is 16 to 17m/s in Figure 2, while it is 11m/s max in Figure 1. Any examination on these velocity values shall be addressed in the analysis, where they are comparison with respect to pressure [7].

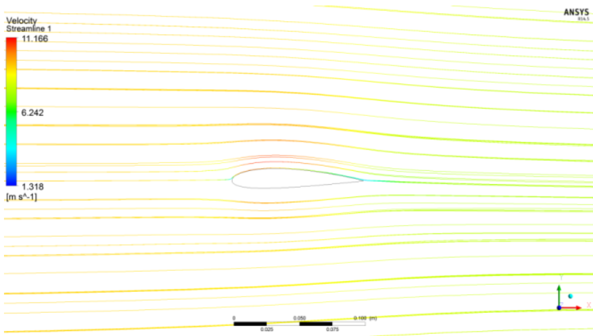

Fig 1. NACA 2415 flow lines (with a pitch angle of 0º)

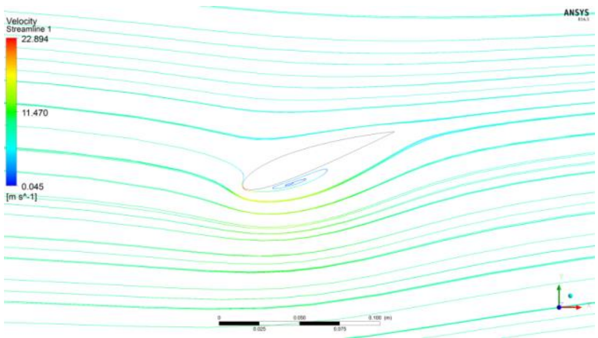

Fig 2. NACA 2415 flow lines (with a pitch angle of 20º)

Even an angular displacement of 5º affects the flow considerably. When the flow line right over the profile shown in Figure 3 is compared to the second line on the profile shown in Figure 4, the line runs more mildly at a pitch angle of 10o. Since the distances of the line in the profile outlet are identical, unlike uppoer zones, the characteristics are not glared.

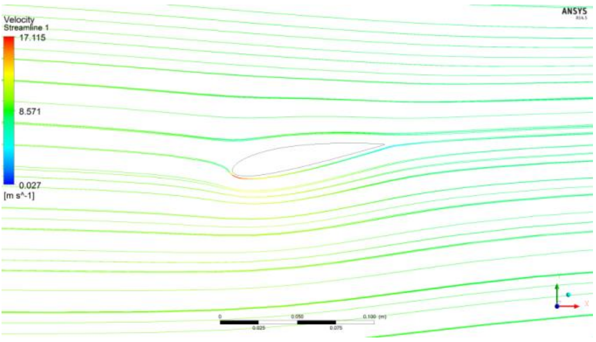

Fig 3. NACA 2415 flow lines (with a pitch angle of 10º)

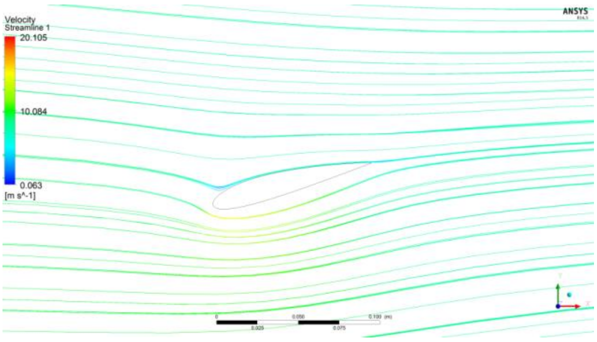

Fig 4. NACA 2415 flow lines (with a pitch angle of 15º)

III. Comparison of Velocity Zones

A velocity difference must occur in upper and lower surfaces of the wings to activate the rotor. In Figure 5, the velocity distribution is almost identical in the lower and upper zones of the profile axis. (Since the profile is not symmetrical, they are not the same completely.) In Figure 6, there is a considerable difference between these zones, and this shows that there is a movement [3].

The still zones with a pitch angle of 20º run along the lower surface. Size of this still zone increases a possibility of turbulence. If the flow is not interrupted at a pitch angle of 0º, this prevents expansion of the death zones. The more the pitch angle increases, the more area of the still zones increase.

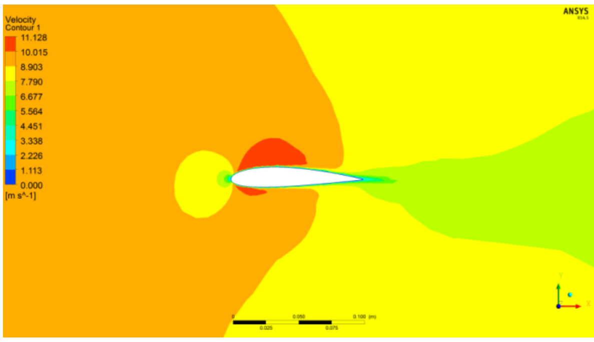

Fig 5. NACA 2415 velocity distribution (with a pitch angle of 0º)

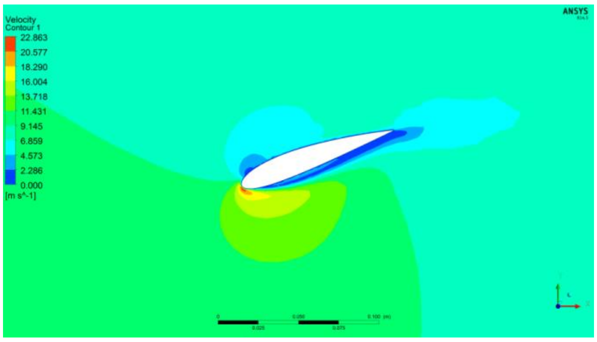

Fig 6. NACA 2415 velocity distribution (with a pitch angle of 20o)

The resultant velocity differences are considered in examining the velocity distribution of the pitch angles of 10º and 15º. In figure 7, this difference is 3 to 4 m/s, while the difference is 8m/s in the lower and upper zones shown in Figure 8. It is required that the velocity difference is large. But, as the velocity difference increases, the turbulence tendency shall also increase [5]. Here, the similarity is observed in end zones in front parts of the profiles. This area is an area marked by red and yellow colors, and the velocity difference is approximately 6m/s. Therefore, this zone is no affected excessively by minor changes in angles.

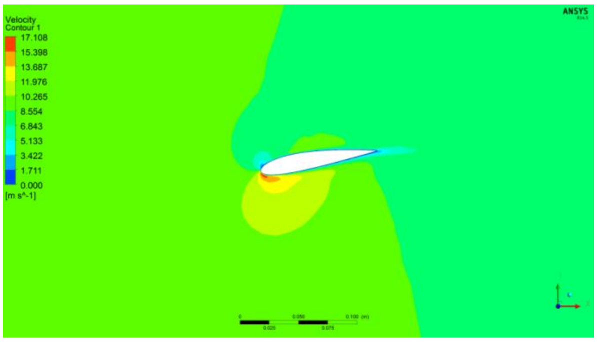

Fig 7. NACA 2415 velocity distribution (with a pitch angle of 10º)

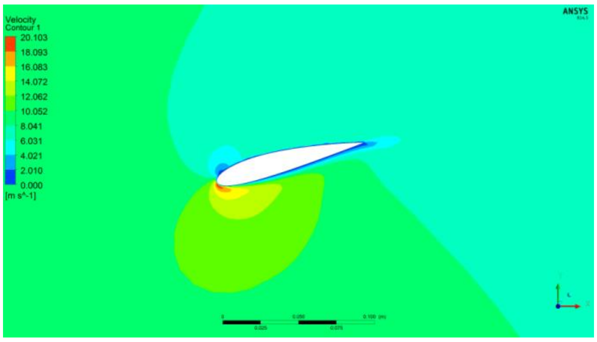

Fig 8. NACA 2415 velocity distribution (with a pitch angle of 15º)

IV. Comparison of Pressure Distribution

The velocity differences described above appear this time as the pressure differences. As a result of varying values of the velocities, any differences occur in pressures as well. In Figure 10, maximum pressure is dominant throughout the upper surface of the profile. In the lower surface, the pressure reduces to 14Pa. The required velocity difference is the same as the required pressure difference.

This is seen clearly in Figure 10. Conversely, such pressure differences are not observed in Figure 9 and most of the

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resultant pressures are in reverse direction. Its reason includes lower pressure zones created by the wind, which blows without any resistance. Reason of the reverse directional pressure occurred in Figure 10 is the fact that the wind collides to the wing and accelerates suddenly. As the pitch angle increase, intensity this sudden movement shall increase and thus, the negative pressure areas shall extend.

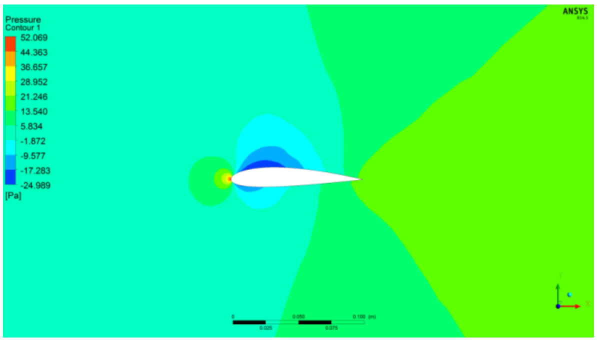

Fig 9. NACA 2415 pressure distribution (with a pitch angle of 0º)

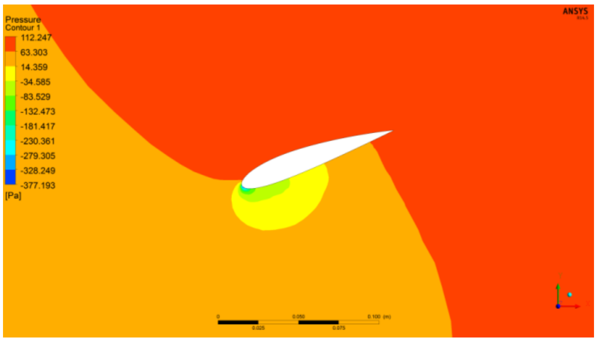

Fig 10. NACA 2415 pressure distribution (with a pitch angle of 20º)

When you look at the upper surfaces of the profiles, maximum pressures are 72Pa (orange zone) and 111Pa (red zone) in Figure 11 and Figure respectively. As the angle is increased by 5o, maximum pressure increases by approximately 39Pa. When you look at the lower zone, minimum pressures are 24Pa (yellow zone) and 39Pa (orange zone) in Figure 11 and Figure respectively. The pressure increase occurred due to an increase in the angle in the lower part is 15Pa. It is seen that the pressure increases occurred in the lower and upper parts are different. If they were not equal, the pressure difference would also be equal in both profiles and it would rotate the rotor at the same velocity [10]. If it is assumed that the wing having a pitch angle of 15o rotates faster, the pressure difference shall be larger respective to a pitch angle of 10o and therefore such differences appear between maximum and minimum pressures [6].

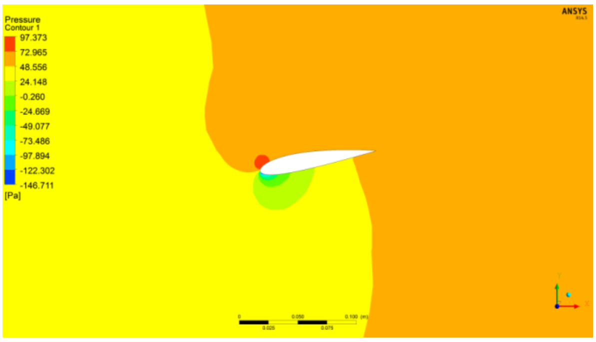

Fig 11. NACA 2415 pressure distribution (with a pitch angle of 10º)

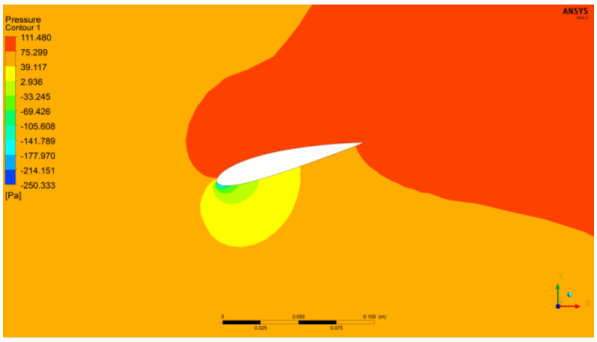

Fig 12. NACA 2415 pressure distribution (with a pitch angle of 15º)

V. Conclusion

In this study, flow, pressure and velocity distributions of the NACA2415 profile vs. pitch angle are examined. In this study, it is addressed that the control is very difficult and accurate.

In analyses done with angles of 0o and 20o, effects of the pitch angles are observed clearly. In analyses done with angles of 10o and 15o, it is concluded that even minor changes in angles may affect the characteristics of the turbine [8]. Another conclusion is the fact that an increase in angle is directly proportion to turbulence occurrence tendency.

The pitch control unit, which has a critical position and cost in the wind turbines, must be calculated and adjusted accurately [9]. As seen in the analyzes, as the pitch angles increase, the drift force shall increase as well. But, there is a limit in the pitch angles due to turbulences and this limit must be considered in design of the wind turbines.

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