Journal of Physics: Conference Series

Computational investigation of deploying microtabs on airfoil wortmann FX63-137

To cite this article: I K Wiratama *et al* 2021 *J. Phys.: Conf. Ser.* **1816** 012108

Computational investigation of deploying microtabs on airfoil wortmann FX63-137

I K Wiratama[1], G N K Yudhyadi[1], M A Sayoga[1], and M A Ramdani[1]

[1]Mechanical Engineering Department, University of Mataram, Lombok, West Nusa Tenggara, Indonesia

E-mail: kwiratama@tm.ftunram.ac.id

Abstract. Flow on the airfoil with deploying microtabs was performed to investigation aerodynamic performance airfoil modified with microtabs. Computer Fluid Dynamic (CFD) simulation has already been conducted to study the effects of heights deploying tab to the aerodynamic performance characteristics of airfoil sections. The aim of this study was performed to determine the effect of tab heights under variations of angle of attack againt the behaviour of stall airfoil and determine the effect of tab heights on the lift coefficient (CL) and drag coefficient (CD) on tab heights of 1.1% C, 2,2% C and 3.3% C for upper and lower surfaces airfoil. The angle of attach airfoil was from -4^o to 32^o with interval 2^0. From the results of CFD simulations showed that the addition of microtabs on the airfoil Wortmann FX63-137 for the lower surface had the effect of increasing the lift force and lift coefficient, the increase occurred consistently and stall occurred at an angle of 26^o for tab heights of 1.1% C and 2,2%C while the tab height of 3.3% C a stall occurred at an angle of 20^o. For upper surface, microtabs caused a decrease in lift force and stalls occurred at angle of 22^o for all tab heights. The drag coefficient also increased under the increasing angle of attack with highest value was at tab height of 1.1% C of 2.542 and an angle of attack of 28^0, while on the lower surface the largest drag coefficient was at a tab height of 3.3% C of 2.73.

1. Introduction

The most important aspect when a wind turbine operation is its aerodynamic performance, which is based on the use of the type airfoil in the design wind turbine blades. Several series airfoils have been used for the design wind turbine blades, such as the National Advisory Committee on Aeronautics (NACA) airfoils, the National Renewable Energy Laboratory (NREL) airfoils and the Solar Energy Research Institute (SERI) airfoils.The airfoil series have been extensively modified in order to incorporate various active control systems, such as the modification airfoil with aileron, flaps and microtabs, into design of wind turbine blades [1, 2, 3, 4].

This paper introduces the use of modified airfoils with microtabs as an active control system. The use of active control systems as a means of regulating large-scale wind turbine power has been widely used while operating at high wind speeds [5] and [6]. The application of an active control system is very useful for large-scale wind turbines considering its function as power regulation also functions for load regulation or reduction of loading forces due to aerodynamic forces when wind energy is converted by the rotor at wind turbine blades [2, 5].

To improve the aerodynamic performance of wind turbines, one of the simple devices that can be effectively used as an active control system is microtabs, by placing tabs on the airfoil surface near the trailing edge. [7, 8, 9] conducted a lot of initial research related to the early development of the microtabs concept. In his research, she conducted a computational study and wind tunnel testing by modifying the GU25-5 airfoil where the microtabs were placed on the lower surface of the airfoil. Additionally, 2-D infinite span models focus on 3-D microtabs with finite width and gaps. The promise and benefits of microtabs in terms of lift augmentation without significant drag penalties were immediately apparent from her work. The [10] continued their research by studying very comprehensively on 2-D computational by examining the tab height and tab location on the upper and lower surface of the S809 and the GU25-5 airfoil. The [11] performed computational investigated the 3-D effect microtabs by modelling finite width microtabs on semi-infinite wing, the results showed that the reduced tab effectiveness as gap size increased.

The combination of computational studies and experimental validation has provided confidence in understanding the behaviour of microtabs in which the microtabs provides the aerodynamic effect needed as an active control system device without technological obstacles in the application of a microtab-based load control system. The aim of this study was to carry out computational investigations to analyze the aerodynamic performance of Wortmann FX63-137 airfoils modified by microtabs where the variation of tab heights were modelled of 1.1% C, 2.2% C, 3.3% C for lower and upper and under variations in angle of attack from -4^0 to 32^0 at intervals of 2^0. The investigation used the same methodology that presented in previously studies by [11] and [12].

2. Method

The investigation of computational deploying microtabs was simulated using Autodesk Computational Fluid Dynamic (CFD). The purpose of this study is to determine the effect of variations tab heights under variations angle of attack on the behaviour of stall airfoil and determine the effect of tab heights on the lift coefficient (CL) and drag coefficient (CD) with tab heights of 1.1% C, 2,2% C and 3.3% C in the upper and lower surfaces.

In this study, airfoil was modified by adding microtabs type solid tab. Tab height for upper surface and lower surface airfoil were similar by variation tab heights of 1.1% C, 2,2% C and 3.3% C for both surface and angle of attach airfoil from -4^o to 32^o by interval 2^0.

2.1. Design airfoil

Geometry data of airfoil Wortmann FX63-136 was inserted into Autodesk Inventor 2019 software to design airfoil. After forming an airfoil, then drawing a microtab on the lower surface or upper surface airfoil, the next step was to extract 1 m with solid tab as shown in Figure 1 and 2.

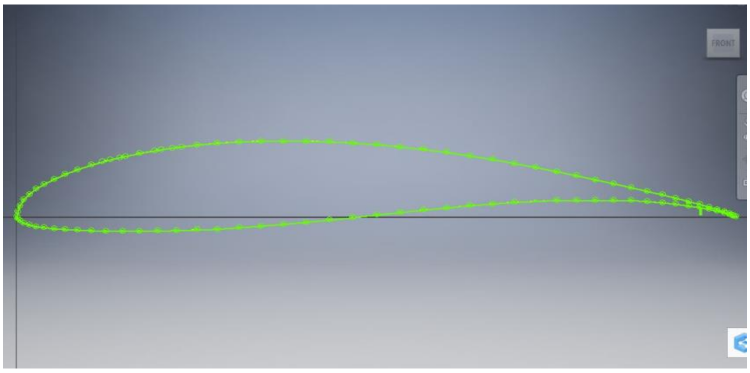
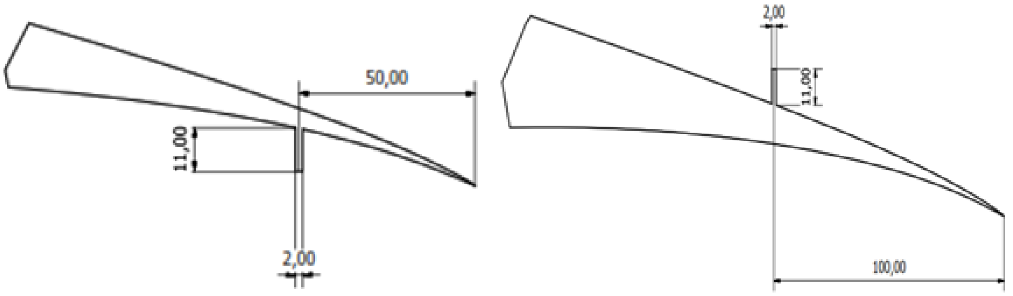


Figure 1. Airfoil modified microtabs



(a) (b)

Figure 2. Detail tab location (a) tab lower surface , (b) tab upper surface.

2.2. Flow solver

The size of external volume refers to the research of [13] was adopted where the recommended provision was 5C from the leading edge to the inlet, from the top of external volume to the upper surface airfoil, from the lower surface airfoil to the bottom of the external volume, and 10C from the trailing edge to outlet external volume. In this boundary condition it consisted of the inlet and outlet as well as wall, the inlet contains the wind speed, because in this simulation the variable being varied was the Reynolds Number in which the air speed must be calculated and all solid boundaries were maintenance as viscous walls.

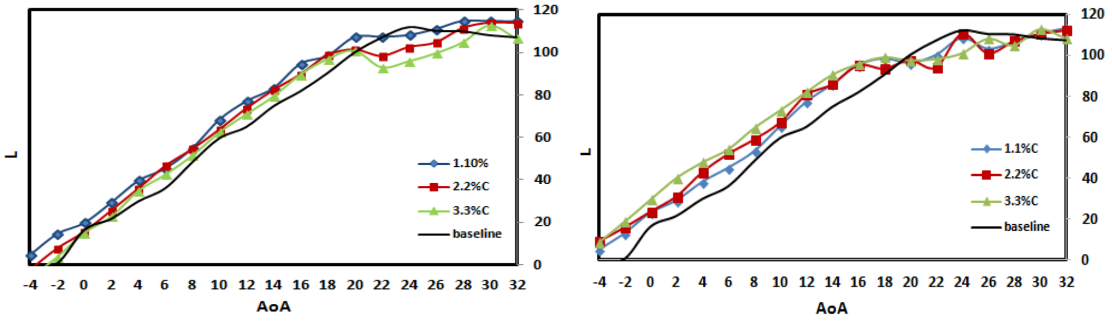
In order to gain the regions and the wake where high gradient were expected to refine mesh, it was important to identify the mesh regions where the results have to be quite accurate. The computation was conducted fully turbulent. A three-dimensional and steady state simulation were conducted with a structured finite-volume flow solver using Reynolds averaged Navier–Stokes (RANS) equations. The shear stress turbulence (STT k-ω) model developed by [14] was employed in computation for each cases, it was superior to separate flow performance as reported by [15] and [16].

3. Result and discussion

The computational study has been conducted to investigate aerodynamic performance airfoil on the various tab heights. The organized of this section are as follow: first part explains about the effect of heights, and second part of this section explains about analysing of aerodynamic characteristic airfoil modified microtabs.

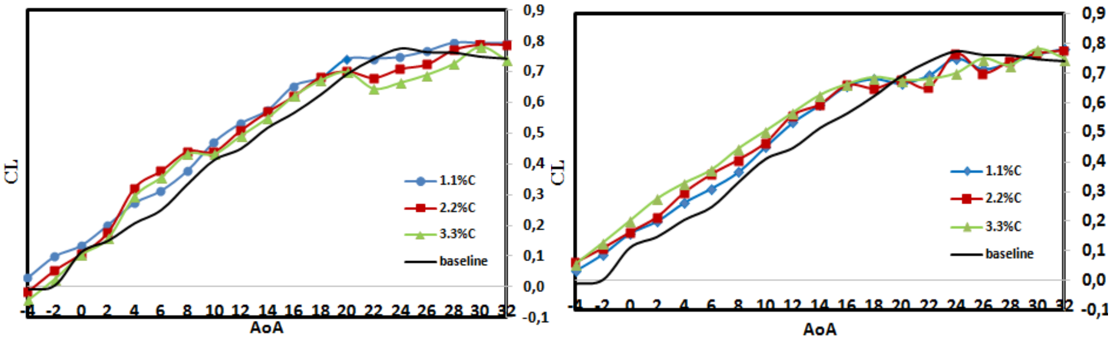
3.1. The effect of variation tab heights

From the results simulation with a wide of variation tab heights of 1,1% C, 22% C and 3,3% C for upper surface and lower surface by using SST k-omega turbulence model, the lift and drag force were obtained. The lift and drag force that occurred due to the difference in flow velocity at the upper and lower airfoil, the difference in flow velocity caused a difference in pressure at the upper and lower airfoil refer to throuh of Figure 8 to 12.



(a) (b)

Figure 3. Comparison lift force of baseline (airfoil without tab) and variation tab heights versus angle of attacht for (a) tab upper surface and (b) tab lower surface

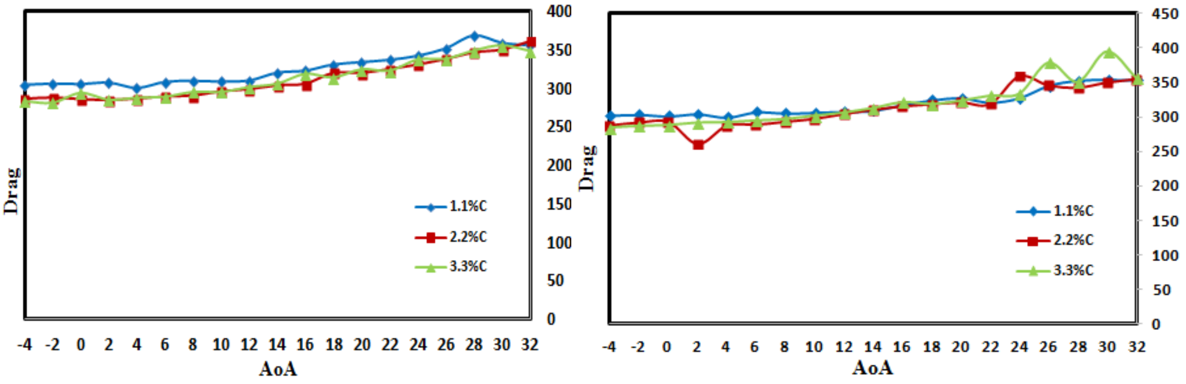


(a) (b)

Figure 4. Comparison lift coefecient of baseline (airfoil without tab) and variation tab heights versus angle of attacht for (a) tab upper surface and (b) tab lower surface.

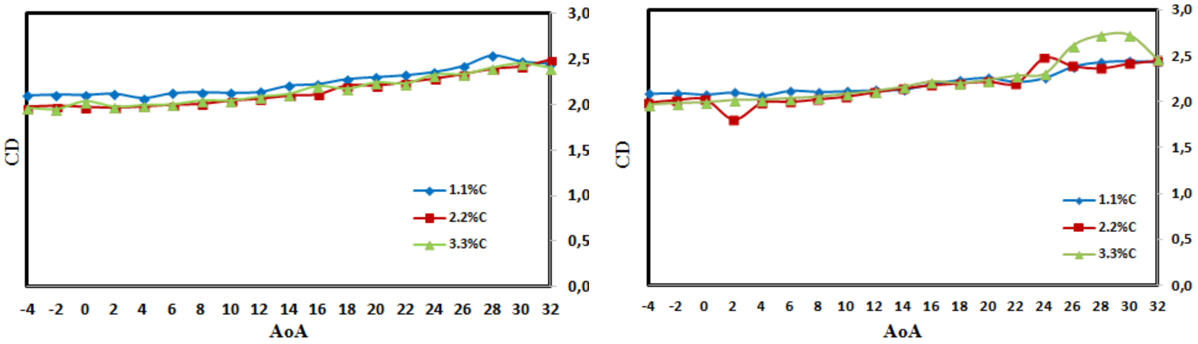
The Figure 3 shows that the comparison of lift force and angle of attack by adding tab on the lower surface causes an increase lift force while the upper surface is lower lift force when compared to baseline. This condition was due to the fact that the angle of attack used was in a positive direction so that the effect of variations in tab height on changed in lift force was not visible on the upper surface when compared to the simulation results on the lower surface. In the Figures 3 and 4 of the three variations tab height for tab placement on the upper surface or lower surface, the lowest lift force and lift coefficient occur at the same angle of attack at an angle of -4^0 while the highest lift force and lift coefficient occur at an angle of attack from 28^0 to 32^0, and the stall occurs at an angle of attack of 24^0 for the tab location on the upper surface and angle of attack of 20^0 and 26^0 for the lower surface.

The addition of microtabs for the lower surface has the effect on the increasing of the lift force and the lift coefficient at tab heights of 1.1% C, 2.2% C and 3.3% C, the increasing is consistent and the stall point occurs at an angle of attack of 26^0 for tab heights of 1.1% C and 2.2% C as well as the tab height of 3.3% C the stall occurs at an angle of attack of 20^0. On the upper surface, the addition of microtabs causes a decrease in lift force when compared to the lower surface and the stall occurs at an angle of attack of 22^0 for all of the tab heights, therefore the best of tab height for the lower surface is 1.1% C because it has the largest L/D ratio of 0.321 at an angle of attack of 24^0 and for the upper surface the best of tab height is 3.3% C because the L/D ratio of all heights is the smallest at the peak point of 0.302 that refer to the Figure 7.



(a) (b)

Figure 5. Comparison drag force of variation tab heights versus angle of attacht for (a) tab upper surface and (b) tab lower surface.

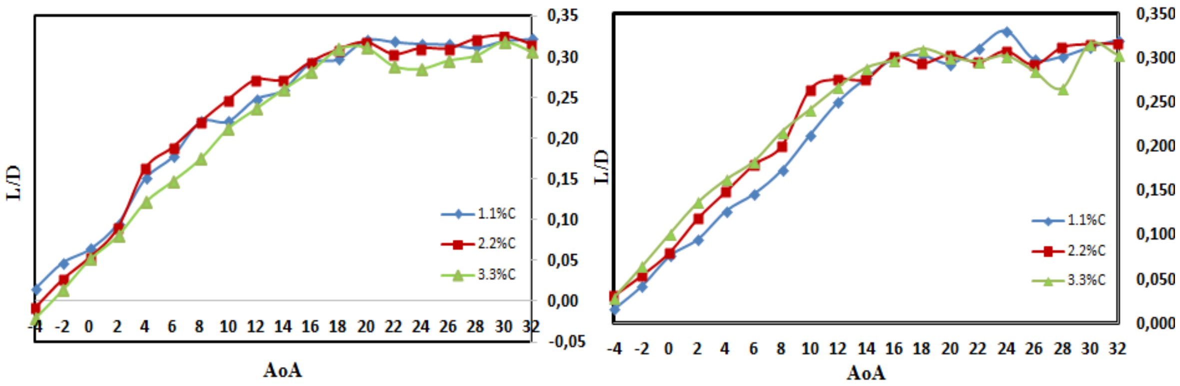


(a) (b)

Figure 6. Comparison drag coeffecient of variation tab heights versus angle of attacht for (a) tab upper surface and (b) tab lower surface.

According to the Figure 5, the addition of tabs on the upper surface or lower surface affects the aerodynamic performance of airfoil where the drag force increases with the increasing angle of attack for the tab location on the upper surface or lower surface but the higher the tab, the drag force that occurs tends to increase on the lower surface and decreased on the upper surface, meanwhile, the Figure 6 shows the drag coefficient on the upper surface and lower surface also increases with the increase in angle of attack. The largest drag coefficient is at tab height of 1.1% C for an upper surface of 2.542 at an angle of attack of 28^0, while on the lower surface the largest drag coefficient is at a tab height of 3.3% C of 2.73.

Aerodynamic performance of airfoil can be measured from the amount of lift/drag ratio, [17]. According to the Figure 7, it can be seen that on the upper surface the L/D ratio is maximum for all tab heights lies at the angle of attack of 20^0 at this point the amount of the maximum lift force and the amount of the drag force are not too large, then at the angle of attack of 22^0 the amount of L/D decrease. It shows that at angle of attack there is a stall phenomenon due to the occurrence of space on the upper surface of the airfoil because the air flow is released. Whereas on the lower surface for tab height 1.1% C of L/D maximum at 24^0 angle of attack, tab height 2.2% C of L/D maximum at 20^0 angle of attack, and tab height of 3.3% C of L/D maximum at angle of attack 18^0. The difference in stall position that occurs is due to differences in the area affected by air flow from each chord, this condition is greatly influenced by air velocity and pressure where the air velocity on the upper surface is high, the pressure becomes low and vice versa at the same time the air velocity on the part lower surface is low but the pressure becomes high, [17]. Therefore the best tab height for the lower surface is 1.1% C because it has the largest L/D ratio of 0.321 at 24^0 angle of attack and for upper surface the best tab height is at 3.3% C because the L/D ratio of all elevations is at its lowest at 0.302



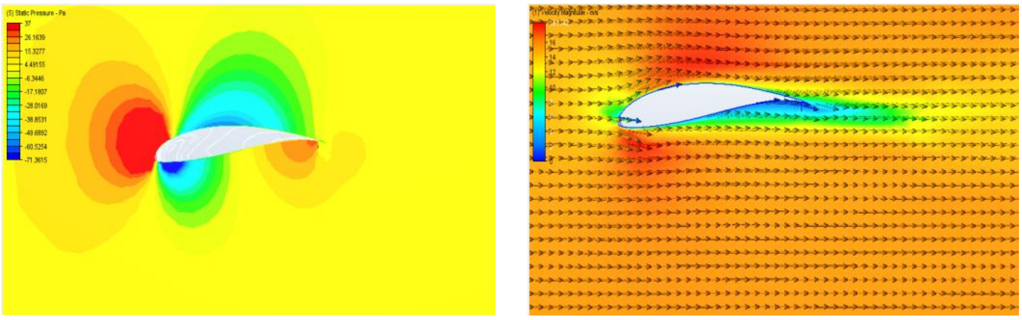
(a) (b)

Figure 7. Comparison ratio lift and drag force of variation tab heights versus angle of attacht for (a) tab upper surface and (b) tab lower surface

3.2. Aerodynamic analysis

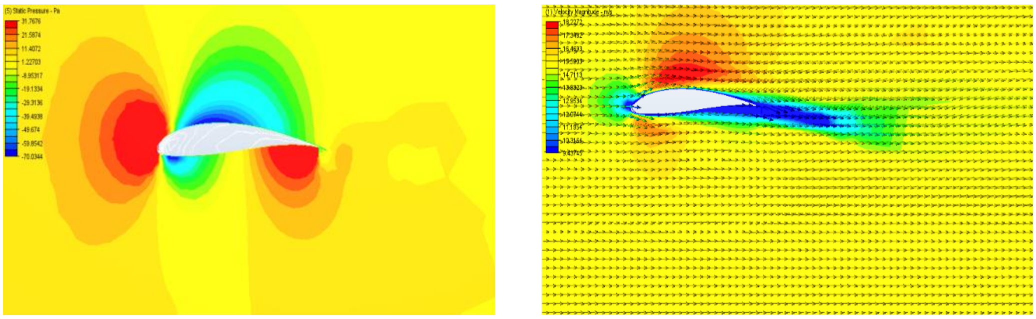
CFD is usefully simulation tool that can provide more detailed insight into the flow phenomena that govern a problem airfoil modified with mirotabs. The comparison of pressure distribution and velocity contour at lower surface are shown on through of the Figure 8 to 12. From those figures show that the change of pressure distribution and velocity contour have correlation under the change in angle of attack and the presence of microtab.

According to through of the Figure 8 to 10, it is clearly that angle of attack airfoil of 0^0 obtained the contours of static pressure over aerofoil is obviouslly symmetrical for upper and lower surface as well as the nose of airfoil is stagnation. Therefore, there are no created pressure different between two surface of airfoil while angle of attactt of airfoil of -4^0 and 4^0 create similar behaviour as angle of attackof 0^0 in static pressure and stagnation point at nose airfoil.



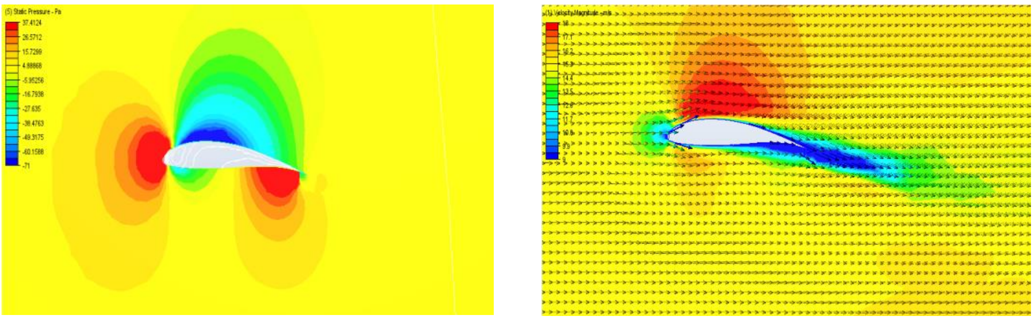
(a) (b)

Figure 8. (a) pressure contours and (b) velocity vector, on an airfoil modified with tab height of 3,3% C lower surface on angle of attack -4^0.



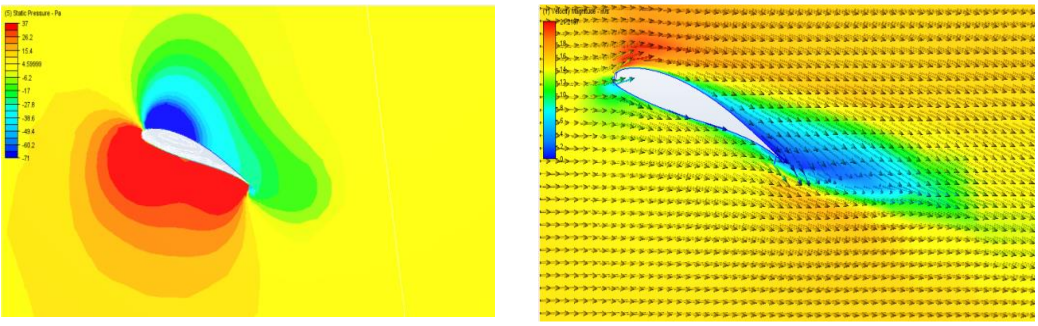
(a) (b)

Figure 9. (a) pressure contours and (b) velocity vector, on an airfoil modified with tab height of 3,3% C lower surface on angle of attack 0^0.



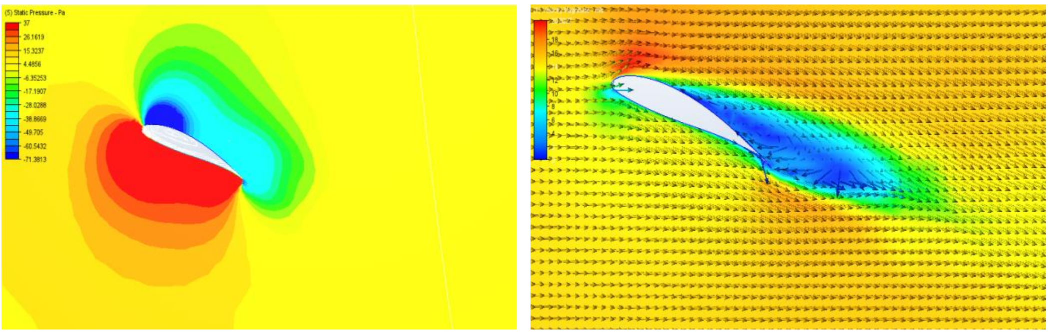
(a) (b)

Figure 10. (a) pressure contours and (b) velocity vector, on an airfoil modified with tab height of 3,3% C lower surface on angle of attack 4^0.



(a) (b)

Figure 11. (a) pressure contours and (b) velocity vector, on an airfoil modified with tab height of 3,3% C lower surface on angle of attack 20^0.



(a) (b)

Figure 12. (a) pressure contours and (b) velocity vector, on an airfoil modified with tab height of 3,3% C lower surface on angle of attack 22^0.

The Figure 11 and 12 show that the pressure distribution on over airfoil varied largely under highly angle of attack. The streamline and velocity countour with deploying microtabs produces a recirculation suction area on the lower surface near the trailing edge. This suction area enhances the flow pattern over the upper surface, changes the effective camber line, and affecs the pressure distribution. The results of pressure coefficient show that tabs located on the pressure side (lower surface) they can produce an increase in lift force while tabs located on the suction side (upper surface) generate a decrease in lift force.

4. Conclusion

The computational investigation has been carried-out. Based on the results of analysis that have been discussed previously, the following conclusions can be obtained: The addition of microtabs at the airfoil Wortmann FX63-137 for the lower surface has the effect on the increasing of the lift force and the lift coefficient at tab heights of 1.1% C, 2.2% C and 3.3% C, the increasing is consistent and a stall occurs at an angle of attack of 26^0 for tab heights of 1.1% C and 2.2% C. For the tab height of 3.3% C the stall occurs at an angle of attack of 20^0. On the upper surface, the addition of microtabs causes a decrease in lift force when compared to the lower surface and the stall occurs at an angle of attack of 22^0 for all of the tab heights, therefore the best of tab height for the lower surface is 1.1% C because it has the largest L/D ratio of 0.321 at an angle of attack of 24^0 and for the upper surface the best of tab height is 3.3% C because the L/D ratio of all heights is the smallest at the peak point of 0.302. For the drag coefficient where the drag coefficient also increases with the increasing angle of attack, the largest drag coefficient is at tab height of 1.1% C for an upper surface of 2.542 at an angle of attack of 28^0, while on the lower surface the largest drag coefficient is at a tab height of 3.3% C of 2.73.

Acknowledgments

The first author thanks to the Ministry of Research, Tech., and Higher Education of the Republic of Indonesia for the financial support of this research grant and paper through The Grant 2020

References

[1] Wiratama I K 2014 Validation of AWTSim as aerodynamic analysis for design wind turbine blade *Journal Applied Mechanics and Materials* **493** 105-110

[2] Wiratama I K and Maheri A 2014 Optimal design of wind turbine blades equipped with flaps. *Journal of Engineering and Applied Science* **9** 1511-1515

[3] Wiratama I K and Satiawan N W 2015 Optimization of distribution microtabs on re-design blade wind turbine AWT-27 *The 14th Int.Conference on Quality in Research, 10-13 August, Bali, 398-404.*

[4] Wiratama I K, Mara I M, and Nuarsa I M 2016 Investigation of factors affecting power curve wind turbine blade *Journal of Engineering and Applied Science* **11** 1819-6608

[5] Gamiz U F, Zulueta E, Boyana A, Hernanz J A and Guede J M 2017 Microtabs design and implementation on a 5 MW wind turbine *Journal Applied Science*. **7** 2-18

[6] Wiratama I K 2012 Aerodynamic design of wind turbine blades utilising nonconventional control systems *Dissertation Northumbria University*

[7] Yen D T, van Dam, C P, Brauchle F, Smith R L, and Collins S D 2000 Active load control and lift enhancement using MEM translational tabs *AIAA Paper 2000–2422 June 2000*

[8] Yen-Nakafuji D T, van Dam C P, Smith R L, and Collins S D 2001 Active load control for airfoils using microtabs *Journal of Solar Energy Engineering* **123** 4: 282-89

[9] Kelling F H 1968 Experimental investigation of a high-lift low-drag aerofoil *ARC CP 1187 GU Aero Report 6802*

[10] Standish K J 2003 Aerodynamic analysis of blunt trailing edge airfoils and a microtab based load control system *M.S Thesis University of California*

[11] Mayda E A, van Dam C P and Yen-Nakafuji D T 2005 Computational investigation of finite width microtabs for aerodynamic load control *AIAA-2005-1185*

[12] Satiawan N W, Citarsa B F, Wiryajati I K and Wiratama I K 2015 An analysis of voltage space vectors utilization of various PWM schemes is dual-inverter FED five-phase open-end winding motor drives *International Journal of Technology* **6** 1031-1041

[13] Maia R S, and Junior M N, 2016 Development of a numerical methodelogy for the analysis of aerodynamics surface. *In. Proc.of the XXXVII Iberian Latin-American Congress on Computational Methods in Engineering Suzana Moreira A´vila (Editor),* 6-9 November. ABMEC, Braslia, DF, Brazil

[14] Menter F R 1993 Zonal two equation k-w turbulence models for aerodynamic flows. In Proc.of the 23rd Fluid Dynamics, Plasma dynamics, and Lasers Conference, Fluid Dynamics and Co-located Conferences *American Institute of Aeronautics and Astronautics*, 6–9 July, Orlando, FL, USA

[15] Kral L 1998 Recent experience with different turbulence models applied to the calculation of flow over aircraft components *Prog. Aerospace Science* **34** 481–541.

[16] Gatski T B 2002 Turbulence modelling for aeronautical flows. vol. VKI Lecture Series: CFD-Based Aircraft Drag Prediction and Reduction *von Karman Institute for Fluid Dynamics: Brussels, Belgium*

[17] Yao J, Yuan W, Wang J, Xie J, Zhou H, Peng M, And Sun Y 2012 Numerical simulation of aerodynamic performance for two dimensional wind turbine airfoils *Int. Conference on Advances in Computational Modelling and Simulation Procedia Engineering* 80 – 86