# 3.Analysis Aerodynamic Performance Airfoil

*by* I Satiawan

# Analysis Aerodynamic Performance Airfoil WORTMANN FX63-137 in Different Reynolds Number

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**Abstract.** The investigation of flow behavior on the upper and lower surface airfoil was performed to know aerodynamic behaviors of airfoil in different Reynold Number. The more flexible simulation by using Computer Fluid Dynamic (CFD) has been used to analyze the behavior of flow which was addressed to application wind turbine blade in low Reynold Number. The aim of study was conducted to know the effecting of the stall behavior airfoil and parametric aerodynamic such as Lift Force (L), Drag Force (D), Lift Coefficient (CL), Drag Coefficient (CD), Lift Force over Drag Force (L/D) on various Reynold Number from $2{,}5 \times 10^5$, $5 \times 10^5$, $7{,}5 \times 10^5$ to $10^6$. From the result simulation, it was found that the stall behavior for each Reynolds Number was at the same angle of attack, which was 24°. While the lift and drag forces are influenced by the Reynolds Number as the Reynolds Number getting bigger, the lift and drag forces increased. However, Reynolds Number did not affect the increase in the lift coefficient, drag coefficient, and L/D.

**Keywords:** Reynold Number · Angle of Attach · Stall · airfoil

## 1 Introduction

Air flow passes through the airfoil cross section will be a difference air flow velocity on upper surface and lower surface airfoil. The air velocity passes upper surface airfoil tends to be faster than lower surface airfoil [1]. Airfoil is such an aerodynamic shape that when air approach and moves through airfoil cross section, air velocity is split and passes upper and lower surface airfoil. An airfoil is a body of such a shape that when it is placed in an air stream, it produces an aerodynamic force. This force is used for different purposes such as the cross sections of wings, propeller blades, wind turbine blades, compressor and turbine blades in a jet engine, and hydrofoils are examples of airfoils [2, 3].

This paper introduces the behaviors of airflow passes airfoil cross section which in the produce aerodynamic performance in different Reynold Number especially in stall condition. The using of airfoils has been widely used especially in the design of wind turbine blade which is need for operational in low Reynold Number. The important


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aspect as the wind turbine operation is its aerodynamic performance, which is based on type of airfoils in use [4, 5]. According to [1], airfoil performance can be measured by the magnitude of the lift/drag ratio which the L/D ratio is the ratio of lift and drag [1, 6] conducted a computational investigation of the inviscid flow on the airfoil using the Ansys software with the NACA 4412 and Wortmann airfoil which was analyzed in 2 dimensions, the goal is to get the airfoil surface pressure distribution as the magnitude of the lift and drag forces generated by the computational method is in accordance with the results of experimental analysis. [7] performed a computational analysis using the NACA 0015 airfoil at a wind speed of 17 m/s. The results show that the lift and drag coefficients increase along with the increase in the angle of attack and the stall phenomenon occurs at an angle of attack of 16° which is the optimum value of the lift coefficient at that angle. [6] conducted a computational analysis using the SST k-ω turbulence model to determine the use of multi airfoil in the blade design on the aerodynamic efficiency of the MW scale wind turbine blades by comparing the simulation results with experiments showing a correlation between numerical and experimental approaches to lift coefficients at angle of attack from −2° to 3° which is the normal operating angle of attach wind turbine blade. [8] investigated the external volume determination on CFD using type O, with the provision that the airfoil distance to the outer boundary of the mesh is 30 chords in a circle where the position of the airfoil is at the centre of the circle. From the results of the simulation carried out, that with the size of the external volume the simulation data is close to the results from the experimental.

The combination of computational studies and experimental validation has provided confidence in understanding the behaviour of flow on the airfoil section in which able to analyses the aerodynamic effect needed in the application of design wind turbine blade. The aim of this study was to know the effecting of the stall behavior airfoil and parametric aerodynamic such as Lift Force (L), Drag Force (D), Lift Coefficient (CL), Drag Coefficient (CD), Lift Force over Drag Force (L/D) on various Reynold Number from $2{,}5 \times 10^5$, $5 \times 10^5$, $7{,}5 \times 10^5$ to $10^6$. The investigation used the same methodology that presented in previously studies by [1].

## 2 Method

The investigation of behavior flow on the airfoil cross section was simulated by computational fluid using Autodesk Computational Fluid Dynamic (CFD). The purpose of this study is to analyses aerodynamic performance such as Lift Force (L), Drag Force (D), Lift Coefficient (CL), Drag Coefficient (CD), Lift Force over Drag Force (L/D) in different Reynold Number especially in stall condition. The various of Reynold Number was from $2{,}5 \times 10^5$, $5 \times 10^5$, $7{,}5 \times 10^5$ to $10^6$.

### 2.1 Design Airfoil

Geometry data used airfoil Wortmann FX63-136 and it was inserted into Autodesk Inventor 2019 software to make of shape profile an airfoil. The design process starts from connecting the points that have been formed from imported excel data using the line feature, after forming an airfoil, the next step is to extrude 1 m long.

### 2.2 Flow Solver

By adopting to the research of [1, 9, 10], the dimensions size of external volume was setted where it was the recommended that size of external volume was 5 C 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 10 C from the trailing edge to outlet external volume. In this boundary condition, it consisted of inlet, outlet and wall. The inlet contains wind speed, because in this simulation the variable varied was Reynold Number therefore air velocity must be calculated. It was critical to identify the mesh regions where the results had to be quite accurate in order to gain the regions and the wake where high gradient were expected to refine mesh. The computation was carried out in full turbulent mode. A three-dimensional and steady-state simulation was performed using Reynolds averaged Navier-Stokes (RANS) equations and a structured finite-volume flow solver. The shear stress turbulence (STT k-) model developed by [11] was used in each case's computation because it outperformed separate flow performance as reported by [12] and [13].

## 3 Result and Discussion

The computational study was conducted to explore the flow behavior and aerodynamic performance of an airfoil at various Reynolds Numbers. This section is arranged as follows: the first part describes assessing aerodynamic performance airfoil, and the second part explains analyzing aerodynamic characteristic airfoil.

The lift and drag force were obtained by using Computational Fluid Dynamic with a wide range of Reynold Numbers ranging from $2{,}5 \times 10^5$, $5 \times 10^5$, $7{,}5 \times 10^5$ to $10^6$ for the top and lower surfaces by using the SST k-omega turbulence model, are depicted in Figs. 1, 2, 3, 4 and 5.

According to Figs. 1 and 2 show that the lift force and lift coefficient from an angle of attach $-4^\circ$ to $22^\circ$ increase and a decrease in the lift force and lift coefficient from angle of attack of $24^\circ$ to $30^\circ$. From those graphs, it can be seen that the Reynolds number affects the increase in the lift force and lift coefficient because the Reynold number is

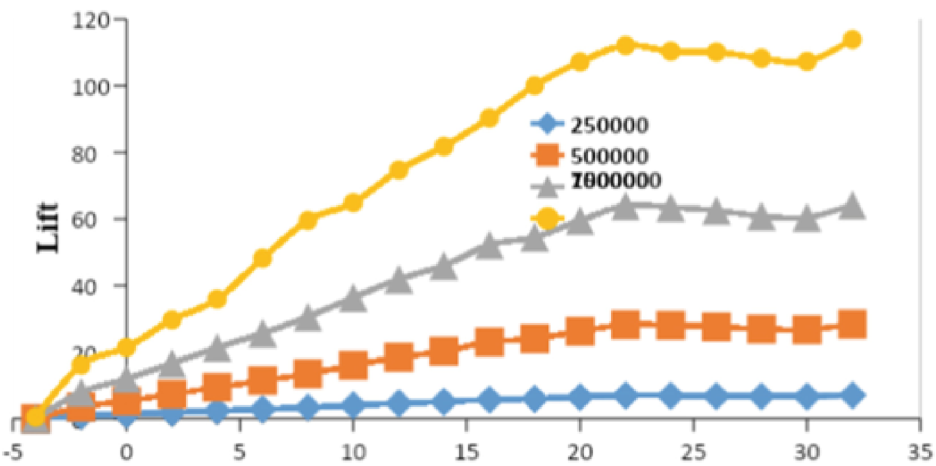


**Fig. 1.** Comparison lift force versus angle of attack on variation Reynold Number

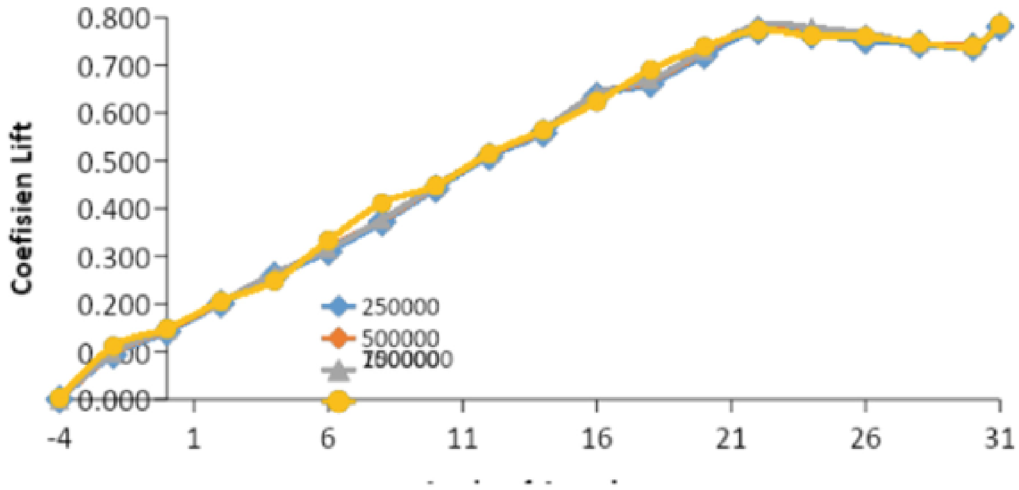


**Fig. 2.** Comparison lift coefficient versus angle of attack on variation Reynold Number.

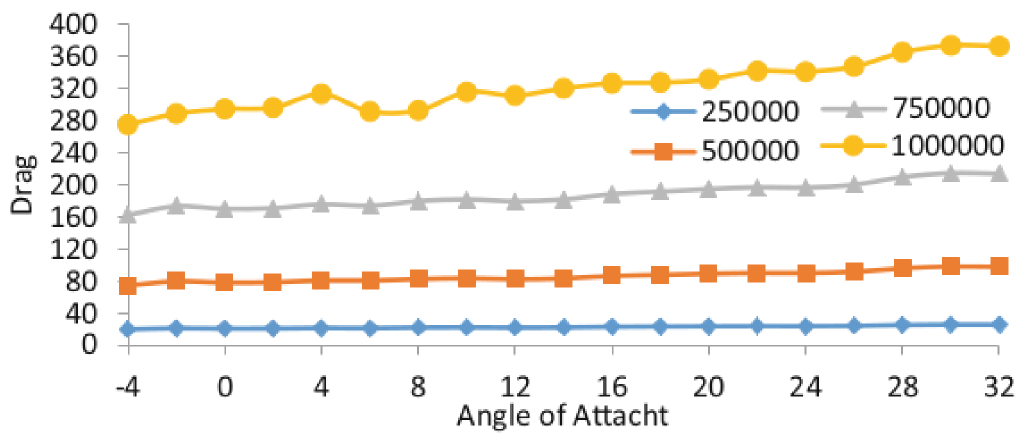


**Fig. 3.** Comparison drag force versus angle of attack on variation Reynold Number.

a function of air velocity so that when the Reynolds number is high, the velocity of the air passing through the airfoil will also be high.

Figures 3 and 4 show the drag force and drag coefficient at various Reynold Numbers is increase along with the increase in the angle of attack, because the higher the angle of attack there is an increase in the area of the collision area in the X direction between the air and the airfoil which causes a collision load between Front airflow with the airfoil is getting bigger which results in a large front airfoil pressure distribution. The Reynolds Number greatly affects the increase in drag force, the greater the Reynold Number of airflow, the greater the velocity of the airflow that will hit the airfoil so that it will increase the force received by the airfoil which causes the reaction of the airfoil to be greater which is equal to the force received by the airfoil especially at an angle of attack of 30°.

Based on Fig. 5 shows that all Reynolds numbers are at an angle of attack of 220, the optimal lift force is obtained and the value of the drag force is not too large, then the graph shows a decrease in the value of L/D, namely at an angle of attack of 240 where at this angle there is a stall phenomenon caused by the occurrence of separation at the upper rear due to airflow being released due to an increase in the angle of attack

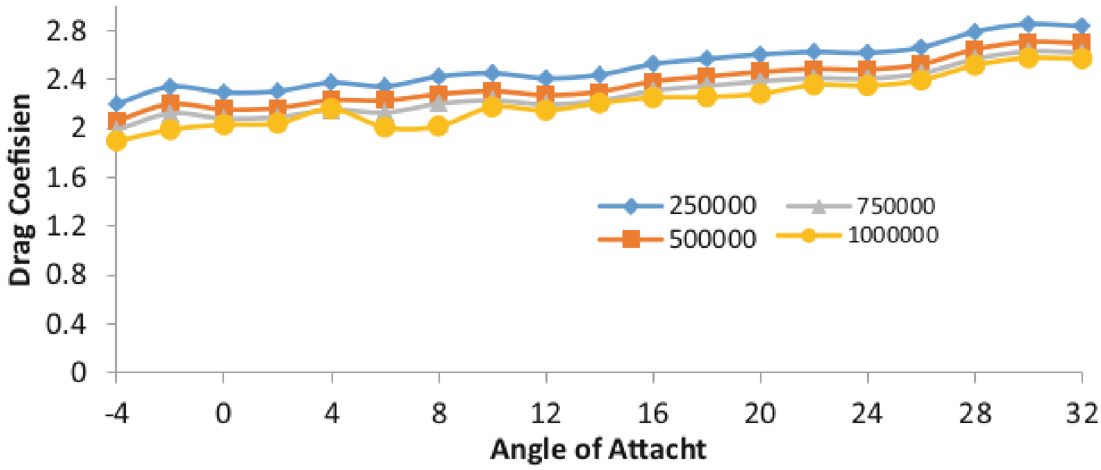


**Fig. 4.** Comparison drag coefficient versus angle of attack on variation Reynold Number.

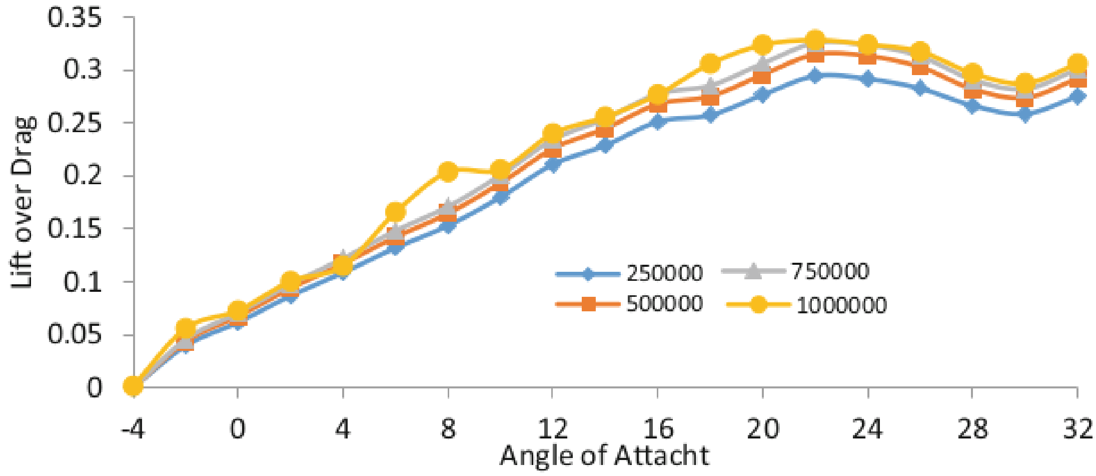


**Fig. 5.** Comparison lift over drag force versus angle of attack on variation Reynold Number.

which causes a decrease in speed followed by an increase in pressure at the top of the airfoil which results in a decrease in lift force and an increase in drag force. The stall phenomenon occurs because the negative pressure gradient will cause a tendency for the boundary layer to separate from the airfoil surface.

## 4 Conclusion

According to the above figures the following conclusion can be drawn:

1. All simulated Reynold numbers do not affect the stall point of the Wortmann FX63-137 airfoil even though the Reynold number is changed, the stall angle is at an angle of attack of 24°.
2. Reynolds Number greatly affects the increase in lift and drag forces, the greater the Reynolds Number, the higher the lift and drag forces and vice versa. While the Reynolds Number affects the decrease in the drag coefficient where the greater the

Reynold Number, the lower the drag coefficient is different from the lift coefficient and L/D does not really affect the increase in the Reynold Number.

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