DETERMINATION OF STALLING REGION FOR SPECIFIC TURBINE BLADE'S PROFILE

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**This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Thermal-Fluids) with Honours.**

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Determination Of Stalling Region For Specific Blade Profile" is the result of my own work except as cited in the references

Signature	**:**	**..**
Name	**:**	Muhammad Syahzani Bin Kamaruddin
Date	**:**	**...**

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids) with Honours.

Signature :. ....

Name of Supervisor: Dr. Yusmady Bin Mohamed Arifin

Date : ....

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DEDICATION

To my beloved mother and father, supervisor, and friends.

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ABSTRACT

Stalling is the phenomena that always happened at the blade profile or airfoil. There is some consideration that need to be taken to curb the stalling phenomena happened to the blade profile such as the blade profile shape, the inlet velocity, and the angle of attack (AOA) for the blade profile. Stalling happened when there is a separation flow at the upper chamber and lower chamber of the blade profile. The separation flow will produce a turbulence flow when it passed the trailing edge of the blade profile. When the region of turbulence flow become larger, the lift coefficient starts to decrease thus, the blade profile had faced the stalling phenomena. The main objective for this study is to find the stalling region for NACA 8415 blade profile at the various angle of attack. This study used computational fluids dynamics (CFD) approach to determine the stalling region. The software that had been used to make the computational fluids dynamics simulation is ANSYS fluent 17.1 version. The analysis for this study only focusing on 2-dimensional analysis geometry only. The fluid is hot air and the inlet velocity is 680m/s at 500°C. The coefficient of lift and drag had been obtained from the CFD simulation and the coefficient of lift and drag vs angle of attack (AOA) had been plotted. From the finding it had been found that the coefficient of lift starts to decrease at the angle of 15°. Thus, the stalling region will be started at angle of 15°.

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ABSTRAK

Pegun adalah fenomena yang sentiasa berlaku pada profil bilah. Terdapat beberapa pertimbangan yang perlu diambil untuk membendung fenomena pegun yang berlaku pada profil bilah seperti susuk bentuk bilah, halaju masukan, dan sudut serangan untuk profil bilah. Pegun berlaku apabila terdapat aliran pemisahan di ruang atas dan ruang bawah profil bilah. Aliran akan dipisahkan apabila sudut serang mengalami peningkatan. Aliran pemisahan akan menghasilkan aliran gelora apabila ia melepasi pinggir belakang profil bilah. Apabila kawasan aliran gelora menjadi lebih besar, pekali daya angkat mula berkurangan dengan itu, profil bilah telah mencapai fenomena pegun. Objektif utama kajian ini adalah untuk mencari kawasan pegun untuk profil bilah NACA 8415 pada sudut serangan yang berbeza. Kajian ini telah menggunakan pendekatan perkomputeran dinamik bendalir (CFD) untuk menentukan kawasan pegun. Perisian yang digunakan untuk menjalankan simulasi perkomputeran dinamik bendalir ialah ANSYS fluent versi 17.1. Analisis untuk kajian ini hanya memberi tumpuan kepada geometri analisis 2-dimensi sahaja. Bendalir yang digunakan ialah udara panas dan halaju masukan adalah 680m / s pada 500 ° C. Pekali daya angkat dan seretan telah diperolehi daripada simulasi CFD dan graf pekali daya angkat dan seretan melawan sudut serang telah diplot. Daripada keputusan yang di peroleh, pekali daya angkat mula menurun pada sudut 15 °. Oleh itu, kawasan pegun bermula pada sudut 15 °.

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LIST OF ABBREVIATIONS

Re	Reynold Number
CFD	Computational Fluid Dynamic
2D	two dimensions
3D	three dimensions
RANS	Reynold Average Navier Stoke
BSL	Baseline
TE	Trailing Edge
LE	Leading Edge
SST	Shear Stress Transport
LEV	Leading Edge Vortices
LSB	Laminar Separation Bubble
SB-VAWT	Straight Blade Vertical Axis Wind Turbine
NACA	National Advisory Committee for Aeronautics

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C_L	Coefficient of lift
C_D	Coefficient of drag
AOA	Angle of attack
k-ω	k-epsilon
k-ε	k-omega

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LIST OF SYMBOLS

p_{gauge}	pressure gauge	pascal
α	angle of attack (AOA)	degree (°)
C_L	coefficient of lift	
K	reduced frequencies	hertz (Hz)
V	velocity of fluid	m/s
l	chord length	m
ρ	density	kg/m^3
μ	dynamic viscosity	kg/m.s
ν	kinematic viscosity	m^2/s

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CHAPTER 1

INTRODUCTION

1.0 Background

Stalling is one of the most mutual phenomena that always happened on airfoil profile. Consider the turbine blade is a flat plate, the distinctive average velocity profiles in laminar and turbulent flow are shown in figure 1.1. The velocity profile in turbulent flow is much fuller compared to the laminar flow with a sharp drop near the surface. The turbulent boundary layer can be consisting of four regions that had been characterized by the distance from the wall. The thinnest layer next to the wall where viscous effects are main is viscous sublayer. The velocity profile in this layer is very nearly linear, and the flow is nearly parallel. Next to the viscous sublayer is the buffer layer, in which the turbulent effects are becoming significant, but the flow is still dominated by viscous effects. Above the buffer layer is overlap layer, in which the turbulent effects are much more significant, but still not dominant, (cengel, 2014).

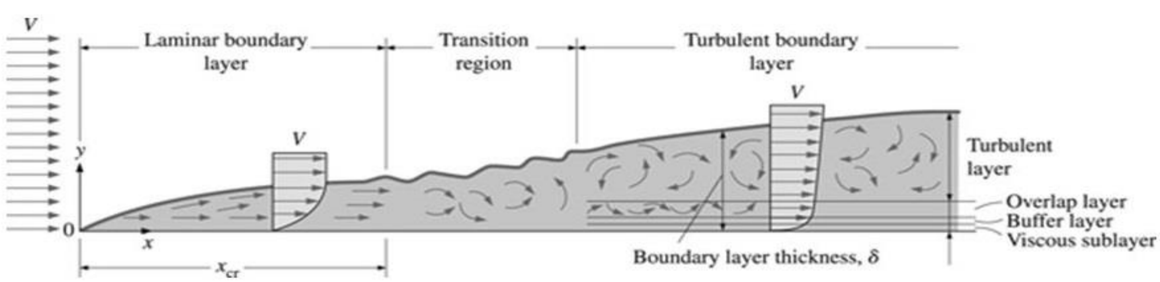

Figure 1.1: development of boundary layer over flat plate, (cengel,2014).

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Flow separation occurred at sufficiently high velocities when the fluid stream separates itself from the surface of the body. The location of the separation point is depending on some factors such as the Reynolds number, the surface roughness, and the level of fluctuations in the free stream. It is usually difficult to predict exactly where the separation will occur unless there is a sharp corners or sudden changes in the shape of the solid surface. When the fluid separates from the body, it forms a separated region between the body and the fluid stream. The separated region occurs when the low-pressure region behind the body recirculating on the backflows had occur. The larger the separated region, the larger the pressure drag.

The complete separation over the entire back surface may also occur on the streamlined body at a sufficiently high of angle of attack (AOA) (about 15° and above). The flow separation on the top of the surface of airfoil will decreases the lift drastically. This decrease will cause the stalling to happen on the airfoil profile.

An important consequence of flow separation is the formation and shedding of circulating fluid structures. It is known as vortices, and it will fill the empty space that had been produced at the wake region. The periodic generation of these vortices downstream are known as vortex shedding. This phenomenon usually occurs during regular flow over a long cylinders or spheres for Re > 90, (cengel, 2014).

The concept of the stalling for aircraft and steam turbine are not much different. For the aircraft, when the blade suddenly changes its angle, the air flow on the upper surface stops sticking to the surface of the wing. Instead the air turns around and produced a turbulence flow and the irregular vortex will present. The sudden changing f angle will give the effect to the lift of wing from the low pressure to the high pressure on the upper surface of the wing. This phenomenon is known as stall.

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An aircraft wing will stall, when the shape of the wing tapers off too quickly as the air moves along its general direction of motion. The wing does not change its shape but the angle of the wing will be changed from the general direction of the motion the angle is also known as the angle of attack (AOA). Stall also can be happened if the surface of the airfoil is not completely level and smooth. A dent in the wing or rotor blade, or a piece of self-adhesive tape can will be enough to create the turbulence on the backside of the wing, even the angle of attack (AOA) is small (Krohn, 1998). Figure 2.1 show the turbulence on airfoil at the different angle of attack.

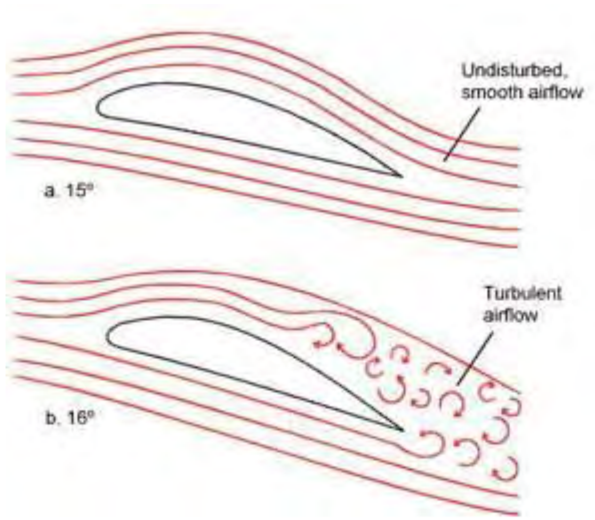

Figure 1.2: the turbulence on airfoil at the different angle of attack (AOA) retrieve fromhttps://www.flitetest.com/articles/how-do-aircraft-fly

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1.1 Problem Statement

Steam turbine had been used in steam power plant to generate the electricity. The turbine had been connected to the shaft. The high pressure and velocity of the steam strike the stationary turbine blades and it will cause the turbine to rotate (Gorla & Khan, 2003). Somehow on every airfoil profile, it will produce a turbulence flow at the certain angle (usually above 15^{o}) at the surface of the profile. This problem will cause the stalling happened.

1.2 Objective

The objectives of this project are as follows:

- To obtain stalling point and region for specific blade's profile by adjusting the angle of attack (AOA).

1.3 Scope of Project

The scope of this project is:

1. This project need to use CFD software to simulate the fluid flow through a single blade profile.
2. The investigation involves specific turbine blade profile and various angle of attack (AOA).
3. This project only investigates the behavior of blade profile in 2 dimensional (2-D).
4. The stalling region will be obtained once the graph C_L and C_D against angle of attack (AOA) had been generated.

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1.4 General Methodology

The action that need to be carried out to achieve the objectives in this project are listed below:

1. Choosing the profile

   The profile had been chosen based on the literature review reading. Which of profile the most suitable to study.

2. Define the parameter

   The number of angle of attack (AOA), type of airflow, velocity of air flow, and the size of the wind tunnel.

3. Drawing

   The 2-D drawing of the blade profile had been draw by using autocad software.

4. Simulation

   The CFD simulation had been run using ANSYS fluent 17.1 software. The fluid flow through the blade profile had been run from the simulation. From simulation, the coefficient of drag and lift had been found.

5. Result analysis

   From the simulation, the graph of C_L/C_D against AOA had been plotted and the stalling region had been determined. The result consists of the coefficient of lift and drag for a specific angle of attack (AOA).

6. Report writing

   The report of this project had been written at the end of this project.

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CHAPTER 2

LITRATURE REVIEW

The literature review showed in this report had been classified into three major domains which is lift coefficient, simulation techniques, and stalling process. The focus is on the formation of the stalling on the steam turbine. The steam turbine consists of bladed components of nozzle, rotating blades and non-bladed component including the inlet and exhaust casing and etc. It is the designer jobs to minimize the energy loss for the component (x.xu et al.,2001). There are many type of turbine one of the example is radial turbine. When talking about designing the radial turbine, the preliminary design work of the radial-inflow turbine is the most important in designing process. The objective of the designing phases is to create an aerodynamic design that will achieve a desired output (Sauret & Gu, 2014). However, sometimes the unsteadiness of the flow on the turbine had been produce by the periodic chopping of the wake region and the formation of the secondary flow vortices (Chaluvadi at al.,2003). There are many applications for the computational fluid dynamics in designing and optimizing turbomachine. It is necessary to obtain accurate prediction of the flow by using the turbulence modelling since the flow of the turbomachine is always turbulent (Lucius & Brenner, 2010).

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2.1 Lift Coefficient

Based on the findings from the article (Hoo, et al., 2005), they had produced the plots for the lift coefficient against time. Figure 2.2, had shown that the sinusoidal variation is nearly smooth when the time is reduced. They had expected this since the wing is wavering with the static stall limits, and the flow is therefore predictable to remain attached throughout the pitching cycle. The increasing of *K* widens the hysteresis loops indicating a larger phase difference with the angle of attack (AOA). The increasing of *K* will affect the coefficient which is in this case the coefficient of lift will be slightly higher (greater than the steady lift generated at a fix angle of attack). They also had compared the result for theoretical and experimental at different of angle of attack (fig 2.1). It can be see that there is a huge difference between theoretical and experimental result for C_L. The curve shows the wing has stalled beyond the AOA of 10°.

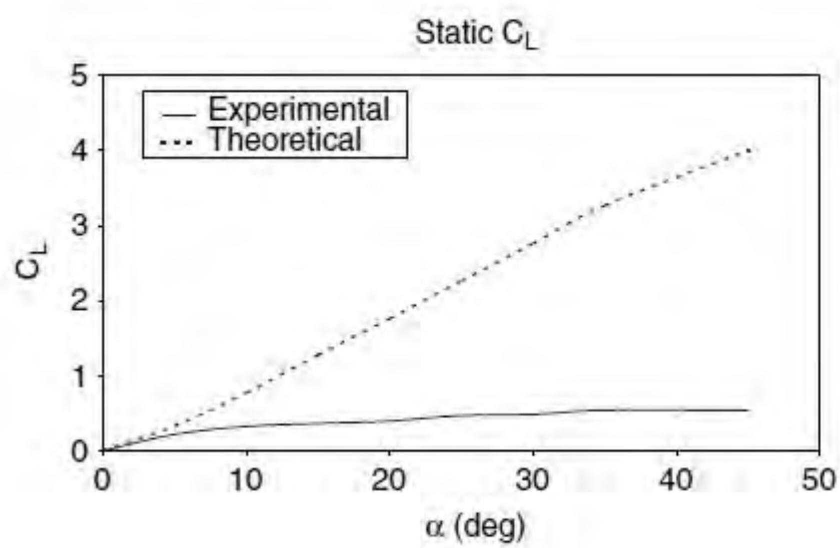

Figure 2.1: Steady state lift coefficient measured at fixed angles of attack compared with theoretical inviscid static lift. Lift recorded when readings attained steady state. Comparison of the curves show the wing has stalled beyond the angle of attack (AOA) of 10° (Hoo, et al., 2005).

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