INVESTIGATION ON TURBINE BLADE'S PROFILE PERFORMANCE

MUHAMAD AKMAL BIN SHAIDUN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MUHAMAD AKMAL BIN SHAIDUN

This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Thermal Fluid)

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DECLARATION

I declare that this project report entitled "Investigation on Turbine Blade's Profile Performance" is the result of my own work except as cited in the references.

Signature :

Name : Muhamad Akmal Bin Shaidun

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 Fluid).

Signature :

Name of Supervisor : DR. Yusmady Mohamed Ariffin

Date :

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ABSTRACT

The performance of a turbine is very important because it is the yardstick in determining the ability of a turbine to produce the power output. There are various aspects to assess when determining the performance of a turbine. However, aspects that will have a big impact on the performance of the turbine are the turbine blade profile. There is various type of blade profile we can found which have different in their dimension such as the thickness, deviation angle, incidence angle and others. The profile categorized in code name called National Advisory Committee for Aeronautics (NACA). These different profiles will produce difference performance level in their work. In order to find which profile blade can produce the higher performance during operation, an analysis on the profile need to be done. The analysis can be carry out by doing computer simulation software call ANYSYS CFD Fluent on the blade. Result from the analysis can use to determine which profile blades have better performance. The analysis conduct on 2-dimension single blade, which will five different profile at same 15-degree angle of attack and same 400 m/s velocity. The selected profile is NACA TN3802, TN 5508, TN 6508, TN 2202, and TN6408. From the simulation, the results that can obtained are pressure and velocity distribution around the blade and the lift and drag acting on the blade. The result obtain can be used to analyze which profile blade is better. Based on the pressure different result, NACA TN 6508 has the highest value at 185723.7 Pa and it has lift to drag ratio at 6.7851, which also the highest among the five profiles selected. The assessment for this analysis more focusing on the lift to drag ratio of the blade. As the result, NACA TN 6508 is chosen as the best blade profile compared to the other four selected blade.

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ABSTRAK

Prestasi turbin adalah sangat penting kerana ia adalah kayu pengukur dalam menentukan keupayaan turbin untuk menghasilkan output kuasa. Terdapat pelbagai aspek yang akan dinilai apabila menentukan prestasi turbin. Tetapi aspek yang akan memberi impak yang besar kepada prestasi turbin ialah profil bilah turbin. Terdapat pelbagai jenis profil bilah yang boleh didapati dan mempunyai perbezaan dalam dimensi seperti ketebalan, sudut penyelewengan, sudut tuju dan lain-lain. Profil ini dikategorikan dalam nama kod dikenali sebagai Jawatankuasa Penasihat Kebangsaan bagi Aeronautik (NACA). Profil yang berbeza akan menghasilkan tahap prestasi yang berbeza dalam kerja mereka. Dalam usaha untuk mencari bilah profil yang boleh menghasilkan prestasi tinggi semasa pengendalian, analisis mengenai profil perlu dilakukan. Analisis ini boleh dijalankan dengan melakukan simulasi komputer perisian yang dikenali sebagai ANYSYS CFD Fluent. Keputusan daripada analisis boleh digunakan untuk menentukan bilah profil manakah yang mempunyai prestasi yang lebih baik. Analisis akan dijalankan pada lima jenis profil yang berbeza didalam lukisan 2-dimensi pada sudut serangan yang sama iaitu 15 darjah dan pada halaju yang sama pada 400 m / s. Profil dipilih adalah NACA TN3802, TN 5508, TN 6508, TN2202 dan TN6408. Dari simulasi, hasilnya yang boleh diperolehi adalah tekanan dan taburan halaju sekitar bilah dan lif dan seret bertindak pada bilah. Hasilnya boleh digunakan untuk menganalisis bilah profil adalah lebih baik. Berdasarkan hasil tekanan yang berbeza, NACA TN 6508 mempunyai nilai tertinggi di 185723.7 Pa dan ia mempunyai lif untuk nisbah drag di 6,7851 dan juga adalah yang tertinggi di kalangan lima profil yang dipilih. Analisis ini lebih memberi tumpuan kepada nisbah bilah angkat kepada menyeret. Penilaian bagi menentukan profil mana yang terbaik adalah lebih focus kepada nisbah bilah angkat kepada menyeret. Sebagai hasilnya, NACA TN 6508 dipilih sebagai profil bilah yang terbaik berbanding empat bilah yang lain.

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LIST OF ABBEREVATIONS

CFD	Computational Fluid Dynamic
ANSYS	Analysis System
NACA	National Advisory Committee for Aeronautic
TN	Turbine

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LIST OF SYMBOL

α	Angle of attack
C_L	Lift coefficient
C_D	Drag coefficient
V	Velocity
p	Density
L	Lift force
D	Drag force
P	Pressure
v	Specific volume
T	Temperature
s	Enthalpy

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CHAPTER 1

INTRODUCTION

1.1 Background

A turbine is a mechanical device that been categorized as rotary type device, which it will, extracts energy from it input such as gas or steam and converts it into useful energy like electricity. A turbine also known as turbomachine and it has at least one moving part called a rotor assembly, where this part attached with a shaft or drum with blades. The input energy will flow into the turbine and acts on the blades so that they move and impart rotational energy to the rotor. There are different types of turbines that been created to meet the suitability of the energy input.

In turbine, blades play an important role. An airfoils blade is a streamlined body having a thick, rounded leading edge and a thin trailing edge in order to achieve a high lift-drag ratio as shown in Figure 1.1. Its maximum thickness occurs somewhere near the midpoint of the chord. When designing the blade, either it's stationary blades or rotating blades the design should have the capability for the blades to obtain the desired pressure drop and turning towards the tangential direction between the driving surface and trailing surface of the vane passage. As the result, flow that comes out of the stationary blades will have the desired velocity in its magnitude and direction. The exit flow will have high velocity with a high tangential component. Thus, the flow enters axially in the stationary as well as the moving blades and both the tangential force and torque exerted by the fluid jet on the following rotating blade row depends on the change in the tangential velocity of the fluid (Shivakumar, 2014).

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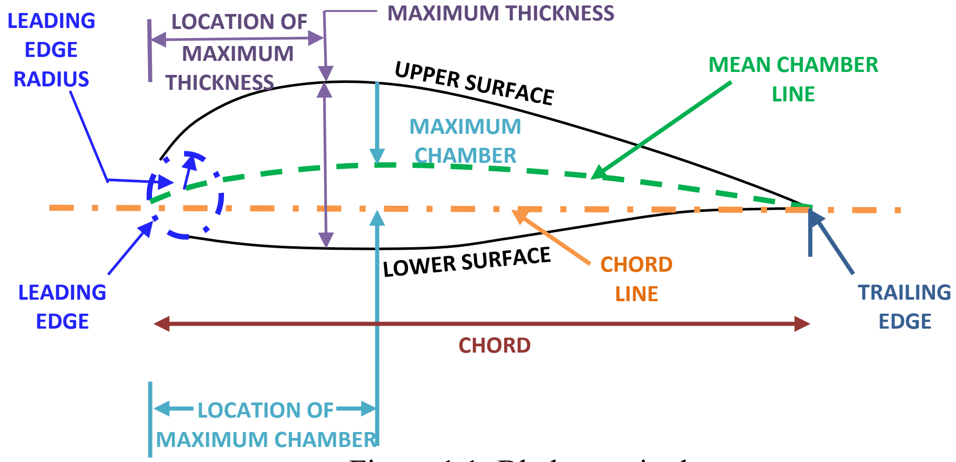

Figure 1.1: Blade terminology

Since there are many type of blade design with different shape and dimensions, each officially registered blade design has been tag with its own code. Before these codes been established, airfoil design was rather arbitrary with nothing to guide the designer except experience with known shapes and experimentation with modifications to those shapes. As the solution, National Advisory Committee for Aeronautic (NACA) has come up with a code called NACA series. The NACA code series has been divided into several series which is NACA 4-digit, NACA 5-digit, 16 series, 6 series, 7-series, and lastly 8-series. In the early, the NACA 4-digit and NACA 5-digit, were generated using analytical equations that describe the camber (curvature) of the mean-line (geometric centerline) of the airfoil section as well as the section's thickness distribution along the length of the airfoil. For the other series, the derivation is using theoretical rather than geometrical methods because all these series are more complicated in its design. This methodology began to change in the early 1930s. As airfoil design became more sophisticated, this basic approach was modify to include additional variables, but these two basic geometrical values remained use for all NACA airfoil series.

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Blades are the heart of a steam turbine, as they are the principal elements that convert the thermal energy into kinetic energy. The efficiency and reliability of a turbine depend on the proper design of the blades. It is therefore necessary for all engineers involved in the steam turbines engineering to have an overview of the importance and the basic design aspects of the steam turbine blades, Blade design is a multi-disciplinary task. It involves the thermodynamic, aerodynamic, mechanical, and material science disciplines. A total development of a new blade is therefore possible only when experts of all these fields come together as a team. Efficiency of the turbine is depending on the parameters, inlet and outlet angle of the blade, blade materials, and profile of the blade and surface finishing of the blade (Kumar, 2014).

1.2 Problem Statement

The performance of a turbine is very important because it is the yardstick in determining the ability of a turbine to produce the power output. There are various aspects to be assessed when determining the performance of a turbine. This is because every aspect found on a turbine will affect the performance of the turbine, such as design of turbine, size of the turbine, and many others.

But aspects that will have a big impact on the performance of the turbine is the turbine blade profile. There is various type of blade profile we can found in the market. These profile will have different in their dimension such as the thickness, deviation angle, incidence angle and others. The profile is categorized in code name called National Advisory Committee for Aeronautics (NACA) as shown in Figure 1.2.

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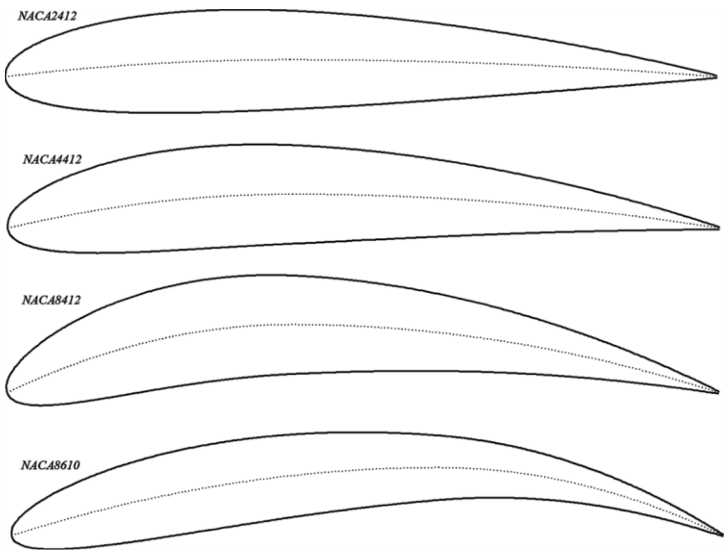

Figure 1.2: NACA blade profile (Bayoumy, 2012).

Since there are different types of blade profile, it's hard to know which one is able to produce high performance when working. These different profile will produce difference performance level in their work. In order to find which profile blade can produce the higher performance during operation, an analysis on the profile need to be done. The analysis can be carry out by doing ANSYS CFD Fluent simulation in two dimensional drawing on the selected blade profile with a fixed angle of attack and constant velocity. Result obtain from the analysis such as velocity and pressure distribution, drag and lift coefficient and pressure different can be used to determine which profile blade have better performance.

1.3 Objective

The objectives of this project are as follows:

1. To investigate various type of standard turbine blade's profile in term of its effect on performance.
2. Suggest a better blade profile compare to the others.

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1.4 Scope of Project

1. The analysis will be conduct on single blade's which will have different profile. For this analysis there are five profile blade selected which is NACA TN3802, TN 5508, TN 6508, TN2202 and TN6408.
2. The turbine type is not specified in the analysis. This allows the analysis to be done on various turbine type.
3. The angle of attack for all blade are set at 15 degree and the air velocity during simulation is set to 400 meter per second.
4. The design blade is analysed using computational fluid dynamics based on k-ε (epsilon) turbulent model and ANSYS FLUENT type of solver preference.
5. This project studies is focused on analysis on lift and drag force coefficient ratio and identify pressure region as well as the velocity magnitude in each aerofoil design to evaluate the best design of blade.

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CHAPTER 2

LITERATURE REVIEW

2.1 Turbomachinery

Nowadays, turbomachinery machine utilized as a part of a few applications in order to give comfort ability for human in daily life. This machine is mostly use to generate electricity power, aircraft propulsion, and vehicular propulsion for civilian and military use. In mechanical engineering, turbomachinery term is described as a machine that consists turbines and compressors as it main working part as shown in Figure 2.1, where it function is to transfer energy between a rotor and a fluid. The energy extract by the turbine then transferred to generator or other uses through the shaft. If the devices extract energy from the fluid, it generally called a turbine. If the devices deliver energy to the fluid, it called a compressor, fan, blower or pump depending on the fluid used and the magnitude of the change in pressure that results. Turbomachinery is the generic name for all these machines. (Ingram, 2009).

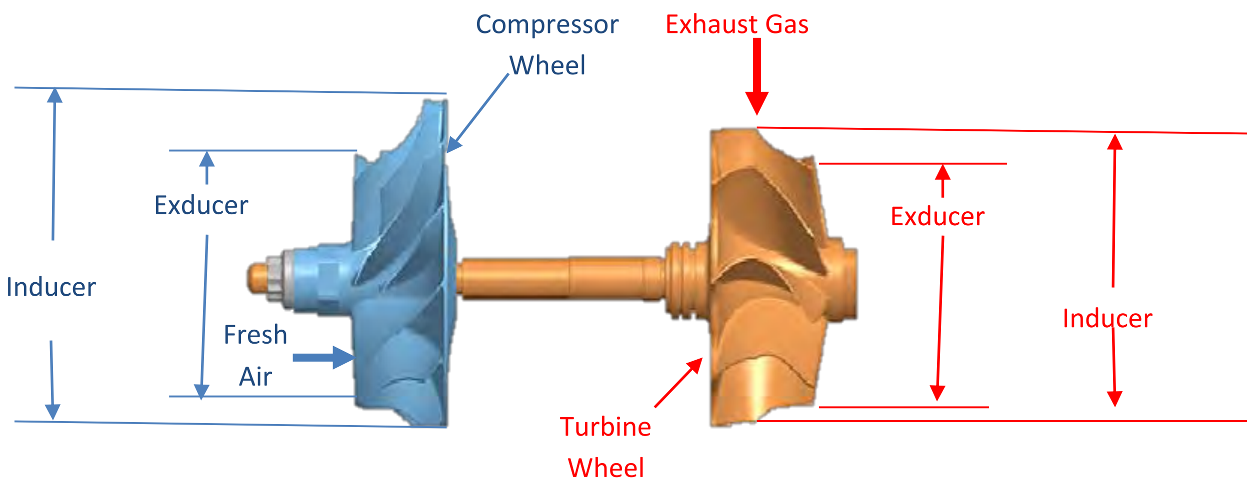

Figure 2.1: Examples of turbine and compressors in turbomachinery machines (Ingram, 2009).

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The turbomachine has been characterized diversely by distinctive creators, however these definitions are comparable and about identical. The turbomachine is a device in which energy exchange accomplished by hydrodynamic forces arising between a moving fluid and the rotating and stationary elements of the machine (Daily 1950). A turbomachine characterized by dynamic energy exchange between one or several rotating elements and a rapidly moving fluid (Wislicenus, 1974). A turbomachine characterized by dynamic action between a fluid and one or more rotating elements. A definition to include the spirit of all the preceding definitions would be. A turbomachine is a device in which energy transfer occurs between a flowing fluid and a rotating element due to dynamic action resulting in a change in pressure and momentum of the fluid (Binder, 1958).

2.1.1 Turbomachinery principal components

The principal components of turbomachinery divided into four main parts as shown in the Figure 2.2. Those four parts are rotating part, stationary part, an input and/or output shaft and lastly a housing. The rotating part carried numbers of vanes or blades and its operating in a steam of fluid or gases. Rotating part is additionally known by the names rotor, runner, impeller, and other, contingent on the specific application. Energy exchange happened just because of the exchange of momentum energy between the flowing fluid and the rotating element and there may not be even a specific boundary that the fluid not permitted to cross. In turbomachinery machine, stationary part generally acts as guide vanes or passages for the proper control of flow direction and the energy conversion process. However, it been said that stationary part is not a necessary part of every turbomachine. The common ceiling fan used in many buildings

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in India to circulate air during summer and the table fan are examples of turbomachines with no stationary element (Kadambi, 1975).

The utilities of an input shaft or an output shaft is liable on the application, either an input or an output shaft may be necessary. Some application of turbomachinery need both shaft to be present. Turbomachine that work as power absorbing, there will be increasing of fluid flowing through it because there is mechanical energy input at the shaft. If the turbomachine is power generating, mechanical energy output is obtained at the shaft due to a decrease in enthalpy of the flowing fluid. It is also possible to have power transmitting turbomachines, which simply transmit power from an input shaft to an output shaft, just like a clutch-plate gear drive in a car, which transmits the power generated by the reciprocating engine to the shaft, which drives the wheels. There are many examples of these types of machines.

Examples of power absorbing turbomachines are mixed-flow, axial-flow and centrifugal pumps, fans, blowers and exhausters, centrifugal and axial compressors, and others. Examples of power generating devices are steam, gas, and hydraulic turbines. The best-known examples of power transmitting turbomachines are fluid couplings and torque converters for power transmission used in automobiles, trucks and other industrial applications. Similar to the stationary part, the housing part also not a necessary part of a turbomachine. Existing of the housing part is can prevent the fluid flow from escape in directions other than those required for energy transfer and utilization or it is use to restrict the fluid flow to a given space. The housing plays no role in the energy conversion process. The turbomachine that has housing is said to be enclosed and that which has no housing is said to be extended (Korpela, 2011).

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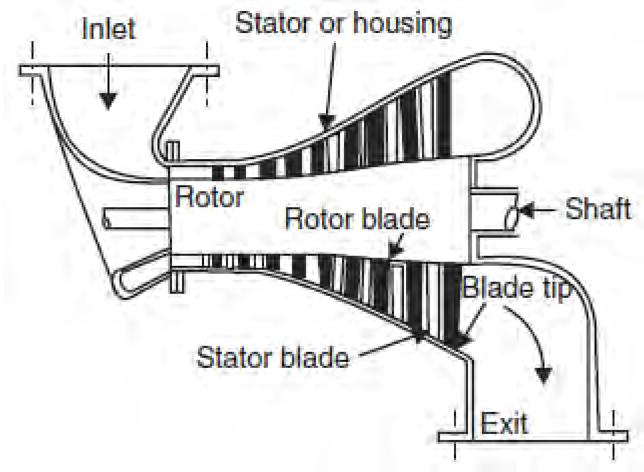

Figure 2.2: Schematic cross-sectional view of a turbine showing the principal parts of the turbomachine (Chima, 1978).

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2.2 Introduction to Turbine

Turbine is one of important part in turbomachinery machines. Turbine play an important role during the conversion of energy because it functions is to extract the energy from the fluids or gases flow and convert it to useful work. Compressed fluid or gases moved with high velocity and pressure acts on the blades so that they move and impart rotational energy to the rotor. Energy that been extracted by the turbine is then transferred to generator through a connecting shaft. There are many type of turbine that been used depending on the purpose of the type of energy conversion. Windmills and waterwheels are the examples of the early time turbine. Nowadays, the most common turbines are steam, gas, and water turbine.

2.2.1 Steam turbine

Steam turbine is the oldest prime mover technologies in power generation. Even though many type of turbine been developed, steam turbine is still in general production used to drive a generator or mechanical machinery. This is due to its versatility and the higher efficiencies in power production. The first steam turbine used for power generation invented in 1884. Following this initial introduction, steam turbines rapidly replaced reciprocating steam engines due to their higher efficiencies and lower costs. Most of the electricity produced in the United States today is generated by conventional steam turbine power plants. The capacity of steam turbines can range from 50 kW to several hundred MW for large utility power plants. Steam turbines are widely used for combined heat and power applications in the United States and Europe (Subramanyam, 2013).

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