INVESTIGATION ON TURBINE BLADE'S PERFORMANCE BY USING 3-DIMENSIONAL CFD

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

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2017

DECLARATION

I declare that this project report entitled "Investigation On Turbine Blade Profile Performance by Using 3-Dimensional CFD" is the result of my own work except as cited in the references

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Date	:	16/6/2017

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) with Honour.

Signature : ....

Name of Supervisor : DR. Yusmady Mohamed Arifin

Date : 16/6/2017

DEDICATION

To my beloved mother and father

ABSTRACT

The study of turbine blade profile performance by using 3-Dimensional CFD is very important because it determining the quality of turbine to produce the power output. Basically, there are two methods when study the turbine's blade profile performance, first is by doing the experimental method and second is by using simulation software such as CFD. In this study, using 3- Dimensional CFD simulation method is chosen, since this method is cheaper and save more time compare to experimental method. The geometry used for this analysis are NACA 8412, NACA 8413 and NACA 8414 that are referring to airfoil geometry. All the selected turbine 's blade profiles are conduct the analysis with the same parameter. The parameters are used for the turbine' blade analysis are velocity inlet of 265 m/s, angle of attack of 0 degrees, temperature of 1112 K and twist angle of 36 degrees. After conduct the simulation, the result is compare to determine which turbine 's blade has the best performance. Hence, the performance of turbine is evaluating based on the coefficient of lift, coefficient of drag, lift and drag coefficient, velocity streamline and also pressure contour. As result of simulation obtain, NACA 8414 is chosen to have the best turbine 's blade profile performance since give good result for all the coefficient of lift, coefficient of drag, lift and drag coefficient, velocity streamline and also pressure contour.

ABSTRAK

Kajian prestasi profil bilah turbin dengan menggunakan 3-Dimensi CFD adalah sangat penting kerana ia menentukan kualiti turbin untuk menghasilkan output kuasa. Pada asasnya, terdapat dua kaedah ketika kajian prestasi profil bilah turbin, pertama adalah dengan melakukan kaedah eksperimen dan kedua adalah dengan menggunakan perisian simulasi seperti CFD. Dalam kajian ini, dengan menggunakan 3- Dimensional kaedah simulasi CFD dipilih, kerana kaedah ini adalah lebih murah dan menjimatkan lebih banyak masa berbanding dengan kaedah eksperimen. Geometri digunakan untuk analisis ini adalah NACA 8412, NACA 8413 dan NACA 8414 yang merujuk kepada aerofoil geometri. Semua profil bilah turbin 's dipilih adalah menjalankan analisis dengan parameter yang sama. Parameter yang digunakan untuk turbin 'analisis bilah adalah halaju masuk 265 m / s, sudut serang 0 darjah, suhu 1112 K dan sudut twist 36 darjah. Selepas menjalankan simulasi, hasilnya adalah perbandingan untuk menentukan turbin 's bilah mempunyai prestasi yang terbaik. Oleh itu, prestasi turbin sedang menilai berdasarkan pekali daya angkat, pekali seretan, lif dan pekali seretan, halaju arus dan juga tekanan kontur. Sebagai hasil simulasi mendapatkan, NACA 8414 dipilih untuk mempunyai terbaik bilah prestasi profil turbin 'sejak memberikan hasil yang baik untuk semua pekali daya angkat, pekali seretan, lif dan pekali seretan, halaju arus dan juga tekanan kontur.

ACKNOWLEDGEMENT

First of all, I would like to convey my gratefulness to my supervisor, Dr. Yusmady Mohamed, for his assistance and his guidance towards the progress of this project. Throughout of this project, Dr Yumasdy has been helping me by sharing his knowledge and skill on how to manage a project. He's also monitoring my progress and guided in the right direction and offering encouragement. Without his guidance and assistance on my progress, obviously my project will be uncertain. Next, special thanks to lecturer of Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka for their advice and help, especially to Dr fudhail , Dr tee for sharing their knowledge about CFD.

My special appreciation and thanks to all my comrades for their invaluable support toward this project. Not to forget, many thanks to my dearest parent Mr Abdul Rahim bin Ismail and Mrs Faridah Binti Tahir for their unfailing encouragement and financial support given to me over the years. Lastly, I would like to express my gratitude to all parties for sharing their advice and knowledge. Thank you, your sincere help will be remembered for my entire life.

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LIST OF ABBEREVATIONS

NACA	National Advisory Committee for Aeronautics
CFD	Computational Fluid Dynamic
BC	Before Century
LHV	Lower Heating Value
GTCC	Gas-turbine combine-cycle

LIST OF SYMBOL

c	Chord length,
l	length
ρ-	density of air
$Vrel^2$	relative velocity
F_D	Drag Force
C_L	Coefficient of lift
C_D	Coefficient of lift
F_L	Lift Force

CHAPTER 1

INTRODUCTION

1.1 Background

The investigation on the turbine blade's profile performance is associated to the concept of turbomachinery. Turbine, compressors and fans are wholly member of the same family of turbomachinery. A turbomachine is a power or head producing machine which employs the dynamic action of a rotating element the rotor; the action of the rotor changes the energy level of the constantly flowing fluid through the turbomachine (Yahya, 2005). The study of turbomachinery is involving in many engineering field such as gas turbine plant, steam turbine plant and many more. In this case, the study of turbine's blade profile is concentrate on gas turbine application.

Gas turbine plant is plant that consists of turbo-compressor, heat exchanger and turbine. The first patent that of gas turbine was introduce is in 1791 by John Barber, his invention was the most important element present in the modern day gas turbine, and his turbine was to design horseless carriage (David Gordon Wilson, 1998). The study of gas turbine continues until the present day. For the study of the turbine's blade profile performance, two methods are considered in this investigation, first is using experimental method or another way is using numerical simulation on turbine's blade performance by using CFD. The second are considered because of performing experiment is require more time and money. (Hadi karrabi, 2011).

Computational fluid dynamic (CFD) is a proven simulation tool which can be used to any field of engineering. The CFD software is extensively use to engineer so that they can perform analyse, and optimize various engineering designs. In this study, the discussion is focused on investigation on various type of standard turbine blade profile in term of its effects on performance. The turbine blade profile just be match to the other blade turbine profile and suggest the one has the best performance. The blade's profiles are used in this study are 3-Dimensional model that have fix turbine blade profile, fix incidence angle, fixed inlet fluid flow velocity but with various case with difference blade profiles. Then the turbine's blade profile is test on the wind tunnel. After that, to perform CFD simulation the data and the information from the journal are use as reference.

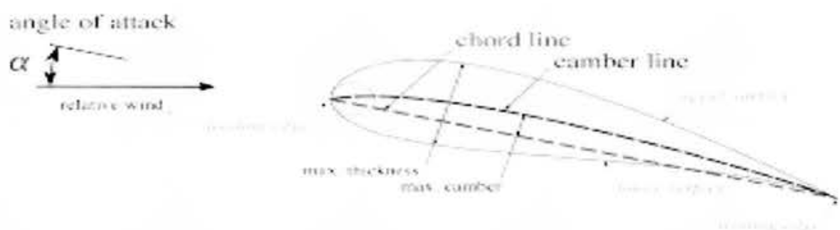

Figure 1.1 Airfoil Geometry (Kaurase2, 2016)

Next the journal and the internet source are used to obtain information for designing the turbine's blade profile. In the journal, most the turbine blade's profiles are referring to the airfoil profile shape. Airfoils are the detailed geometric shapes that are used to produce mechanical forces due to relative motion of the airfoil and a surrounding fluid. Most of turbines are using airfoil shape to improve the mechanical power. The shape of airfoil profile is depends on what application it used. For example the wind turbines normally the airfoil that have been used is NACA 6409 and NACA 4412 and for gas turbine use NACA 8412 (Kaurase2, 2016). Therefore, it is important to know study the previous journal before do the simulation using CFD.

1.2 Problem Statements

Study the flow of turbine's blade profile in 2-Dimensional is always play important part when designing a turbine blade. The use of 2-Dimensional turbine's blade profile model can provide much in formation when performs analysis using CFD. For example, the efficiency of turbine's blade, the coefficient of drag, the velocity flow through the turbine blade, the coefficient of lift and the angle of attack of turbine blade. Although the 2-Dimensional turbine blade can provide good analysis and many information, but there a certain analysis in 2-Dimensional could not be done when using CFD analysis. According to the (Hadi karrabi, 2011), There are many methods that can be used to simulate axial turbine such as 0D, 1D, 2D, quasi 3D and 3D. In order to achieve the main objective, the numerical model must enable us to input all the detail geometry. 3D simulation of turbomachinery has the highest accuracy. Therefore, the investigation on turbine's blade profile must be in 3-Dimensional because 3-Dimensional can perform twisted angle shape of model. In this project three turbine blade's profile are choose for the study of turbine's blade performance which are NACA 8412, NACA 8413 and NACA 8414 (Kaurase2, 2016).

1.3 Objective

The objectives of this study are as follows:

1. To investigate various type of standard turbine blade profile (twisted) in term of its effect on performance.
2. To suggest a better turbine's blade profile that has better performance compare to others.

1.4 Scope of project

The scopes of this project are:

1. The study is using 3-Dimensional CFD software in order to stimulate the fluid flow through a single blade profile.
2. The single turbine blade's profiles are used in this analysis are NACA 8412, NACA 8413 and NACA 8414.
3. The parameter set up for single turbine's blade profile are chord length of 10cm, span length of 50 cm, angle of attack α at 0 degrees and twisted of angle β at 36 degrees.
4. The parameter geometry of test section for wind tunnel used for this analysis is in box shape with length of 100 cm, height and width of 50.6 cm.
5. The analysis is ANSYS FLUENT 16.0 as solver preference and the model use for this analysis is K-epsilon turbulence model.
6. Evaluation of the performance of turbine's blade profile are based on coefficient of drag, coefficient of lift and lift to drag ratio at angle of attack 10 degree in order to suggest the best performance of turbine's blade profile.

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction of Turbomachinery

The investigation on the turbine blade's profile performance is identified with the idea of turbomachinery. Turbine, compressors and fans are all individual from a similar group of turbomachinery. A head generating machine or power which uses the dynamic action of a rotating component of rotor is known as turbomachine, the energy level of the continuously flowing fluid through the turbomachine change the activity of rotor (Yahya, 2005). This turbomachine can produce change in enthalpy in a stream of fluid through it and exchange work through a rotating shaft; the interaction between the fluid and the machine is essential fluid-dynamic lift. This change in enthalpy also can be brought by the heat transfer. The overall enthalpy change in through the engine is almost negligible when considering the heat transfer (Wilson, 1998).

The first person who encourage of the early development of turbomachinery was Hero of Alexandria in 100 BC. He invented a device known as Aeolipile shown in figure 2.1 This device is operating when the container is heated the simple bladeless radial steam turbine is will spin The steam jets exiting the turbine can produce torque which is same concept as tip jet or a rocket engine (Meher-Homji, 2000). Therefore, the advancement of turbomachinery invented by Hero of Alexandria has encouraged many famous researchers to studies about turbomachinery.

Figure 2.1: Aeolipile Developed by Hero of Alexandria(Meher-Homji, 2000)

In 1500AD Leonardo Da Vinci study the device known as chimney jack as shown in figure 2.2 .This device has turbine which allow hot air passed over a fan like a blades and crude bevel gear use to rotate the spit (Meher-Homji, 2000).

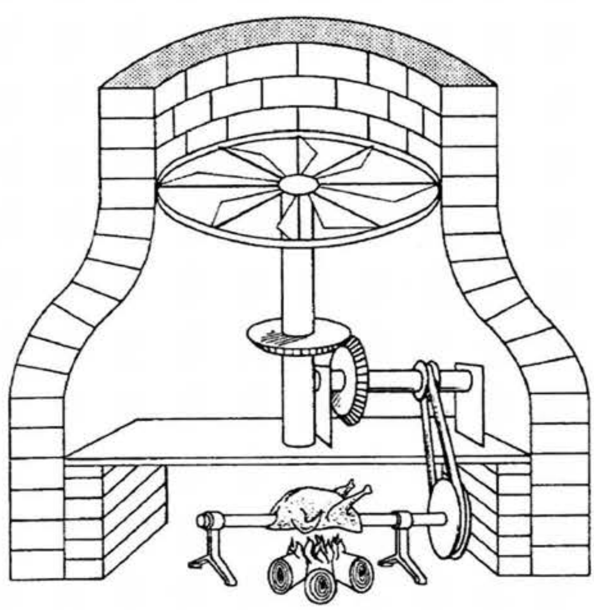

Figure 2.2: Chimney Jack (Meher-Homji, 2000)

In 1687, Sir Isaac Newton uses his formula of law of motion, which was fundamental to the development of all type of turbomachinery. The device name as "Newton Steam Carriage" shown in figure 2.3 and also known as "Steam Wagon". This device can utilize a reaction jet to provide forward movement. In this device there are a spherical boiler with a four-wheel carriage mounted over fire and nozzle that designed to provide a reaction jet (Meher-Homji, 2000).

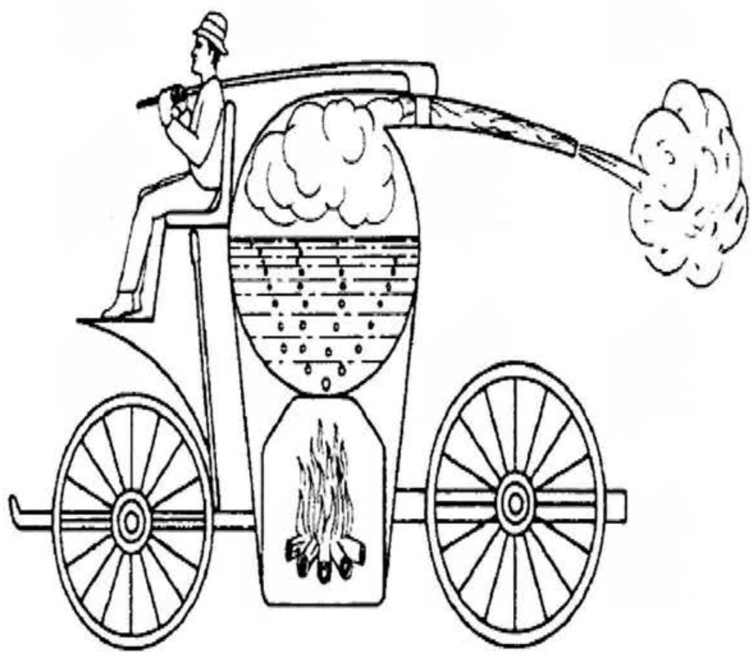

Figure 2.3: Newton's Steam Carriage (Meher-Homji, 2000)

The development of turbomachinery is known through the world, until now many applications that use concept of turbomachinery have been introduced such as Pelton turbine, wind turbine, gas turbine and many more. In this study, the investigation of turbine blade profile is applying on the gas turbine.

2.2 Gas Turbine

Gas turbine term is referring as an abbreviation for a gas turbine engine, which define as heat engine that accepts heat, reject heat and produces work. Basically the form of fuel that is burned is the input heat (giving rise the term as "combustion engine"), and other it also come from another process through a heat exchanger. The heat is rejected to atmosphere in the form of hot engine –exhaust flow, and also can be rejected through heat exchanger. Through all the process, the work may be given as output torque in turning shaft or as the velocity and pressure in a jet, which produce in larger size of compressor. The other term "gas turbine" also can be applied more narrowly for just the turbine expander. (Wilson ,1998)

The early design use thermodynamic cycle of the modern gas turbine was introducing by John Barber in 1791. In his design the turbine is equipped with a chain –driven reciprocating type of compressor and had a combustor and turbine. He then proposed the use of gas, charcoal or other suitable fuel to produce inflammable gas as shown in Figure 2.4: Patent Drawing of John Barber of Gas Turbine Cycle in 1791 (Meher-Homji, 2000).

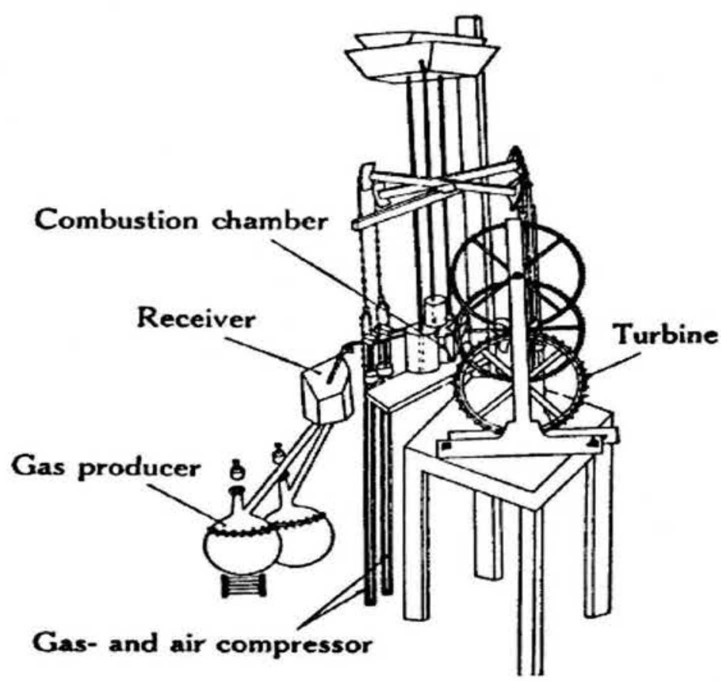

Figure 2.4: Patent Drawing of John Barber of Gas Turbine Cycle in 1791 (Meher-Homji, 2000)

In 1872 J. F(Franz) Stolze developed the first practical gas turbine with trials being made in 1900 and 1904. The design of his gas turbine was a single shaft unit supported by a bearing at each end and had a single silo combustor. The power of both end of the shaft belt drove alternators were rated at 150kW. There axial flow compressor comprised 10 stages (pressure ratio of 2.5:1) and the reaction turbine had 15 stages. The inlet temperature of turbine machine operated is 400°C and the efficiency of compressor is cover by 70 percent for the unit to be self-sustaining. Stolze's gas turbine uses a reheater with combustor being essentially a rudimentary coal gasifies. Some the heated air that come from recuperator was used to volatilize the coal. The recuperator was a U bank tube and linked to the compressor discharge plenum below the gas turbine. Finally, the gas turbine exhaust gas was routed under the machine to pass over 96 U tubes before discharging into main stack (Meher-Homji, 2000).

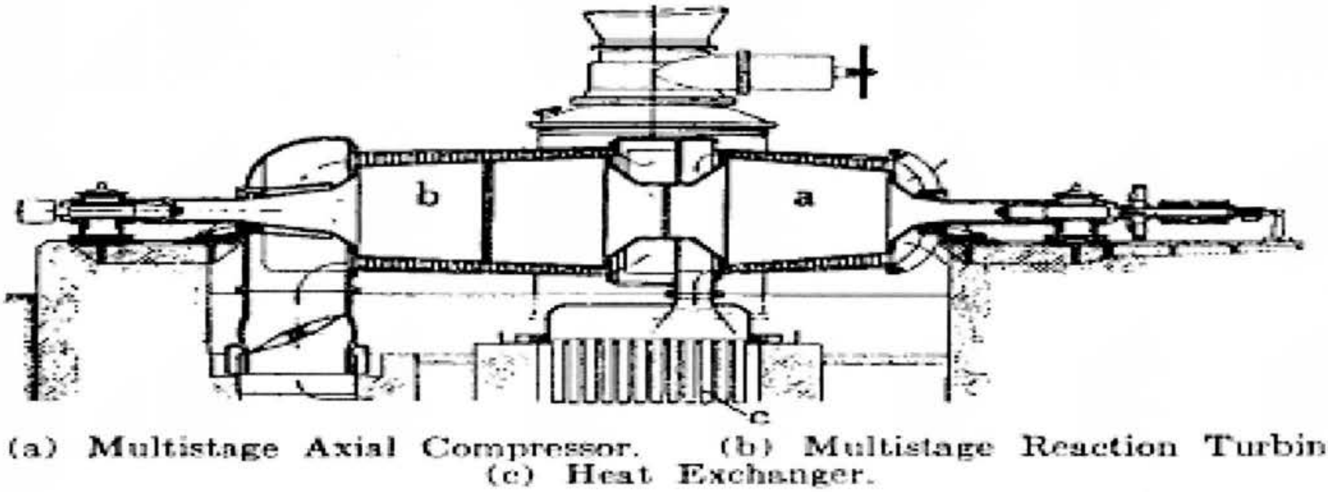

Figure 2.5 : Franz Stolze Gas Turbine Arrangement :(Meher-Homji, 2000)

In addition, the development of gas turbine still continues up until today. In 2011, the modern design of gas turbine by company known as Mitsubishi Heavy Industries Ltd was introduce. The gas turbine model is known as M501J model show in figure 2.6. This gas turbine is known as "Gas-turbine combine-cycle (GTCC) power generation because it is the cleanest and most efficient power generating system of all the fossil-fuel burning process. The developer claims that the GTCC power generations is demand on market because GTCC system can be constructed quickly and provide a stable source of electricity (Hada, 2013).

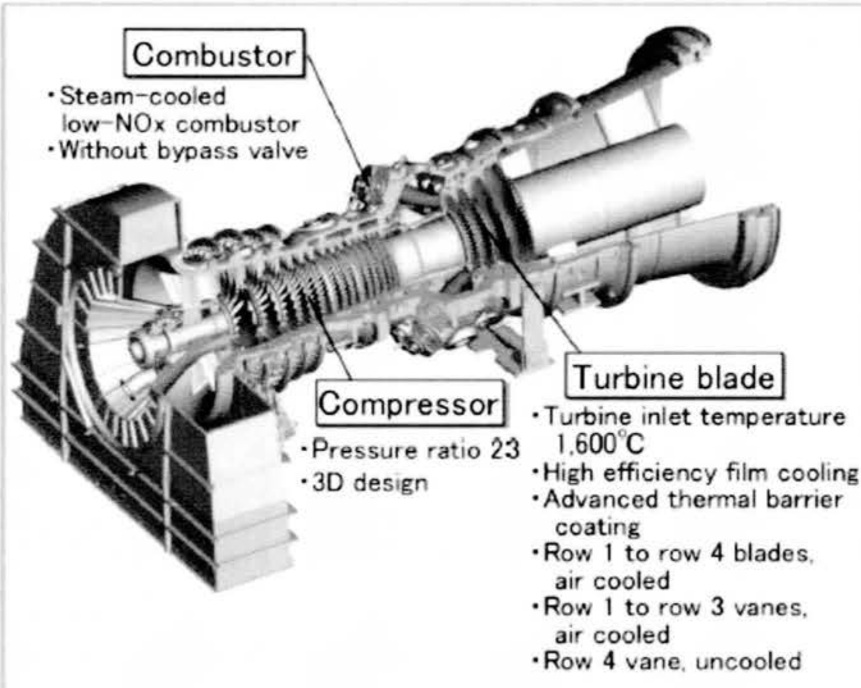

Figure 2.6:M501J Gas Turbine Features (Hada, 2013)

In feature the M501J gas turbine was designed with a turbine inlet temperature at 1600°C by integrating the proven component technologies utilize in the 1400°C F-series and the 1500°C G and H-series turbine. The previous development of gas turbine has given benefit to the M501J gas turbine for the national 1700 °C gas turbine project show in figure 2.7 The adaption of higher inlet temperature and newest component technology have given combine-cycle gross thermal efficiency significantly better than the conventional machine which is 61.5% on LHV (Lower Heating Value) basic shown in figure 2.8. Therefore, carbon dioxide emission approximately 60% can be reducing compare to a conventional coal-burning thermal power plant if use J-series combine-cycle power plant (Hada,2013).