I/ We declare that had read this work and in my/ our opinion which the project was adequate from the scope and quality aspects for the award of the Bachelor degree of Mechanical Engineering (Thermal Fluids).

Signature : ....

1st Supervisor name : NAZRI MD DAUD

Date : 14/5/09

Signature : ....

2nd supervisor name : ....

Date : ....

INVESTIGATION OF TURBINE BLADE FAILURE AND STRESS DISTRIBUTION BY MSC NASTRAN PATRAN IN CARGO SHIP TURBOCHARGER

CHIA HWEE SIANG

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Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

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DECLARATION

"I hereby, declare this thesis is result of my own research except as cited in the references"

Signature	: ………………………….
Author's Name	: CHIA HWEE SIANG
Date	: 10/04/2009

Specially dedicated to my family, friends and companion

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ABSTRACT

MSC Nastran Patran technique was used to simulate and analysis for the turbocharger turbine blade failure investigation. The Finite Element Method (FEM) is applied and used for the turbine blade simulation for identifies the failure region and point by the stress distribution. The Finite Element Method (FEM) findings and results are a major consideration in design. Furthermore, the loads, boundary condition and material properties are defined. The Finite Element Model is submitted for the structural analysis once is completed. The similar turbine blade simulations from the literature study are referred and study in order to achieve the objectives of the Projek Sarjana Muda (PSM). The simulation results revealed that the stress distribution on the turbine under the various case such as comparison of dimension which is 80 mm, 100 mm (original dimension) and 120 mm and materials, Inconel X-750, Inconel 718 (original material), Inconel 650 and Inconel 620. Meanwhile, the result verified that Inconel 718 with 80 mm turbine blade provided higher Young's Modulus and stiffness characteristic in the project. Inconel 718 is well representative material for turbine blade due to the ability of withstands high pressure and temperature and insures the long wear life. Thus, the Inconel 718 and 80 mm dimension blade is applied in the overall simulation. The simulation result is indicated that the blade root is withstanding highest pressure which is showed the good agreement with the realistic turbine blade failure. The MSC Nastran/Patran is powerful method used to identify the critical areas at the turbine blade where the weakness point appear base on stress distribution result and essential to the marine industrial.

ABSTRAK

Teknik MSC Nastran Patran digunakan untuk mesimulasi dan analisis siasatan kegagalan bilah turbin turbocharger. Finite Element Method (FEM) diaplikasikan dan digunakan untuk simulasi bilah turbin untuk mengenal pasti rantau and kawasan kegagalan oleh agihan tekanan. MSC / Patran adalah pra-pemproses untuk simulasi CAE. Tujuan Solidwork (CAD) adalah untuk mencipta peragaan bilah turbin turbocharger. Peragaan bilah turbin diinput kepada MSC / Patran. Tambahan pula, daya, syarat sempadan dan ciri-ciri bahan oleh bilah turbin didefinisikan. Bilah turbin serupa simulasi-simulasi daripada kajian literature adalah dirujuk dan mengkaji untuk mencapai matlamat-matlamat Projek Sarjana Muda (PSM). Simulasi menunjukkan agihan tekanan keputusan pada bilah turbin daripada perbandingan kes-kes seperti dimensi-dimensi 80 mm, 100 mm (dimensi asal) dan 120 mm serta bahan bahan perbezaan, Inconel X-750, Inconel 718 (bahan asal), Inconel 650 dan Inconel 620. Keputusan menunjukkan Inconel 718 dengan 80 mm bilah turbin mempunyai Young’s Modulus paling tinggi dalam project ini dan menunjukkan keputusan yang paling sentuju dengan keputusan kegagalan yang sebenar. Selain itu, Inconel 718 adalah bahan yang paling sesuai untuk menahan tekanan dan suhu yang tinggi dalam implikasi turbocharger. MSC Nastran/Patran program adalah satu kaedah yang berkesan digunakan untuk menentukan agihan tekanan dan kawasan yang lemah wujud dalam bilah turbin.

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LIST OF SYSMBOLS

F	=	Force Acting to the Turbine Blade Surface, N
p	=	Pressure Acting to the Turbine Blade Surface, pa
A	=	Turbine Blade area, m^2
M	=	Bending Moment, Nm^{-2}
I	=	Moment of Inertia, m^4
C	=	Carbon
Mn	=	Manganese
S	=	Sulphur
Ni	=	Nickel
Cr	=	Chromium
Fe	=	Iron
Si	=	Silicon
Cu	=	Copper
Al	=	Aluminum
Mo	=	Molybdenum
P	=	Phosphorus

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CHAPTER 1

INTRODUCTION

1.1 Overview

Turbocharger is a forced-induction compressor powered by engine exhaust gas. The purpose of turbocharger is to increase the mass entering the engine to generate more power for marine application. The turbocharger turbine, which consist of a turbine wheel and a turbine housing, convert the engine exhaust gas into mechanical energy to drive the compressor impeller. The exhaust gas is restricted by the turbine's flow cross-sectional area and thus result the pressure and temperature drop between inlet and outlet of turbocharger. This pressure drop is converted by turbine into kinetic energy to drive the turbine rotor. There are two main turbine types of turbocharger, axial flow and radial flow. In an axial turbine for exhaust gas turbochargers, the inner wall of the rotationally symmetrical exhaust gas deflection duct is designed as a deflection collar rigidly connected to the turbocharger shaft and rotating with it.

In modern gas turbine turbocharger, the turbine performance increases as the pressure drop between the inlet and outlet increase. Thus, the turbine rotor blade inlet temperature has been increased in order to increase power and achieve higher efficiency. However, this has resulted in a higher heat load and thermal stress on turbine component. The turbine blade tips are one of the most critical regions susceptible to failure due to the large thermal load and heat load and difficulty in cooling. Furthermore, for the typical gas turbine rotor blade, there is a gap between the rotating blade tip and the stationary shroud surface called the tip gap. Rotor blade tip failure is caused primarily by hot leakage flow through the tip gap due to the pressure difference between the blade pressure side and suction side, causing a thin boundary layer and a high heat transfer coefficient. Therefore, sophisticated cooling technique must be employed to cool the blade tip in order to maintain the performance requirements.

For typically marine application turbocharger, the turbine rotor is operated at high revolution speed that is often in excess of 10000 rpm. Failures in blades are suspected to occur as a result of thermal mechanical stresses or fatigue load. Moreover, other causes of turbine blade crack such as creep-rupture as well as resonant vibration of turbine rotor. A crack blade can be enough to throw the turbocharger assembly out of balance. The imbalance will prevent the system achieved the maximum rpm and eventually pound the shaft bearing out of round. The present study investigates the possible causes of the failure of turbine blades. MSC Nastran/Patran is used to calculate the thermal centrifugal stresses and natural frequency to find the position failure of turbine blade. Low Cycle Fatigue (LCF) lives of blades are roughly estimated by using the stress and strain level determined by MSC Nastran/Patran. However, the investigation indicates that the failure with resonant force and High Cycle Fatigue (HCF).

Analysis the geometrical design for the broken and crack turbine blade of turbocharger by considering the various size of turbine blade used such as 8 cm, 10 cm or 12 cm of turbine blade. Furthermore, as could be observe from the original conventional cargo ship turbocharger design, the turbine blade dimension is in approximately 10 cm such variation in between 8 cm to 12 cm is considered in this study and simulation in the event that it can operate and inherently converting exhaust gas to rotate the compressor, and hence improved the efficiency of the system. Moreover, it most complies with the design specification such that the clearance between the turbine blade and the housing is in tolerable. On the other hand, various materials analysis is presented. The development of materials improved the properties as well as turbine efficiency. In addition, some simulation on the turbine blade will be simulated to observe the deformation and the stress distribution that lead the to the turbine blade failure.

1.2 Objective of the Project

The project is to analysis the characteristic turbine blade in cargo ship diesel engine turbocharger. The present study investigated the possible cause of the turbine blade failure. Thermal centrifugal stresses and frequency are calculated to detect the turbine blade failure region. The main objectives in this project study are as following:

i. To investigate the possible causes of turbine blade failure in marine application.
ii. To model the conventional turbocharger turbine blade based on the actual dimension and geometry in cargo ship engine.
iii. To simulate the turbine blade failure using Nastran/Patran.

1.3 Scope of the Project

The project is involved the simulation and specific field on the turbocharger turbine blade analysis. Thus, the scopes are listed as following:

i. Literature review and study of turbine blade used in conventional cargo ship engine turbocharger.
ii. The 3-dimensional view drawing of actual dimension turbine blade by using Solid work for the further simulation.
iii. Simulation of turbine blade using Nastran/Patran on static stresses distribution analysis and deformation.
iv. Obtain simulation at different condition such as the various dimension of turbine blade (8cm, 10 cm, 12 cm) being used and different materials configurations.
v. Simulation identified the optimum blade profile in which the region of turbine blade that can sustain the higher pressure, force and stresses under operating condition.
vi. To understand the turbocharger turbine blade profile.
vii. Numerical study and design of turbine blade under high temperature and rotational speed.

1.4 Problem Statement

The conventional turbocharger turbine blade facing the crack and broken turbine blade due to the thermal stresses, higher thermal load from exhaust gas, materials, design error that cause the failure and thus, throw the assemble out of balance as well as lead the vibration of the system. Generally, these problems are affecting due to the increased of pressure drop between inlet and outlet to increased power and efficiency. Hence, the inlet temperature of turbine rotor is increased. This has resulted in a higher heat load and thermal stresses of turbine components. The turbine blade tips are one of the most critical regions susceptible to failure due to the large thermal load and heat load and difficulty in cooling. During the performance test of turbocharger by other study, failures in blade tip trailing edge occurred and cracks were found in the mid regions of the blade edges illustrated in Figure 1.1 and Figure 1.2. Thus, this study is purposed to investigate the position of blade failure occurred by the Finite Element Method (FEM).

Figure 1.1: Upper Views of the Failed Blade and Surrounding

(Source: Poursaeidi, E. et. al. (2007))

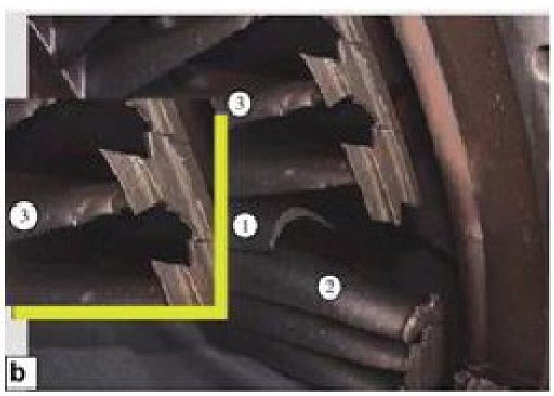

Figure 1.2: Leading Edge Damage in Turbine Blade

(Source: Poursaeidi, E. et. al. (2007))

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The turbocharger turbine which consist of a turbine wheel and turbine housing, converts the engine exhaust gas into mechanical energy to rotate the compressor. The engine exhaust gas is restricted by turbine’s flow cross-sectional area and thus result the pressure and temperature drop between the inlet and outlet. Furthermore, this pressure drop is converted by the turbine into kinetic energy for the purpose to drive the turbine wheel. On the other hand, the turbine performance is directly proportional to the pressure drop between inlet and outlet. The conventional turbine blade usually made of cast iron, steel or aluminum which converts the steam to drive the compressor.

2.2 Background

Hou, J.F. et. al. (2000) had preceded an investigation of fatigue failures of turbines blade in gas turbine engine by mechanical analysis. Blade failures in gas turbine engines often lead to loss of all downstream stages and can have a dramatic effect on the availability of the turbine engines. Through failure investigation is essential for the effective management of engine airworthiness. In this paper blade fatigue failures are investigated by mechanical analyses and by examination of failed blades. A series of mechanical analyses were performed to identify the possible causes of the failures by