FINITE ELEMENT ANALYSIS OF UPPER CRANKSHAFT SIX STROKE ENGINE USING CAE SOFTWARE

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A dissertation submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering with Automotive Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2009

SUPERVISOR’S DECLARATION

I hereby declare that I have checked this thesis and in my opinion this thesis is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

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DEDICATION

This project is dedicated to both of my beloved parents,
Anidin bin Hj. Muhammad Nor & Zaitun Hj. Norsidek
for their priceless love and support.

ACKNOWLEDGEMENT

In the name of Allah, the Most Benevolet, the Most Merciful. Alhamdulillah, all praise to the al mighty god, Allah swt for the countless goodness that are given to me and all the required necessity to complete this project.

In particular, I wish to express my sincere appreciation to my main thesis supervisor, Mr. Mohd Rashidi Bin Maarof, for all his endless supports, encouragement, guidance, compromise and advise, without him I would not have been able to complete this final year project successfully.

My sincere gratitude to Dr Mustafizur Rahman who willing to assist and guide me to succeed in spite of his busy schedule. His compliments and critics had helped me most in keeping me focused on my project and to finish in time. Also thanks for his kindness to share his knowledge on the software.

I am also indebted to Universiti Malaysia Pahang (UMP) for providing internet facility. Librarians at UMP also deserve special thanks for their assistance in supplying the relevant literatures. Their views and tips are useful indeed.

Special thanks to my beloved parents for all their loves and encouragement to excel in this project. Thanks for their continuous support through all the hard time and for their trust in me.

Not to forget my appreciation to all of my lecturers and my fellow undergraduates' friends for their kindness to provide assistance and shared all the useful knowledge they had with me to complete this project. Finally I would like to thanks all person who had helped me learn the used software.

ABSTRACT

This dissertation describes the stress distribution of the upper crankshaft for six stroke engine by using finite element analysis. The finite element analysis is performed by using computer aided engineering (CAE) software. The main objectives of this project are to investigate and analyze the stress distribution of upper piston at the real engine condition during combustion process. The dissertation describes the mesh optimization with using finite element analysis technique to predict the higher stress and critical region on the component. The upper crankshaft is implemented in the six stroke engine of 110 cc Modenas motorcycle. Aluminum 356-T7 is selected as an upper crankshaft material. Despite all the stresses experience by the upper crankshaft does not damage the upper crankshaft due to high tensile strength but the upper crankshaft may fail under fatigue loading. Thus, it is important to determine the critical area of concentrated stress for appropriate modification. With using computer aided design (CAD) which is SOLIDWORK, the structural model of an upper crankshaft is developed. Furthermore, the finite element analysis performed with using MSC PATRAN and MSC NASTRAN. The stress analysis results are significant to improve the component design at the early developing stage. The result can also significantly reduce the cost and time to manufactured the component and the most important to satisfy customer needs.

ABSTRAK

Disertasi ini menggambarkan serakan tekanan terhadap crankshaf atas dengan menggunakan keadah analisis elemen terhingga. Kaedah analisis elemen terhingga dilakukan dengan menggunakan perisian kejuruteraan bantuan computer (CAE). Objektif utama projek ini adalah untuk mengkaji dan menganalisis serakan tekanan terhadap crankshaf atas dalam keadaan sebenar enjin semasa proses pembakaran. Disertasi menggambarkan pengoptimuman jala dengan menggunakan teknik analisis elemen terhingga untuk menjangka tekanan yang lebih tinggi dan kawasan kritikal pada komponen. Crankshaf atas digunakan pada enjin motorsikal Modenas enam lejang 110 cc. Aluminum 356-T7 dipilih sebagai bahan crankshaf atas. Meskipun semua tekanan yang dialami oleh crankshaf atas tidak merosakkan crankshaf tetapi crankshaf atas mungkin rosak apabila daya lesu dikenakan. Oleh demikian, sangat penting untuk menentukan kawasan kritikal yang ditumpu oleh tekanan untuk pengubahsuaian yang sesuai dapat dilakukan. Dengan menggunakan perisian lukisan bantuan komputer (CAD) iaitu solidwork, model struktur crankshaf atas dapat dihasilkan. Seterusnya, analisis elemen terhingga dilakukan dengan menggunakan PATRAN MSC dan MSC NASTRAN. Keputusan analisis tekanan amat berguna untuk memperbaiki reka bentuk komponen pada tahap awal penghasilan. Keputusannya juga dapat mengurangkan kos dan masa untuk menghasilkan komponen dan yang paling penting bagi menjamin kepuasan dan memenuhi kehendak pelanggan.

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LIST OF NOMENCLATURES

ρ	Density
k	Thermal conductivity
T	Temperature
E	Modulus of elasticity
σ_{UTS}	Ultimate Tensile strength
P	Pressure
mm	Millimetre
E	Exponent
Pa	Pascal
MPa	Megapascal
GPa	Gigapascal

LIST OF ABBREVIATIONS

Al	Aluminium
CAD	Computer-aided Design
CAE	Computer-aided Engineering
FE	Finite Element
FEM	Finite Element Modeling
FEA	Finite Element Analysis
FVM	Finite Volume Method
FDM	Finite Different Method
2D	Two Dimension
3D	Three Dimension
TET	Tetrahedral
cc	Centimetre Cubic
CPU	Central Processing Unit
MPC	Multi Point Constraints

SAE	Society of Automotive Engineers
ASME	American Society of Magazine Editors
Max	Maximum
Min	Minimum

CHAPTER 1

INTRODUCTION

1.1 Background

UMP has come to a challenge to create a first national motorcycle engine with six stroke system by taking Modenas motorcycle four stroke engines as the main subject for the modification. The concept of the engine was inspired from Ducati motorcycle engine system which has been the pioneer of this type of engine. There are few slight differences between a six stroke motorcycle engine and a conventional motorcycle engine where the engine was designed with additional piston and crankshaft at the upper part of the cylinder block. The engine was initially use four stroke system but the additional upper part will operate in the same cylinder which will add 2 extra strokes from the upper cylinder. The six stroke system will increase the pressure ratio of the compression stage thus the efficiency of the engine will be increased.

The six stroke engine also has additional crankshaft which directly attached to the upper piston. This project will be specifically analyze this upper crankshaft using CAE software since this is the first study to be carry out using simulation on this engine. The failure analysis will be carried out and this project is focused on determination of computational maximum stresses resulting from combustion pressure on the crankshaft during steady state condition. Stresses that are involved due to above load are analyzed using CAE software.

The crankshaft is the principal member of the crank train or crank assembly, which latter converts the reciprocating motion of the pistons into rotary motion or vice versa. As a rule, crankshafts are forged in a single piece, but occasionally they are built up. Built-up crankshafts are used in small single- and double-cylinder motorcycle engines. The enclosed flywheels of these engines take the place of the crank arms, the crankpin and crank journals being bolted to the flywheels, which latter are cast with solid webs. The built-up construction also has advantages when it is desired to support the crankshaft in three or more ball bearings, as with a one-piece shaft all intermediate bearings would have to be stripped over the crank arms, and therefore would have to be made extraordinarily large.

Advanced engineering analysis and design validation are increasingly needed by major manufacturers and designers. This frequently leads to an increase in the sophistication of the methods and technologies required. The distance between solid modellers and analysis engineers has nowadays almost disappeared. The three types of software that used in this project are SOLIDWORK (CAD), Msc.PATRAN (CAE) and Msc.NASTRAN(CAE). The analysis types that are use with the CAE software are Static Stress with Linear Material Model. From the simulation result of the upper crankshaft, locations of weak-spots can be located and the maximum stress at each location can be analyzed.

1.2 PROJECT TITLE

Finite Element Analysis of Upper Crankshaft Six Stroke Engine Using CAE Software

1.3 PROJECT OBJECTIVES

- To develop a structural design of upper crankshaft of six stroke engine.
- Identify the suitable mesh properties for the simulation.
- To analyze the stress of the crankshaft using finite element analysis (FEA) in different orientation

1.4 PROJECT SCOPES

- Structural modeling using SOLIDWORK.
- Mesh optimization for the accurate simulation.
- Finite Element modeling and analysis using MSC. Patran and MSC. Nastran.

1.5 PROBLEM STATEMENTS

This project will focus on the study of maximum stresses on an upper crankshaft of six stroke motorcycle engine at steady state condition resulting from engine combustion pressure during starting the engine.

1.6 FLOW CHART

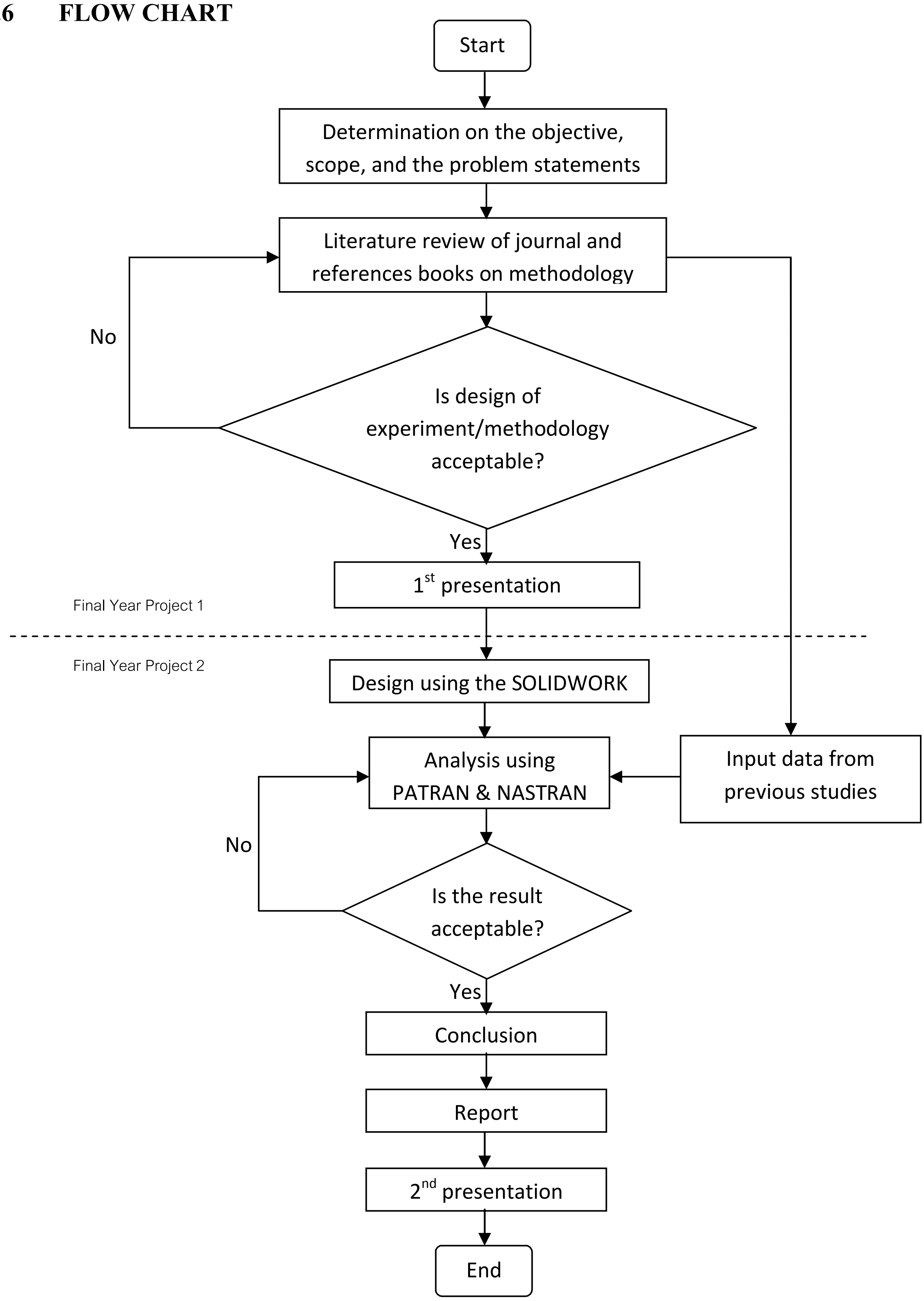

Figure 1.6: Flow chart of project

CHAPTER 2

LITERATURE STUDY

2.1 SIX-STROKE ENGINE

The six-stroke engine is a type of internal combustion engine based on the four-stroke engine, but with additional complexity to make it more efficient and reduce emissions. Two different types of six-stroke engine have been developed since the 1990s.

In the first approach, the engine captures the heat lost from the four-stroke Otto cycle or Diesel cycle and uses it to power an additional power and exhaust stroke of the piston in the same cylinder. Designs use either steam or air as the working fluid for the additional power stroke. The pistons in this type of six-stroke engine go up and down six times for each injection of fuel. There are two power strokes: one with fuel, the other with steam or air. The currently notable designs in this class are the Crower six-stroke engine, invented by Bruce Crower of the U.S. ; the Bajulaz engine by the Bajulaz S.A. company of Switzerland; and the Velozeta Six-stroke engine built by the College of Engineering, at Trivandrum in India.

The second approach to the six-stroke engine uses a second opposed piston in each cylinder that moves at half the cyclical rate of the main piston, thus giving six piston movements per cycle. Functionally, the second piston replaces the valve mechanism of a conventional engine but also increases the compression ratio. The currently notable designs in this class include two designs developed independently: the Beare Head engine, invented by Australian Malcolm Beare, and the German Charge pump, invented by Helmut Kottmann.

Blair (1990) studied about two-stroke engine which is the piston controlled the intake opening and closing that combine the intake and compression stroke in 180° crank rotation. For four-stroke engine, the cycle is more fuel-efficient, clean burning and higher engine power output compare to the two-stroke engine due to higher volumetric efficiency, higher combustion efficiency and low sensitivity to pressure losses in exhaust system. A single-cylinder two-stroke engine produces power every crankshaft revolution, while a single-cylinder four-stroke engine produces power once every two revolutions (Rajput, 2005). The two-stroke engine operational concept is applied to the original existing four-stroke engine cylinder head. The combination of this two engine operation is called six-stroke engine. There will have two pistons which are upper piston and the original four-stroke piston at the bottom in one cylinder of engine head. The ratio of stroke between upper piston and original four-stroke piston is 4:2 (Beare, 1998).

2.2 ALUMINUM 356-T7 (Al 356-T7)

Aluminum's appearance is dulled and its reactivity is passivated by a film of aluminum oxide that naturally forms on the surface of the metal under normal conditions. The oxide film results in a material that resists corrosion. A unique combination of properties makes aluminum one of our most versatile engineering and construction materials. A mere recital of its characteristics is impressive. In term of light weight, aluminum 356-T7 has a density (ρ) of 2.68 Mg/m^3, compared with 7.9 Mg/m^3 for iron. Hence, for the same component, the aluminum will be about one-third of the mass of the iron version and make aluminum crankshaft is more lightweight compare to cast iron crankshaft.

Aluminum has a great affinity for oxygen and any fresh metal in air rapidly oxidizes to give a thin layer of the oxide on the surface. This surface layer is not penetrated by oxygen and so protects the metal from further attack. This self-protecting characteristic gives aluminum its high resistance to corrosion. Unless exposed to some substance or condition that destroys this protective oxide coating, the metal remains fully protected against corrosion (Kalpakjian, 1995). Next, aluminum has high thermal conductivity compare to cast iron. The high thermal conductivity enables heat to be more rapidly conducted away and so result in the crankshaft running at a lower temperature and increase the crankshaft lifespan (Philip & Bolton, 2002).

At temperature (T) up to about 300 ˚C in the engine, the material used must retain its properties (Rajput, 2005). High thermal expansion is however a problem for aluminum. Table 2.2 gives properties data for aluminum 356-T7.

Table 2.2: Properties of Aluminum 356-T7

Material	Aluminum 356-T7
Density, ρ (Mg/m³)	2.7
Poisson Ratio	0.35
Modulus of Elasticity, *E* (Gpa)	72.4
Ultimate Tensile Strength, σ_{UTS} (MPa)	172

Source: Budynas & Nisbett (2008)