"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Mechanical Engineering (Structure-Material)"

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Date : 30 MEI 2006

DYNAMIC FORCES & STRESS RESULTANT IN A CONNECTING ROD

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This thesis is submitted to Mechanical Engineering Faculty in partial fulfillment of the requirements for the award of Bachelor's Degree in Mechanical Engineering (Structure & Material)

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May 2006

"I hereby declare that this thesis entitled "Dynamic Forces & Resultant Stress in a Connecting Rod" is the result of my own research except as cited in the references"

Signature :

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Date : 29/5/06

Dedicated to my beloved Mother, family and to

Mr. Muhammad Zahir Hassan,

for their love, support and prays

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ABSTRACT

This research involves major areas of the connecting rod design that include computer simulation, the use of laboratory experimentation and consideration theories of failure. There is prediction of dynamic forces and internal stress resultant acting on the connecting rod from PROTON Wira engine. An MSC.ADAMS model of the crank, connecting rod and piston were built in order to predict the dynamic loads acting at the little and big end of the connecting rod. Then, MSC.ADAMS can be used to obtain the variation of quantities such as angular velocity, angular acceleration, and force in x-axis and y-axis. The connecting rod direction of motion must be identifying to make sure the stress is acceptable due to the force.

Then, the predicted loads were used as inputs to a finite element model by using COSMOSXpress. In this part of the research, there is experimental work needed to determine the mass moment of the connecting rod and compare it with theoretically determined values. The factor of safety was used in this work to quantify severity of the applied stresses with respect to the available strength.

ABSTRAK

Kajian ini melibatkan beberapa kawasan penting dalam rekabentuk rod penyambungan piston termasuklah simulasi berkomputer, penggunaan eksperimen di makmal dan pertimbangan dalam teori kegagalan. Terdapat juga ramalan daya dinamik dan tekanan yang terhasil pada rod penyambungan piston daripada enjin PROTON Wira. Pada model aci engkol dalam MSC.ADAMS, rod penyambungan piston dibina menyikut susunan untuk meramalkan daya dinamik yang berlaku pada penyambungan besar dan kecil pada rod penyambungan piston. Kemudian, MSC.ADAMS boleh digunakan untuk mendapatkan beberapa perbezaan nilai seperti halaju sudut, pecutan sudut dan daya pada paksi x dan paksi y. Pergerakan dan arah rod penyambungan piston haruslah dikenalpasti terlebih dahulu untuk memastikan tekanan yang diperolehi diterima mengikut daya yang dikenakan.

Kemudian, ramalan daya yang diperolehi digunakan sebagai input dalam model elemen terhad dengan menggunakan COSMOSXpress. Dalam bahagian kajian ini, eksperimen haruslah dilakukan bagi mendapatkan momen jisim rod penyambungan piston dan dibandingkan mengikut nilai teori dan nilai eksperimen. Faktor keselamatan digunakan dalam kajian ini untuk menjumlahkan tekanan yang diperolehi dengan memberi perhatian yang lebih bagi mendapatkan kekuatan pada rod penyambungan piston.

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SYMBOL	DEFINITION
I_o	Mass Moment of Inertia
F	Force
m	Mass
a	Angular Velocity
r	Radius of Angle
T	Torque
k	Radius of Gyration
I_G	Mass Moment of Inertia for General
M	Moment
b	Width
d	Length
R	Radius
G	Mass Centre
P	Any Other Point
f	Frequency
$\overline{y}$	Centre of Mass Force
h	Height
T_A	Time Period When Suspended At Point Big End
T_B	Time Period When Suspended At Point Little End
K_G	Radius of Gyration
a	Distance From Point Big End to Centre of Gravity
b	Distance From Point Little End to Centre of Gravity

Fx	Force at Crankshaft Angle for Connecting Rod Little End in x-axis
Fy	Force at Crankshaft Angle for Connecting Rod Little End in y-axis
F_R	Resultant Force at Crankshaft Angle for Connecting Rod Little End

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CHAPTER 1.0

INTRODUCTION

1.1) Overview

This project studied the prediction of dynamic forces and stress resultant acting on the connecting rod from a PROTON Wira engine. Connecting rods are subjected to mass and gas forces and results in axial and bending stresses. Bending stresses are due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore, a connecting rod must be capable of transmitting axial tension, axial compression, and bending stresses caused by cycle on the piston and by centrifugal force. Commonly, failure of a connecting rod is one of the most common causes of engine failure in cars. The problem is when the broken rods frequently put through the side of the crankcase and destroy the engine beyond repair.

From this situation, it can result from overheating, a physical defect, or failure of the rod bolts from a defect or improper tightening. But, now day's car companies have found the solutions to the problem. When building a high performance engine, the connecting rods are the great attention to be paid. So, to eliminate the stress, risers in connecting rod are important. There is a technique of grinding the edges of the rod to a smooth radius to reveal otherwise a small crack which would cause the rod to fail under stress.

In connecting rods, the most important fasteners in any engine are the connecting rod bolts, as they hold the key to the entire rotating assembly. The rod bolts must support the primary tension loads at the big end caused by each rotation or cycle of the crankshaft. When the crank rotates, the big end of the connecting rod essentially becomes oval-shaped and the rod bolts bend. In addition to utilizing a rod bolt with sufficient strength to withstand the tremendous cyclical strains placed upon it, it is absolutely imperative that the bolts must be properly tightened. The big end of the connecting rod is fabricated as a unit and cut or cracked in two to establish precision fit around the big end bearing shell. When rebuilding an engine, care must be taken to ensure that the caps of the different con rods are not mixed up. Therefore, the big end caps are not interchangeable between connecting rods.

1.2) Statement of Problems

The overall aim of this project is to investigate the strength of the pistons by using both finite element analysis (FEA) and experimental modal analysis of connecting rod. The force and the stress at the little end and big end of the connecting rod are important that would be useful for a fully complete analysis. In the engine, there are frictions and high temperature in the piston's cylinder and this can affect the structure.

The FEA software is used to analyse the behaviour of the connecting rod and the experimental modal analysis is carried out to support the computational modelling. Modal properties, namely mode shape of connecting rod can be obtained through FE model prediction. From existing geometry of the connecting rod, the 3D model is created using MSC.ADAMS program and exported to COSMOSXpress to obtain the stress resultant in the connecting rod. In MSC.ADAMS program, the dynamic force of the connecting rod can be predicted equal to the geometry of the connecting rod.

1.3) Objectives

This part of the research is involving the prediction of dynamic forces and internal stress resultants acting on the connecting rod from PROTON Wira. MSC.ADAMS model of crank, connecting rod and piston are build in order to predict the dynamic loads acting at the little and big end of the connecting rod. The predicted loads should be used as inputs to a finite element model using a simplified 2D representation of the connecting rod geometry in MSC.NASTRAN. In this part of the research the mass moment of the connecting rod is determined by experimentation and to compare this with theoretically determined values.

On completion of this research, the objectives are:

1. Estimate the mass moment of inertia of a component by experiment and theory.
2. Predict accelerations, dynamic loads and stress resultants in a plane mechanism through computer simulation (MSC.ADAMS & COSMOSXpress)
3. Discuss theories of failure for a component.

1.4) Connecting Rod Description

In piston engine, the connecting rod connects the piston to crankshaft. They are not rigidly fixed at either end, so that the angle between the con rod and the piston can change as the rod moves up and down and rotates around the crankshaft. The connecting rod is usually made of steel, but to get high performance, it can use titanium or aluminium. There are two parts of connecting rod called little end and big end. The small end attaches to the piston pin or wrist pin, which is most typically press fit into the connecting rod but can swivel in the piston. The big end connects to the journal bearing on the crank throw. Typically, the big end has a pin bored through the bearing so that the big end can pressurized the lubricating motor oil to squirts onto the cylinder wall for lubricating the travel of the pistons and piston rings. The connecting rod is under tremendous stress from the reciprocating load by the piston. The load also increases rapidly with increasing engine speed.

1.5) Definition of Dynamic Force and Resultant Stress in Connecting Rod

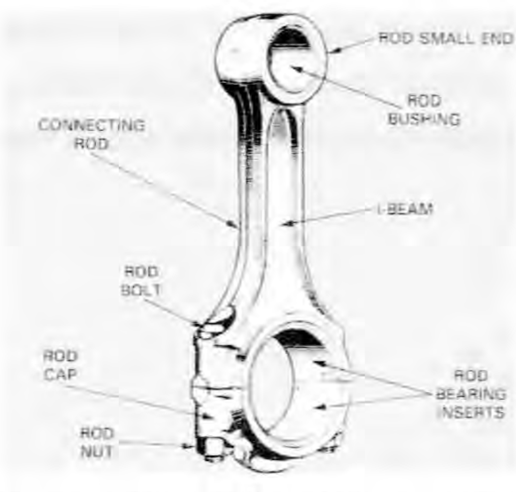

Figure 1: Connecting Rod Nomenclature

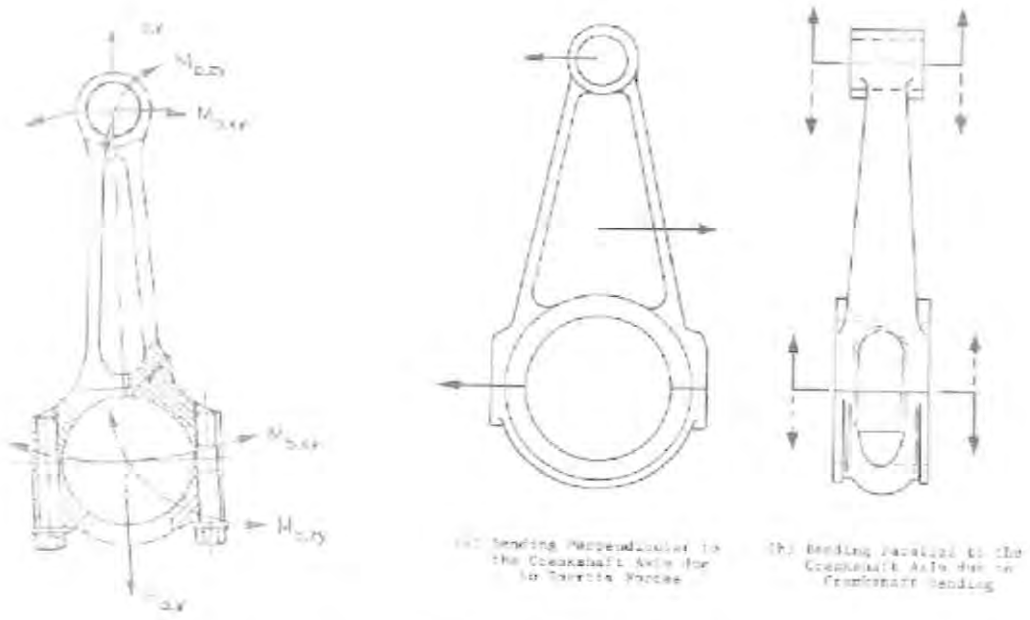

Figure 2: Loading of Connecting Rod

The connecting rod undergoes a complex motion, which is characterized by inertia loads that induce bending stresses. In view of the objective of this study, it is essential to determine the magnitude of the loads acting on the connecting rod. In addition, the significance of bending stresses caused by inertia loads needs to be determined, so that we know whether it should be taken into account or neglected during the optimization. Nevertheless, a proper picture of the stress variation during a loading cycle is essential from fatigue point of view and this will require finite element analysis, FEA over the entire engine cycle.

Connecting rods are subjected to mass and gas forces. The superposition of these two forces results in axial and bending stresses. Bending stresses originate due to eccentricities, crankshaft, case wall deformation, and rotational mass force. Therefore, a connecting rod must be capable of transmitting axial tension, axial compression, and bending stresses caused by the thrust and pull on the piston and by centrifugal force. A connecting rod is subjected to several millions of repetitive cyclic loadings. It is, therefore, typically designed for infinite-life and the primary design criterion is endurance limit. The loading is constant amplitude axial tension and compression and multi-directional variable amplitude bending, as inertia force, torque and moment are all functions of engine speed (rpm).

Also, because of mass distribution, different mean loads, and therefore R-ratios (i.e. ratio of minimum stress to maximum stress) for particular areas of the connecting rod are obtained. In addition, a connecting rod should be designed with high reliability. It should be strong enough to remain rigid under the loading, while light enough to reduce the inertia forces which are produced when the rod and piston stop, change directions, and start again at the end of each stroke. Failures of connecting rods are often caused by bending loads, acting perpendicular to the axes of the two bearings. Failure in the shank section as a result of these bending loads can occur in any part of the shank between piston pin end and crank-pin end. At the crank end fracture failure can occur at the threaded holes or notches for the location of headed bolts. Pin-end failures can occur from fretting in the bore against a fitted bushing.

CHAPTER 2.0

LITERATURE REVIEW

2.0) Extend of Subject Area

2.1) Literature Review

2.1.1) Overview

Many recent papers in the literature indicate the resurgence of interest in the use of lightweight connecting rod materials for inertial force reduction, increased speed, and cost effective methods of manufacturing. The studies carried out in the literature cover a variety of topics related to connecting rods including load or stress analysis, durability analysis, manufacturing aspects, economic issues and cost analysis, and optimization studies.

2.1.2) Theory

The mass moment of inertia, I_o can be though for as a body's resistance to angular acceleration. The mass moment of inertia I_o is a function of the bodies mass and distribution of mass. The mass moment of inertia I_o can be calculated for a body:

Figure 3: Mass Moment of Inertia I

$F = m.a$ (1)

$a = \alpha.r$ (2)

$T = F.r$ (3)

Substitute equation (1) and (2) into (3)

$T = ma.r = mr^2\alpha$

Since; $T = I_o\alpha$

$I_o = mr^2$ (4)