FINITE ELEMENT ANALYSIS OF CAM AND ITS FOLLOWER CONTACT STRESS MECHANISM

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ABSTRACT

Camshaft can be defined as a machine element having the curve outlined or a curved grooved, gives the predetermined specified motion to another element called the follower. In automotive field, Camshaft and its follower take importance roles to run the engine. Nowadays the car maker have developed the vary schemes of cam profile to match with the engine performance. Since the system deals with high load and high speed and many analyses have been carried out on the failure of the components. The analysis is done either by experimental or finite element analysis. The result from the finite element analysis is an approximate of the component failure. In the mean time, the software development is improving in this few decades. Problems with the components such as cam and rocker arm are wears while the valve bends. This project aim determines the stress concentration on the cam and followers during normal operation. More over, this project used the cam, rocker arms, valve lifter, exhaust valve and accessories used in 4G13 engine in type. Solidworks, Cosmosmotion and Algor software are used for determination of stress concentration on the components. The finite element analysis are done for determination of stress concentration during 30 degree of cam where the roller fully climbing the cam and during maximum exhaust valve lift. Cam is rotated at 2000 rpm, 3000 rpm and 6000 rpm of crank rotation. In the analysis, the typical values for coefficient of friction, materials, and spring rate are used. The result from finite element analysis showed that the maximum stress concentration occurred at rocker arm that leads to the failure of the component. Value for maximum stress is over the allowable stress for rocker arm material. Other components are approximately safe where the maximum stress is not over the allowable stress for components.

ABSTRAK

Aci sesondol ialah salah satu mesin elemen yang mempunyai bentuk melengkung dan mempengaruhi pergerakan spesifik kepada elemen yang lain yang dinamakan pengikut. Di dalam automotif, aci sesondol dan pengikut mempunyai peranan yang penting to menggerakkan enjin. Masa sekarang, pengeluar kereta telah memperkenalkan pelbagai jenis aci sesondol untuk disesuaikan dengan keupayaan enjin. Memandangkan aci sesondol dan pengikut berfungsi pada keadaan tekanan dan kelajuan yang tinggi, banyak kajian telah dijalankan untuk mencari kegagalan dan kelemahan pada komponen tersebut. Kajian yanag dijalan sama ada melalui eksperimen atau analisis. Keputusan kajian melalui analisis adalah anggaran kegagalan pada komponen tersebut. Pada masa yang sama, banyak program komputer yang terkini diperkenalkan. Masalah yang wujud pada aci sesondol dan lengan jempelang ialah kerosakan pada komponen tersebut manakala injap bengkok. Projek ini menumpukan kepada tumpuan ketengangan pada aci sesongkol dan pengikut semasa keadaan pengunaannya yang normal. Selain itu, aci sesongkol dan pengikut didalam enjin 4G13 digunakan untuk tujuan analisa. Solidworks, Cosmosmotion dan Algor program digunakan untuk mencari tumpuan regangan pada komponen. Analisis telah dijalankan untuk mencari tumpuan regangan semasa sudut 30 pada aci sesondol ketika reroda hampir lengkap mendaki aci sesondol dan ketika pembukaan maksimum injap eksos. Aci sesondol berputar pada 2000 rpm, 3000 rpm dan 6000 rpm pada aci sesongkol. Di dalam analisis ini, nilai khusus untuk geseran, bahan dan kadar spring digunakan. Daripada analisis, tumpuan regangan yang maksimum wujud pada lengan jempelang. Nilai regangan melampaui nilai yang dibenarkan untuk lengan jempelang. Komponen lain dianggarkan selamat dimana nilai tegangan maksimum tidak melebihi nilai tegangan maksimum yang dibenarkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A	-	Apparent area of contact
Aa	-	Real area of contact
av	-	Valve acceleration
c	-	Radial clearance
ec	-	Eccentricity of the point of cam/tappet contact
E	-	Composite modulus of elasticity
E1, E2	-	Young's modulus for each materials
f	-	Friction coefficient
F	-	Friction force
Fb	-	Friction force due to hydrodynamic shear of lubricant
Fv	-	Viscous friction component in the mixed lubrication regime
h	-	Tappet lift
hv	-	Valve lift
Ic	-	Cam width
M	-	The total torque for one cam
Mf	-	The frictional torque for one cam
Mtot	-	The total torque for one cam
t	-	Viscous torque
u1, u2	-	Surface velocities of the cam and tappet with respect to the contact patch
u3	-	Sliding velocity
w	-	Cam width
δ	-	The temperature-viscosity coefficient
γ	-	Rate of change of shear stress with pressure
λ	-	Film thickness parameter
σ	-	Measured composite surface roughness
η	-	Dynamic viscosity of the lubricant

LIST OF ABBREVIATIONS

CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
CMM	-	Coordinate Measurement Machine
FEA	-	Finite Element Analysis
FMEP	-	Friction mean effective pressure
rpm	-	Round per minute
SLA	-	Stereolithography
SLS	-	Selective Laser Sintering

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

In the least decade, the automotive sector has reached a very high production capacity. This sector contributed in the world economy as this increasing capacity, its stable growth is anticipated in the world economy. The economic value of the work capacity in the automotive sector is estimated as 1.6 billion Euros and this figure shows that the automotive sector is the 6^{th} economic sector worldwide (Bayrakceken H. et al, 2005). The growth surely increased the production of automobile engine. Thus, the understanding of the engine component pays great importance in automotive industry.

Camshaft can be defined as a machine element having the curve outlined or a curved grooved, gives the predetermined specified motion to another element called the follower. The possible applications of cams are unlimited, and their shapes occur in great variety. In automotive field, most of the engines used the camshaft. Camshaft and its follower such as lifters, push rod, rocket arms, valves, valve springs, and cam bearings take importance roles to run the engine.

The key parts of any camshaft are the lobes. The lobes open and close the intake and exhaust valves as the camshaft rotate. As the engine speed change or increase, the cam profile is also change. The car maker now day have developed the vary schemes of cam profile to match with the engine performance. More over the camshaft will be perfect only at one engine speed. At any other engine, the camshaft will not perform to its fully potential.

The factors influences the camshaft and its follower performance are the material properties, lubrication system, system operating, and the mechanical contact stress. It will generate the friction, temperature and caused it to wear or broke.

Many studies have been carried out on the automotive failure analysis and showed that the camshaft and its follower on the automobile engine is fracture or wear caused by the material, contact stress, and the temperature change in the valve train. For the determination of the failure and wear reasons, a hands-on reverse engineering approach is using. The standard cam shape and its follower used in 4G15 engine types is measure. Two pieces of software are needed for this analysis, the SOLIDWORK and ALGOR V16. The mechanical and stress analysis is carried out for the determination approximation of failure factors. A comparing with traditional approach such as mathematical analysis, the results obtain by using the latest software is more accurate and easier to understand.

1.2 Problem Statements

Rocker arms and valves bend due to the mechanical contact stress. The rocker arm resist to moving until sufficient force is applied to them. As the result, the rocker arms bend or flex slightly. The cam is broken and resulted failure to the components. The failure of the cam is detected caused by the high load and high speed of the component during operation. The lubrication system and the microstructure composite also influence the failure of the camshaft and its follower. The temperature rise as the failure of the lubrication system and the material properties of cam and its follower caused it to wear or broke.

1.3 Objectives

To investigate the nature of cam and its follower during operation using CAE software

1.4 Scopes

Using CAE software to determine the experimental stress and finite element

i General / common cam used in automotive industry

1.5 Flow Chart

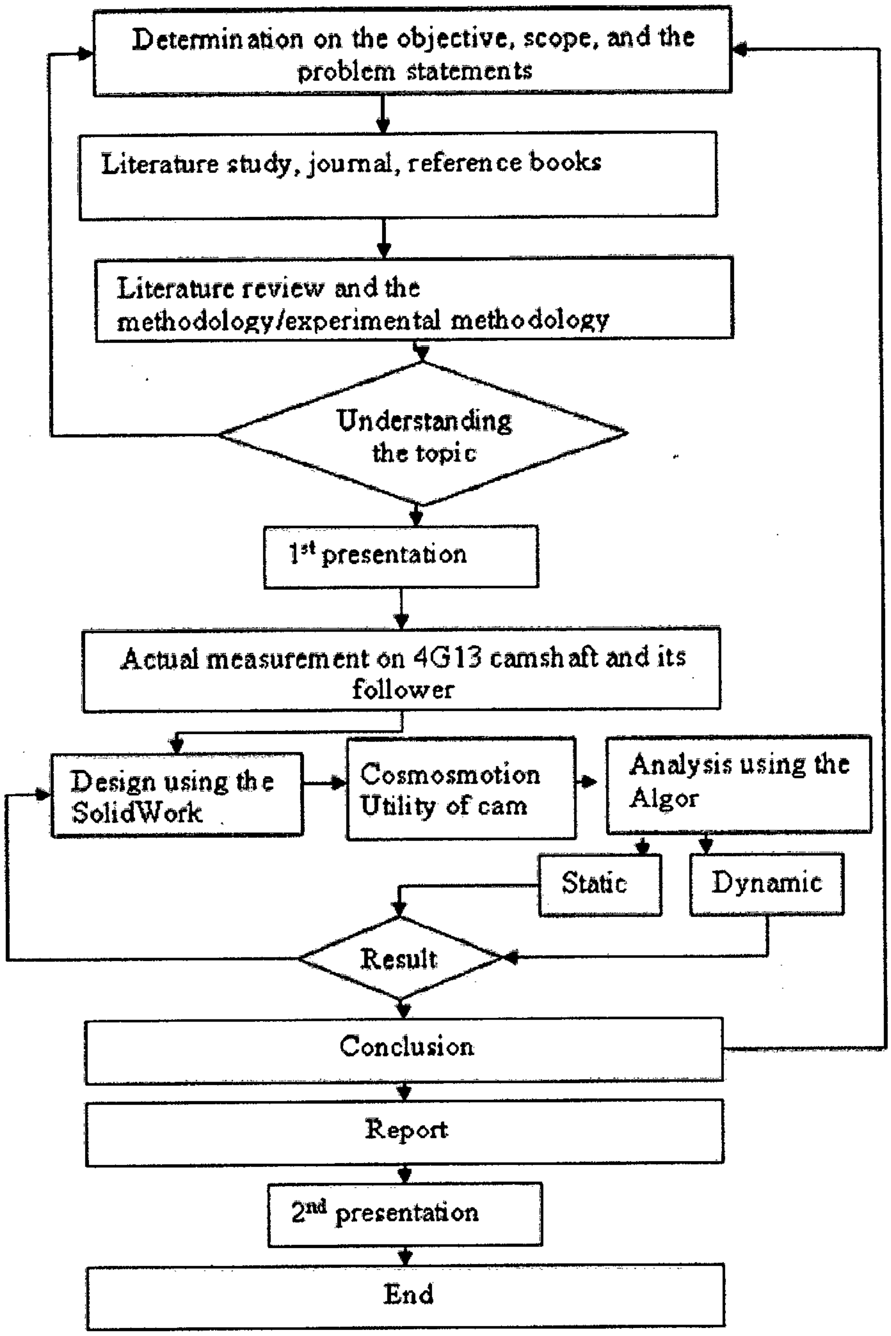

Figure 1.1 Flow chart for project.

1.6 Gantt Chart

	GANTT CHART / PROJECT SCHEDULE FOR FYP1																
	PROJECT ACTIVITIES	WEEKS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Discuss on the title of the FYP	■															
2	Discuss on the objectives and the scopes of the FYP		■														
3	Chapter 1 including the objectives, scopes, and the problem statements		■														
4	Submit the chapter 1. Discuss on the format of project		■	■													
5	Literature study. Find the information related to the literature review	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
6	Discuss on the chapter 2, the literature review, journal and related information				■												
7	Chapter 2.1, the introduction of cam shaft and its follower				■												
8	Discuss on the chapter 2.1.				■												
9	Chapter 2.2, introduction of CAE and CAD, and method analysis				■	■											
10	Discuss on the analysis and the methodology					■											
11	Chapter 3 the methodology					■	■	■	■								
12	Preparation for the presentation									■	■	■	■	■	■		

Figure 1.2 Gantt chart for final year project 1.

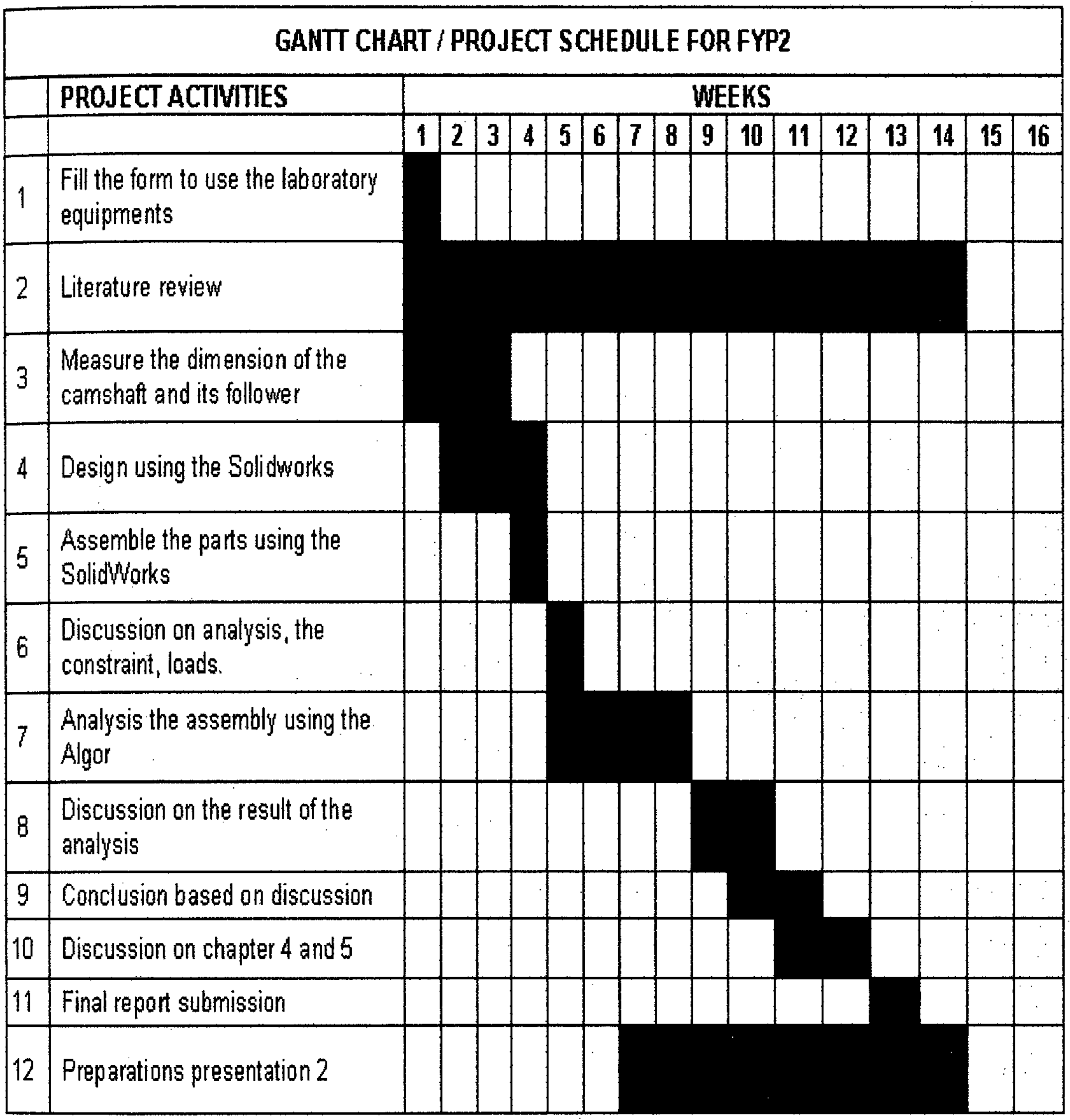

Figure 1.3 Gantt chart for final year project 2.

CHAPTER 2

LITERATURE REVIEW

2.1 Combustion Fundamental

There are four phases of operation per cycle on four stroke engines, each corresponding to an upward stroke of a piston. This mean there are two revolutions of the crankshaft in order to produce a power stroke. The details of the each phase within the four stroke cycle as follows:

Intake stroke:	The piston inside the cylinder travels downward, drawing the intake valve open and the mixture of air and fuel into the cylinder
Compression stroke:	As the engine continues to rotate, the piston is forced upward in the cylinder, compressing the air-fuel mixture
Power stroke:	when the piston gets near the top of the cylinder, the spark at the spark plug ignites the fuel-air mixture. The piston is forced downward
Exhaust stroke:	The engine continues to rotate, and the piston again moves upward in the cylinder. The exhaust valve opens, and the piston forces the burned gases out of the exhaust valve

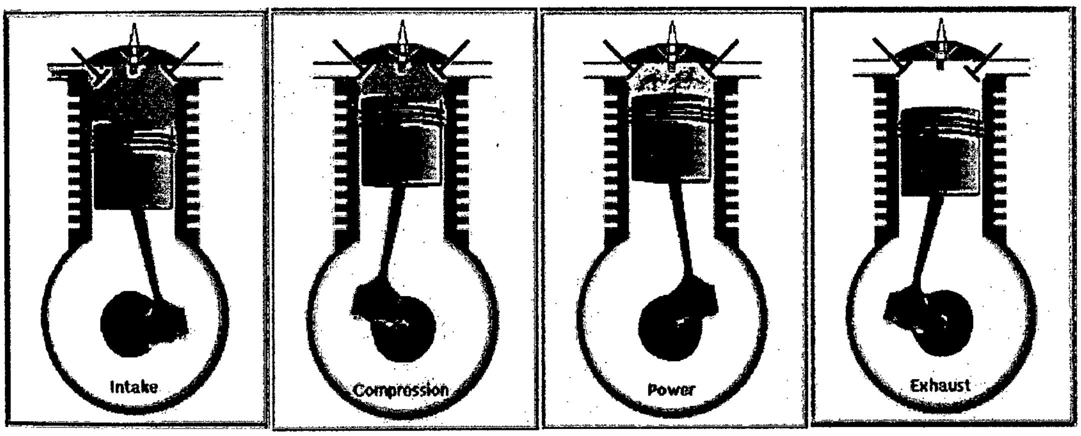

Figure 2.1 Four-stroke cycle diagram (Bew, 2002).

2.2 Engine Upper End

Parts of the upper end of the engine include the cylinder head and valve train. The valve train includes the parts that open and closed the valves. This part included the camshaft, lifters, pushrod, rocker arms, valves, and spring.

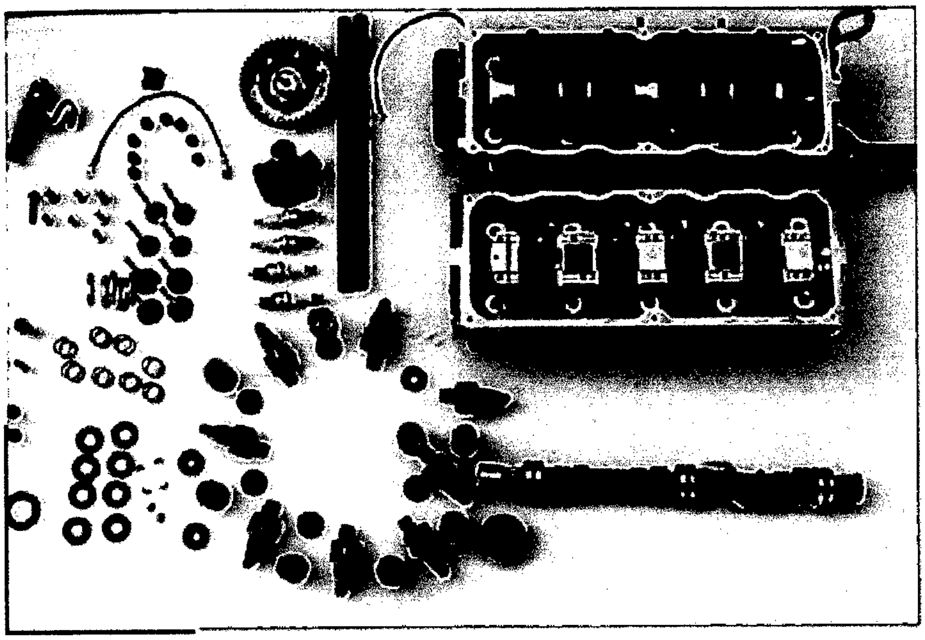

Figure 2.2 The valve train components (Crane cam ,2007).

2.3 Fundamental of Camshaft and its Follower

A cam mechanism is consisting of two moving elements, the cam and the follower, mounted on a fixed frame. The cam mechanisms can be classify by the modes of input and output motion, the configuration and arrangement of the follower, and the shape of the cam. More over, the cam can also classify by the different types of motion events of the follower and by mean of a great variety of the motion characteristic of the cam profile.

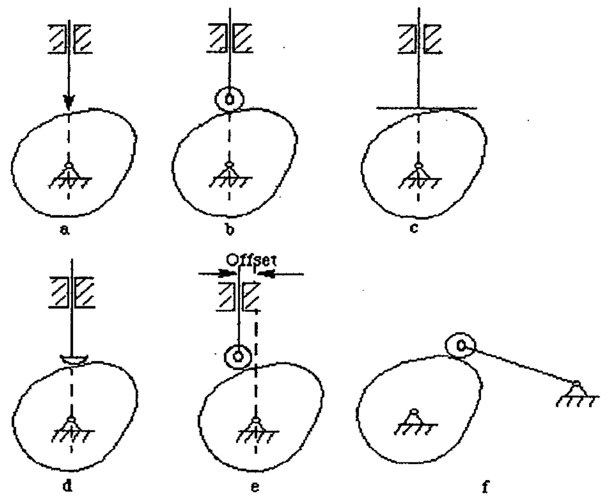

Figure 2.3 Classification of cam motion (Finger S. et al, 2006).

Figure 2.3 a, b, c, d, e showed the rotating cam-translating follower and **Figure 2.3** f showed the rotating follower. The follower arm swings or oscillates in a circular arc with respect to the follower pivot (Finger S. et al, 2006).

In automotive field, the cam is designed to control the open and close intervals of the inlet and exhaust valves relative to each piston position along its respective stroke. For this purpose, the radial cam is used consist of a circular disc having a semi-oval triangular protrusion. Rotation of the cam causes its profile to slide against the smooth flat closed end of a cylindrical member known as the follower (Bayrakceken H. et al, 2005). The cam profile can divide into three phases for the follower lift or valve opening side and a corresponding follower fall or valve closing side. The phases are the cam ramp, the cam flank and, the cam nose.

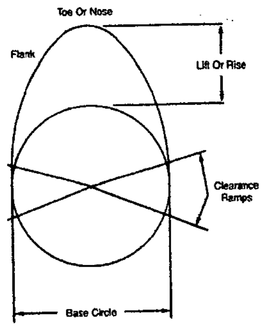

Figure 2.4 The phases of the cam lobe (Bew, 2002).

There is the an initial opening ramp phase on the follower lift side of the cam which joins the base circle to the cam lobe with very small lift rate. The flank-opening phase function is to accelerate the follower lift to a point of maximum velocity. This point is the position on which the flank concave curve meets the nose convex curve (Bew, 2002). The nose-opening phase on the lift side of the profile is the last phase which decelerates the follower velocity to zero as the follower approaches the full lift position. The amount of decelerates experienced during deceleration phase is controls by the valve spring.

The second side which is the follower fall or valve closing side starts from the maximum lift position and ends with the follower at zero lift. The closing of the nose phase is the initial phase of the closing flank. This phase causes the follower to accelerate from zero to maximum velocity. Again this rate of accelerate is control by the valve spring. During the closing flank, the follower is decelerates until the velocity is almost zero. The final stage of the second side of the profile is when the follower velocity becomes zero and the follower is in the position of zero lift. In summary the base circle of the cam defines the period that valve is closed, the clearance ramp defines the time of transition between closure and measurable valve lifting, the flank or ramp provides the time for the characteristic of valve opening, the nose defines the full valve opening and maximum opening displacement and but not list the duration defines the time that valve is off its seat.