

SUPERVISOR DECLARATION

“I hereby declare that I have read this thesis 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 (Automotive)”

Signature :

Supervisor I : MOHD ADRINATA BIN SHAHARUZAMAN

Date :

Signature :

Supervisor II : EN. MOHD HANIF BIN HARUN

Date :

AN EXPERIMENTAL STUDY OF STEERING WHEEL
VIBRATION IN STATIC CONDITION

MUHAMMAD TAUFIQ BIN ABDUL KHALID

This report is submitted in partial fulfillment of the requirement for the
Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka (UTeM)

MAY 2011

DECLARATION

“I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged.”

Signature:

Author:

Date:

ACKNOWLEDGEMENT

First, I would like to express my greatest gratitude to Almighty Allah for giving me a chance to complete my project with all His blessings. I would like to acknowledge my project supervisor, Mr Mohd Adrinata Bin Shaharuzaman. The fundamental idea of this project is his and he was a valuable source of information about this project. I am very thankful that he supervised my work and provided me with the much needed assistance in understanding the project. Without his guidance and support, I may not be able to achieve the goals of this project.

To all my lecturers who had thought me this far, very special thanks to them. To all my friends who gave their support to construct my project. Not forget, I would like to acknowledge my technician, Mr Hairul Nizam Bin Daud, because helping me in completing my project. Finally, I would also like to thank my parents, Mr. Abdul Khalid Bin Ismail and Mdm Che Jorah Binti Haji Shafei for their lifelong encouragement. Without their support and confidence in me, I won't have made until this far.

ABSTRACT

Vibration causes discomfort situation when driving car. Vehicle such as cars are regularly exposed to vibration. The purpose of this project is to determine the dynamic properties of steering wheel and to analyze the highest vibration level for Perodua Kancil in Static condition. The modal analysis method is used to complete this project. Modal analysis cans analysis the steering wheel vibration characteristic. The limitation in this project is in static condition with is the experiment will be conduct in free-free boundary and constraint condition. For the first experiment, modal analysis is use to determine the natural frequency of 2, 3 and 4 spoke steering wheel in free-free boundary. The second experiment also will be use modal analysis method to determine the natural frequency but in constrain condition for 2, 3 and 4 spoke steering wheel. The third experiment is to analyze the highest vibration level for Perodua Kancil in static condition. So the result of this project will be the natural frequency of 2, 3 and 4 spokes steering wheel in free-free boundary and constraint condition. The highest vibration level for Perodua Kancil also will be determined after completing this project. Today's car is much more comfortable and has improved so much in many ways including in vibration aspect.

ABSTRAK

Getaran menyebabkan situasi tidak selesa semasa memandu kereta. Kenderaan seperti kereta secara umumnya lebih terdedah terhadap getaran. Tujuan projek ini adalah untuk menentukan sifat-sifat dinamik stereng dan menganalisis tahap getaran tertinggi bagi Perodua Kancil dalam keadaan statik. Kaedah analisis modal digunakan untuk menyelesaikan projek ini. Modal analisis akan memberikan ciri-ciri getaran stereng tersebut. Keterbatasan dalam projek ini adalah dalam keadaan statik dan dilakukan dalam keadaan bebas dan sekatan. Untuk eksperimen pertama, analisis modal ini digunakan untuk menentukan natural frekuensi untuk 2, 3, dan 4 spoke stereng kereta. Eksperimen kedua juga akan menggunakan kaedah analisis modal untuk menentukan natural frekuensi dalam keadaan sekatan bagi 2, 3, dan 4 spoke stereng kereta. Eksperimen ketiga adalah untuk menganalisis tahap getaran tertinggi bagi Perodua Kancil dalam keadaan statik. Jadi hasil keputusan dari projek ini adalah natural frekuensi untuk 2, 3 dan 4 spoke stereng kereta. Tahap getaran tertinggi bagi Perodua Kancil juga akan ditentukan selepas menyelesaikan projek ini. Kereta pada hari ini jauh lebih selesa dan telah meningkat begitu banyak cara, termasuk dalam aspek getaran.

CONTENT

CHAPTER	SUBJECT	PAGE
	DECLARATION	ii
	ACKNOWLEDGEMENT	iii
	ABSTRACT	iv
	ABSTRAK	v
	CONTENT	vi
	LIST OF TABLE	xi
	LIST OF FIGURE	xvi
	LIST OF SYMBOL	xvii
	LIST OF APPENDIX	xviii
CHAPTER 1	INTRODUCTION	
	1.1 Background	1
	1.2 Problem Statement	3
	1.3 Objectives	3
	1.4 Scope	3
CHAPTER 2	LITERATURE REVIEW	
	2.1 Introduction	4
	2.2 History of Steering System	4
	2.3 Fundamental of Steering System	6
	2.3.1 Steering System	6

CHAPTER	SUBJECT	PAGE
	2.3.2 Steering System Component	7
	2.3.2.1 Recirculating Ball	8
	2.3.2.2 Rack and Pinion	8
	2.3.3 Steering Wheel	10
	2.3.4 Power Steering	12
2.4	Vibration	
	2.4.1 Vibration in Humankind daily Life	13
	2.4.2 Introduction of Vibration	13
	2.4.2.1 Type of Vibration	14
	2.4.2.2 Simple Waves of Vibration	15
	2.4.3 Vibration on Human	16
	2.4.3.1 Hand Arm Vibration (HAV)	17
	2.4.3.2 Whole Body Vibration (WBV)	17
	2.4.4 Vibration on Vehicle	18
	2.4.5 Steering Wheel Vibration	20
	2.4.6 Vibration Effect	22
 CHAPTER 3	 METHODOLOGY	
	3.1 Background	23
	3.2 Experimental Modal Analysis of Steering Wheel Vibration for Free Free Boundary	26
	3.2.1 Objective of the Experiment	26
	3.2.2 Apparatus	26
	3.2.3 Procedure of Experiment	30
	3.2.3.1 Preparation before Experiment	30
	3.2.3.2 Measurement of Natural Frequency	31
	3.3 Experimental Modal Analysis of Steering Wheel Vibration for Free Free Boundary (Using Dactron RT Pro)	36

CHAPTER	SUBJECT	PAGE
	3.3.1 Objective of the Experiment	36
	3.3.2 Apparatus	36
	3.3.3 Procedure of Experiment	40
	3.3.3.1 Preparation before Experiment	40
	3.3.3.2 Measurement of Natural Frequency	43
3.4	Experimental Modal Analysis of Steering Wheel Vibration for Constraint Condition	46
	3.4.1 Objective of the Experiment	46
	3.4.2 Apparatus	46
	3.4.3 Procedure of Experiment	49
	3.4.3.1 Preparation before Experiment	49
	3.4.3.2 Measurement of Natural Frequency	50
3.5	Experimental To Analyze The Highest Vibration Level For Perodua Kancil In Static Condition	53
	3.5.1 Objective of the Experiment	53
	3.5.2 Apparatus	53
	3.5.3 Procedure of Experiment	56
	3.5.3.1 Preparation before Experiment	56
	3.5.3.2 Measurement Data	57
 CHAPTER 4	 RESULT AND DISCUSSION	
4.1	Background	60
4.2	Results for Experimental Modal Analysis of Steering Wheel Vibration for Free-Free Boundary	61
	4.2.1 2-spoke Steering Wheel	61
	4.2.2 3-spoke Steering Wheel	63
	4.2.3 4-spoke Steering Wheel	65

CHAPTER	SUBJECT	PAGE
	4.2.4 Natural Frequency for 2, 3 and 4-spoke steering wheel for Free-Free Boundary	67
4.3	Results for Experimental Modal Analysis of Steering Wheel Vibration for Free-Free Boundary using Dactron RT Pro	68
	4.3.1 2-spoke Steering Wheel	68
	4.3.2 3-spoke Steering Wheel	69
	4.3.3 4-spoke Steering Wheel	70
	4.3.4 Natural Frequency for 2, 3 and 4-spoke steering wheel for Free-Free Boundary using Dactron RT Pro	71
4.4	Results for Experimental Modal Analysis of Steering Wheel Vibration for Constraint Condition	74
	4.4.1 2-spoke Steering Wheel	74
	4.4.2 3-spoke Steering Wheel	75
	4.4.3 4-spoke Steering Wheel	76
	4.4.4 Natural Frequency for 2, 3 and 4-spoke steering wheel for Constraint Condition	77
4.5	Results for Experimental Modal Analysis of Steering Wheel Vibration for Static Condition	80
	4.5.1 Idle Condition at 1400 rpm	80
	4.5.2 Aircond ON Condition at 1200 rpm	82
	4.5.3 3000 rpm	84
	4.5.4 The highest vibration level in static condition	86
	4.5.5 Highest vibration level for 2, 3, 4-spoke steering wheel at idle condition (1400 rpm)	87

CHAPTER	SUBJECT	PAGE
	4.5.6 Highest vibration level for 2, 3 and 4-spoke steering wheel at aircond ON condition (1200 rpm)	88
	4.5.7 Highest vibration level for 2, 3 and 4-spoke steering wheel at 3000 rpm	89
	4.5.8 Highest vibration level for 2-spoke steering wheel at 1400, 1200 and 3000 rpm	90
	4.5.9 Highest vibration level for 3-spoke steering wheel at 1400, 1200 and 3000 rpm	91
	4.5.10 Highest vibration level for 4-spoke steering wheel at 1400, 1200 and 3000 rpm	92
	4.5.11 Relationship of Natural Frequency	93
 CHAPTER 5	 CONCLUSION AND RECOMMENDATION	
	5.1 Conclusion	95
	5.2 Recommendation	97
	 BIBLIOGRAPHY	 98
	REFERENCE	100
	APPENDIX	101

LIST OF TABLE

TABLE	TITLE	PAGE
4.0	Natural frequency for 2-spoke steering wheel	62
4.1	Natural frequency for 3-spoke steering wheel	64
4.2	Natural frequency for 4-spoke steering wheel	66
4.3	Natural frequency for 2, 3 and 4-spoke steering wheel	67
4.4	Natural frequency of 2, 3 and 4-spoke steering wheel using RT Pro	71
4.5	Natural frequency of 2, 3 and 4-spoke steering wheel in constraint	77
4.6	Highest vibration level in static condition condition	86
4.7	Relationship of Natural Frequency	93

LIST OF FIGURE

FIGURE	TITLE	PAGE
1.0	Model T at 1908 by Henry Ford (Source: http://www.auto123.com)	2
1.1	New Ford Fusion 2010 (Source: http://theautomedia.com)	2
2.0	The vehicle use tiller or handle system (Source: http://www.ausbcomp.com/~bbott/cars/carhist.htm)	5
2.1	Modern steering wheel (Source: http://www.muslimrahman.com)	5
2.2	The vehicle turning with the circular shape (Source: http://auto.howstuffworks.com/steering1.htm)	6
2.3	Three main part of the steering system (Source: “Total Automotive Technology”, page 885)	7
2.4	Steering column part (Source: “Total Automotive Technology”, page 885)	7
2.5	Recirculating ball steering gear (Source: http://auto.howstuffworks.com/steering3.htm)	8
2.6	A complete rack-and-pinion steering assembly (Source: “Auto Suspension and Steering”, page 19)	9
2.7	Cutaway of rack-and-pinion steering assembly (Source: “Auto Suspension and Steering”, page 19)	9
2.8	Early vehicle had use tiller or handle steering (Source: “Auto Suspension and Steering”, page 14)	10

FIGURE	TITLE	PAGE
2.9	A steering wheel at design stage (Source: Yang, Z.Z. et al. (2005))	11
2.10	Component of a typical steering wheel (Source: Yang, Z.Z. et al. (2005))	11
2.11	Type of steering wheel (Source: Yang, Z.Z. et al. (2005))	12
2.12	Power steering system (Source: http://coysdenver.com/service/powersteering.shtml)	12
2.13	Damage of the machine caused by vibration phenomena (Source: http://www.lindsayengineering.com/services/vibration-analysis-testing/)	14
2.14	Free vibration (Source: http://www.mfg.mtu.edu/cyberman/machtool/machtool/vibration/intro.html)	14
2.15	Force vibration (Source: http://www.roymech.co.uk/Useful_Tables/Vibrations/Forced_Vibrations.html)	15
2.16	Type of human vibration (Source: http://www.MMF.de)	16
2.17	Hand arm vibration (Source: http://www.MMF.de)	17
2.18	Whole body vibration (Source: http://www.MMF.de)	17
2.19	Vibration transmits from engine to driver (Source: Kim, K.C. et al. (2007))	18
2.20	Main sources of vibration disturbances in a vehicle (Source: Shayaa, M.S. et al. (2001))	19
2.21	The case of idle shake and booming noise (Source: Kim, K.C. et al. (2007))	20

FIGURE	TITLE	PAGE
2.22	Vibration modes of steering system (Source: Kim, K.C. et al. (2007))	21
3.0	Flow chart of final year project	24
3.1	Test platform with table	26, 36
3.2	Accelerometer	27, 36, 47, 54
3.3	2-spoke	27, 37, 47, 54
3.4	3-spoke	27, 37, 47, 54
3.5	4-spoke	27, 37, 47, 54
3.6	ICP type signal conditioning	28
3.7	5mm nut	28, 38
3.8	Glue	28, 38
3.9	Impact hammer	29, 37, 39, 48
3.10	Rope	29,39
3.11	DEWESOFT software	29
3.12	Affix 5mm nut at steering	30, 40
3.13	Nut position	30, 40
3.14	Connect the accelerometer to the input channel of ICP signal conditioning	31
3.15	Hang up steering wheel	31, 41
3.16	Accelerometer location at 30° and 150° of steering wheel angle	32, 42
3.17	Set the ICP channel	32
3.18	Set the sensetivity for right and left point of accelerometer	33
3.19	Spectrum analyzer mode window	33
3.20	Set up the FFT options	34
3.21	Hit steering wheel	34
3.22	Impact analysis	35
3.23	LDS Dactron Data Aquisition	38, 48, 55
3.24	Dactron RT-Pro software	39, 48, 55

FIGURE	TITLE	PAGE
3.25	LDS Dactron Data Acquisition connection	41
3.26	Dactron RT Pro interface	45, 52, 59
3.27	Perodua Kancil for experiment	46, 53
3.28	Accelerometer at steering wheel for constraint condition	49
3.29	Accelerometer at steering wheel	56
3.30	Accelerometer at steering column	56
3.31	Accelerometer at steering buck head	56
4.0	Graph of natural frequency for left point – 2 spoke	61
4.1	Graph of natural frequency for right point – 2 spoke	61
4.2	Graph of natural frequency for left point – 3 spoke	63
4.3	Graph of natural frequency for right point – 3 spoke	63
4.4	Graph of natural frequency for left point – 4 spoke	65
4.5	Graph of natural frequency for right point – 4 spoke	65
4.6	Graph of natural frequency for 2-spoke steering wheel	68
4.7	Graph of natural frequency for 3-spoke steering wheel	69
4.8	Graph of natural frequency for 4-spoke steering wheel	70
4.9	1 st mode shape steering wheel (Source: Yang, Z.Z. et al. (2005))	72
4.10	2 nd mode shape steering wheel (Source: Yang, Z.Z. et al. (2005))	72
4.11	Mode shape of the system (Source: Avitabile, P. (no date))	73
4.12	Graph of natural frequency for 2-spoke steering wheel in constraint condition	74
4.13	Graph of natural frequency for 3-spoke steering wheel in constraint condition	75
4.14	Graph of natural frequency for 4-spoke steering wheel in constraint condition	76
4.15	1 st mode vertical bending	78

FIGURE	TITLE	PAGE
	(Source: Kim, K.C. et al. (2007))	
4.16	1 st mode lateral bending	78
	(Source: Kim, K.C. et al. (2007))	
4.17	2-spoke: idle condition	80
4.18	3-spoke: idle condition	80
4.19	4-spoke: idle condition	81
4.20	2-spoke: Air Cond ON condition	82
4.21	3-spoke: Air Cond ON condition	82
4.22	4-spoke: Air Cond ON condition	83
4.23	2-spoke: 3000 RPM condition	84
4.24	3-spoke: 3000 RPM condition	84
4.25	4-spoke: 3000 RPM condition	85
4.26	Highest vibration level for 2, 3 and 4-spoke steering wheel at idle condition (1400 rpm)	87
4.27	Highest vibration level for 2, 3 and 4-spoke steering wheel at aircond ON condition (1200 rpm)	88
4.28	Highest vibration level for 2, 3 and 4-spoke steering wheel at 3000 rpm	89
4.29	Highest vibration level for 2-spoke steering wheel at 1400, 1200 and 3000 rpm	90
4.30	Highest vibration level for 3-spoke steering wheel at 1400, 1200 and 3000 rpm	91
4.31	Highest vibration level for 4-spoke steering wheel at 1400, 1200 and 3000 rpm	92
5.0	The International Organization for Standardization (ISO); Guidelines relating magnitude to comfort for passenger on public transport (Sources: Griffin, M.J (1990))	96

LIST OF SYMBOL

HAV	=	Hand Arm Vibration
WBV	=	Whole Body vibration
Hz	=	Hertz
A	=	Amplitude
f	=	Frequency, Hz
ω	=	Omega
π	=	Pi
a	=	Acceleration, m/s^2
k	=	Spring constant
c_d	=	Damper constant
m	=	Mass, kg
x	=	Displacement, meter
P	=	Force, N
t	=	Time, s
ICP	=	Integrated Circuit Piezoelectric
BNC	=	Bayonet Neill Concelman

LIST OF APPENDIX

APPENDIX	TITLE	PAGE
A	2-spoke Steering Wheel	101
A-1	Left point- 2 spoke steering wheel (2 nd punch)	101
A-2	Left point- 2 spoke steering wheel (3 rd punch)	101
A-3	Right point- 2 spoke steering wheel (2 nd punch)	102
A-4	Right point- 2 spoke steering wheel (3 rd punch)	102
B	3-spoke Steering Wheel	103
B-1	Left point- 3 spoke steering wheel (2 nd punch)	103
B-2	Left point- 3 spoke steering wheel (3 rd punch)	103
B-3	Right point- 3 spoke steering wheel (2 nd punch)	104
B-4	Right point- 3 spoke steering wheel (3 rd punch)	104
C	4-spoke Steering Wheel	105
C-1	Left point- 4 spoke steering wheel (2 nd punch)	105
C-2	Left point- 4 spoke steering wheel (3 rd punch)	105
C-3	Right point- 4 spoke steering wheel (2 nd punch)	106
C-4	Right point- 4 spoke steering wheel (3 rd punch)	106
D	Simple Plate Sine Dwell Response	107
E	Gantt chart for PSM 1	108
F	Gantt chart for PSM 2	109

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Nowadays, transportation is one of most important element in helping people to move. Transports give human the freedom to move from one place to another place. People do not have to told how important the automobile in their live. The automobile such as car, van and also heavy duty vehicle is used to help people in completing their daily life activities. The automotive industry was starting about more than 100 years ago. Years by years, a lot of new technologies grow rapidly. As an example, in 1860, the first practical Internal Combustion engine has been invented by J.J.E. Lenoir, the engine technology is grow rapidly within the innovation in our automotive technology. Increasing of vehicle use over the years has directly increased the design element and characteristic in the vehicle to achieve more efficiency, cleaner, more economy and more reliable.

The modern vehicle is totally different from the vehicle of years ago. Vehicle nowadays are designed to produce fewer emission and less pollution. Modern vehicle also is more save if compare to the vehicle years ago. The green technology in automotive industry such as hybrid technology, help to protect our environment from the pollution of the vehicle. A lot of world brand use the environment issue in creating their new model. Figure 1.0 and Figure 1.1 show the evolution in automotive industry by

Ford, from the first model, Model T 1908, to the new styling and futuristic model, Ford Fusion 2010.



Figure 1.0: Model T at 1908 by Henry Ford
(Source: <http://www.auto123.com>)



Figure 1.1: New Ford Fusion 2010
(Source: <http://theautomedia.com>)

Today, an innovation is taking place in steering system technology in automotive industry. Steering technology in automotive grow rapidly. There have two basic type of steering system which is recirculating ball and rack and pinion. In the 1950's, General Motor introduces the hydraulic assisted power steering system. This system used recirculation ball system. The rack and pinion steering system, eventually develop and used in many lighter and sportier vehicle. The steering system is used to control the direction of the vehicle. The steering system is design to control the direction of the front wheel over all type of road condition, with through turn and at different speed of the vehicle.

1.2 PROBLEM STATEMENT

Vibration causes discomfort situation when driving car. Vehicle such as car are regularly exposed to vibration. In recent research (Kim K.C. et al. 2007), the sources of vibration include the engine, wheel, tires, and the profile of road surface. The sources of vibration travel through the engine and the body structure of the car. When the vibration sensed by the driver through steering wheel, it is described as steering vibration.

1.3 OBJECTIVES

The main objective of these final years project is to conduct experimental modal analysis of steering wheel vibration for Perodua Kancil 850cc. Two experiments will be conducted which are free-free boundary and constraint condition. Natural frequency and the mode shape of the steering wheel will be determined. The next objective is to study the behavior of steering wheel vibration for 2-spoke, 3-spoke and 4-spoke steering wheel. The analysis for this experiment are more focusing to this 3 type of spoke which is can fixed into Perodua Kancil 850 cc steering column. The highest vibration level for Perodua Kancil at static condition also will be determined.

1.4 SCOPE

The scope of these final year project is:

- a) The car type that use in these experiment is national compact car with automatic transmission, front wheel drive and non-power steering.
- b) The experimental analysis for the steering wheel for free-free boundary condition and constraint condition.
- c) The experiment will be conduct for the stationary passenger car (Static).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The automotive industry is one of the most influential technological advances of this time. People use transportation every day for travel from one place to another place. This chapter will discuss about how steering system works and what is the vibration of steering wheel.

2.2 HISTORY OF STEERING SYSTEM

Function of steering system is to control the direction of a vehicle's motion. Steering system was not needed until the growing of the modern vehicle technology that follows the time frame of vehicle improvement. Before the modern steering system was develop, steering consists of getting the animal pulling the vehicle to move in the desire direction or to change the direction of the vehicle. The earliest vehicle steering system utilized a tiller or handle, which was connected to the wheel by simple linkage. The handle worked well when vehicle were small and light, but when the weight and size of the vehicle increase, its replace with the steering system to multiply the turning force of the wheel.



Figure 2.0: The vehicle use tiller or handle system.
(Source: <http://www.ausbcomp.com/~bbott/cars/carhist.htm>)

Today's drivers have become accustomed to the fact that steering a vehicle no longer requires much effort. The driver gets a lot of benefit from the hydraulic or electric power steering systems that are powered by the engine and support even the slightest steering wheel movement. Modern power steering systems give the driver direct feedback by instantly responding with the right amount of power corresponding to the vehicle speed and driving situation. The modern steering system has been improving a lot of driving situation.



Figure 2.1: Modern steering wheel
(Source: <http://www.muslimrahman.com>)