"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 Bachelor Mechanical Engineering (Automotif)"

Signature : .....

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Date : 7-5-2009

DESIGN AND DEVELOPMENT OF TIRE FORCE MEASURING DEVICE

GOH CHEP KIEN

A project report submitted in partial
fulfillment of the requirements for the award of
the Degree of Bachelor Mechanical Engineering (Automotif)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

06 APRIL 2009

"I hereby declared that this thesis is my own work except the ideas and summaries which I have clarified their sources"

Signature: ……

Author : ……

Date : ……

Specially dedicated to my family, friends and companion

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ABSTRACT

The thesis is concerned about the design and development of tire force measuring device to detect six-component of forces and moments on a tire. The steering angles of the tire can be adjusted. A conveyor is acted as road frictions or road profile, used to provide tire speed by motor generator. In order to design a tire force measuring device, ideas of design are sketched and drawn. Design process and design criteria are considered to choice from the different device's structure. Finite Element Software is used to analysis the device structure and simulates the strain gauges to detect the forces and moments. The prototype of tire force measuring device is built and tested.

ABSTRAK

Tesis ini adalah mengenai pengajian tentang rekabentuk dan pembinaan alat pengukuran enam paksi daya dan momen tayar. Sudut-sudut *steering* boleh diubahkan. Satu pengangkut, *conveyor,* digunakan sebagai profil jalan (*road profile)* untuk memecut tayar dengan pembantuan penjana bermotor. Dalam perekabentukan alat pengukaran daya tayar, design konsepsi direka dan dilukis. Proses rekabentuk and kritiria rekabentuk ditimbangkan untuk memilih struktur rekebentuk yang brelainan. Perisian *Finite Element* digunakan untuk mengoptimakan dimensi alat pengukuran daya dan juga digunakan sebagai perubahan pergerakan tolok ketegangan untuk mengukur daya-daya dan momen-momen. Struktur pengukuran daya tayar dibina dan dikajikan.

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CHAPTER 1

INTRODUCTION

1.1 WHEEL DYNAMICS TEST RIG

As a degree undergraduate student of *Universiti Teknikal Malaysia Melaka* (UTeM), the wheel dynamics test rig is designed as *"Projek Sarjana Muda"* (PSM). Wheel dynamics test rig is functional as investigation the handling dynamics of the vehicle tires. However, this rig is built according to a quarter car model which including supporting platform, suspension system, wheel, conveyer belt and tire force measuring device. To make sure the rotational of the tire, roughness must be given by the conveyer belt which will be powered by an electric motor up to desired speed of 60km/h.

The main characteristic of the test rig is the six component force sensor which known as tire force measuring device in this project. There are three orthogonal forces are longitudinal force (F_x), lateral force (F_y) and vertical force (F_z) while the three orthogonal moments are divided into the rolling moment (M_x), pitching moment (M_y) and yawing moment (M_z) which are the six component forces and moments (Sheng A. Liu and Hung L. Tzo, 2002).

Steering angle of the tire can be manipulated with adjustable test rig controlling arm. Investigation of effect on handling dynamics due to the various steering angle will be done. Strain gauges are installed on the tire force measuring device to detect the changes of voltage due to deformation of the device structure.

The experienced voltages by the tire force measurement device structure are being converted into strain and stresses then forces and moments.

Mr. Lee Tze Jian will continue the project by applying Wheatstone half bridge on the wiring of the strain gauges which will be connected to a data acquisition card (DAQ) to collect the resistance changes on the sensor device. The data obtained and recorded in the personal computer. Data acquisition Toolbox, MATLAB's subprogram, Simulink and GUIDE are used to interpret those data collected.

1.2 BACKGROUND

Nowadays, the commercial tire force measuring device system in the market is mostly applying large amount of strain gage in the strain gages based (Wei S. and Stephen D.H., 2005). The more strain gages used, the higher the costly and more complex for the whole tire force measurement system. A tire, when running on the road will generate the three orthogonal forces as well as three orthogonal moments. The forces are longitudinal force (Fx), lateral force (Fy), and vertical force (Fz). In the time, these forces will cause the three orthogonal moments; rolling moment (Mx), overturning moment (My) and self-aligning moment (Mz) respectively. Normally, when tire pass through a road profile, the forces and moments are transferred from tire-road contact to the wheel axle (Wei S. and Stephen D.H., 2005). As a result, if any shafts or beams are connecting to the wheel, they may detect the tire forces and moments cause by the road profile (Wei S. and Stephen D.H., 2005).

Tire force measuring device, also known as six component forces sensor is used to measure the external forces by converting an input mechanical force into an electrical output. A six-component force sensor is a unit which functions to simultaneously measure three forces and moments. As a result, tire force measuring device is the sensor to detect and collect the tire forces and moments when they are transformed from tire-road contact surface with road profile to the wheel and then being transferred to the tire force measurement device. Strain gages bonded securely

as a whole to appropriate locations in the member forms Wheatstone half bridge circuits, from either resistance or voltage outputs of which the magnitudes and directions of the three forces and three moments are determined by matrix calculation (Liu S.A. and Tzo H.L. 2002).

The main focus part in this project are designed by using Computer Aided Three Dimensional Interactive Application (CATIA) and optimized by using MSC Finite Element Method (FEM) of the tire force measurement device. CATIA is the 3D modeler of Dassault Systems. CATIA Version-5 (CATIA V5) which is a multi-platform CAD/CAM/CAE commercial software suite, used for design drawing of tire force measuring device. CATIA V5 is the cornerstone of a true integration of people, tools, methodologies and resources within as enterprise. Its unique product, process, resources model and workplace approach provide a truly collaborative environment that fosters creativity, sharing, and communication of 3D product and process-centric definitions (Azmil A.F. 2007).CATIA V5 also widely use as study course and as design software in industries due to CATIA is good in surface creation and computer representation of surfaces. According to Ku K 2006, CATIA model as the master to rationalize the geometry, and to coordinate between various systems, and to calculate quantities. Its has the capabilities of a free-form design sketcher for solid objects, representation of constraints and parameterization in engineering design, representation of tolerances and the ESPRIT–funded SCOPES project in assembly modeling.

Finite Element Method (FEM) is a method for solving complex elasticity, and structural analysis in the field of civil engineering, mechanical engineering, aerospace engineering etc. Mechanical engineering design involves the reallocation of materials and energy to improve the quality of life. The design optimization idea is given the possible designs and design criteria which exists a design in the best or optimal. According to Huebner K. H. 2001, the use of various structural optimization methods is improved the design of a critical automotive component.

In the instrumentation arena, the most dominant application is bridge circuit application. Strain gage as a resistive element sensitive to displacement has been extensively for a century within bridge circuit application. Nowadays, process

variable such as pressure, motion, load weight, vibration will employ strain gage bridge circuit as the fundamental sensor device. Structural beam deflection, internal strain within concrete structure also uses combination of strain gage elements with bridge circuit signal as instrumentation application (www.dataforth.com). In this project, combination of stain gages with Wheatstone half bridge is employed for the tire force measuring device's deflection to determine the forces and moments acting on tire.

Tire force measuring device not only contributes in automotive industrial, but also in the aircraft industrial for developing on automobile and aircraft industries since tire force measurement device having the high sensitivity and ability to measure for every tire force produces. As a conclusion, tire force measuring device is the most suitable device for automotive and aircraft area so that analysis and test on tire force is carried on through detecting by tire force measuring device. As a result, this project is carried on the study of the tire force measuring device which having high potential of sensitivity to detect tire force.

1.3 PROBLEM STATEMENT

Tires, the main pars on a vehicle, are traveled the vehicle chassis or body by providing power and energy from engine and transmissions. There are three forces and moments acting on tire causes by road profile. To determine the three orthogonal forces and three orthogonal moments, tire force measuring device is designed and developed by attaching strain gauges as force sensor. In this project, a six-axis component forces and moments device is attached of 12 strain gage. A data acquisition device (DAQ), which connected wirings from strain gauges will transfer the changes of resistances into voltages form. Wheatstone half bridge is used to determine the changes of voltages through DAQ. The possible problems occur during this study are:

i. Direction of the three orthogonal forces and moments acting on when conveyer belt rotating the tire. Strain gauges installation make causes the accuracy of the data.

ii. Design concepts and design criteria should be implied in the study. Consideration of material used and deformation of the force sensor due to the forces and moments taking heavily effect on the design.

1.4 OBJECTIVE

- To study the six-component forces and moments acting on tire.
- To study the design concept and design criteria.
- To design tire force measuring device using CATIA V5.
- To study FEM in used of MSC Patran to analysis a design device structure.
- To study the strain gages usage and attachment location of strain gages.
- To build the tire force measuring platform for detecting the tire forces and moments.

1.5 SCOPE

This project will involve the specific field on designing tire force measuring device. The scopes that cover in this project are as following:-

- Design and built tire force measuring device
- Test tire force measuring device function

1.6 SIGNIFICANCE OF STUDY

This study provides the means of design environments of user on the wheel dynamics test rig that collecting desired data. Consideration on the design concepts and design criteria will interface the convenience of the user in term of saving time, cost and also desired data collected. Data obtained from the tire force measuring device can be used for further studies on the vehicle system like analysis on tires.

CHAPTER 2

LITERATURE REVIEW

2.1 DESIGN AND FABRICATION OF THE SIX COMPONENTS TIRE FORCE MEASURING

When quarter car model is running on a road, there are three orthogonal forces and three orthogonal moments can be transformed from the tire-road contact center to the wheel axle. Tire force measuring device is design to detect these forces and moments, but actually it is detecting the forces and moments acting on the device itself due to the loads at the tire. Equations are derived to transform these forces and moments acting on the tire to the tire force measuring device (Wei S. and Stephen D.H. 2005).

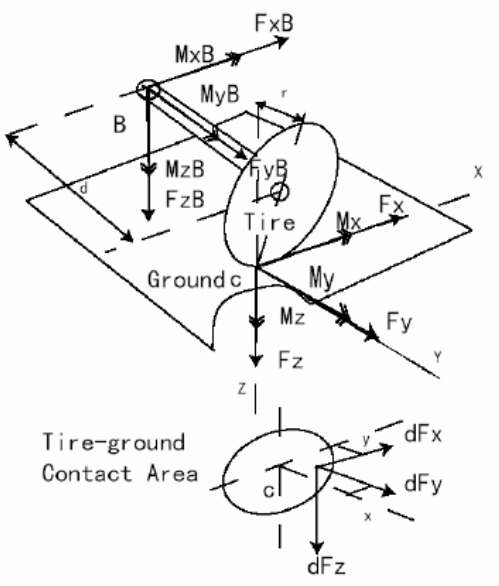

Figure 2.1: Forces and moments acting on the tire and tire measuring device