FINITE ELEMENT ANALYSIS OF AN INDEPENDENT STEERING SYSTEM FOR A PENDULAR VEHICLE

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A report submitted in fulfilment of the requirements for the degree of

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DECLARATION

I declared that this project report entitled "Finite Element Analysis of an Independent Steering System for a Pendular Vehicle" is the result of my own work except as cited in the references.

Signature :……………………………

Name :..

Date :………..................................

APPROVAL

I hereby declare that I have read this project report 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.

Signature :..

Name of Supervisor :...

Date :..

DEDICATION

This report is dedicated to my beloved mother and father.

ABSTRACT

Independent steering system is the most important system in any vehicle. This lets the driver get full control over the car maneuver. The cradle or subframe is an important component of the vehicle with various functions. It is used to improve the ride comfort and handling capability. The aim of using an automotive subframe is to spread large local loads across wider area of the body structure and making the vibration and harshness separated from the body structures. This paper is aim to find the most suitable thickness for the cradle in order to withstand the stresses. This paper also described the type of steering system such as steer-by-wire, four wheel steering, rack and pinion and the recirculating ball steering. Material used for manufacture this cradle are aluminium. The analysis of the cradle is by using Finite Element analysis (FEA) of CATIA software. The analysis are done using thickness of 6mm, 8mm and 10mm. The amount of force for rear cradle is 883N and 442N for the front cradle. From the analysis it is concluded that 6mm thickness is the most suitable thickness for the cradle and the minimum thickness that can be used to manufacture the cradle is 2mm.

ABSTRAK

Sistem stereng bebas adalah sistem terpenting untuk mana-mana kenderaan. Ini membolehkan pemandu mengawal sepenuhnya manuver kereta. Tujuan stereng adalah untuk memandu roda depan dengan maklum balas pemanduan supaya pelbagai jenis permukaan dapat dikendalikan sepenuhnya. Cradle atau subframe adalah komponen penting kenderaan dengan pelbagai fungsi. Ia digunakan untuk meningkatkan keselesaan perjalanan dan kemampuan pengendalian. Tujuan menggunakan subframe automotif adalah menyebarkan muatan lokal yang besar ke kawasan struktur badan yang lebih luas dan membuat getaran dan kekerasan dipisahkan dari struktur badan. Kertas ini bertujuan untuk mencari ketebalan yang paling sesuai untuk menahan tekanan. Kertas ini juga menerangkan jenis sistem stereng seperti kawalan oleh wayar, roda empat roda, rak dan pinion dan kawalan bebola berpusing. Bahan yang digunakan untuk pembuatan cradle ini adalah aluminium. Analisis cradle ini adalah dengan menggunakan analisis Elemen Terhingga (FEA) menggunakan perisian CATIA. Analisis dilakukan dengan menggunakan ketebalan 6mm, 8mm dan 10mm. Jumlah daya untuk cradle belakang adalah 883N dan 442N untuk cradle depan. Dari analisis tersebut is dapat disimpulkan bahawa ketebalan 6mm adalah ketebalan yang paling sesuai untuk buaian dan ketebalan minimum yang boleh digunakan untuk membuat buaian adalah 2mm.

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LIST OF SYMBOLS

σ	**=**	**Stress**
F	=	Force applied
A	=	Cross sectional area of the object
ε	=	Strain
e	=	Extension
$l_{\circ}$	=	Stretched length
E	=	Young’s modulus
I	=	Moment of inertia
M	=	Internal bending moment in the beam

CHAPTER 1

INTRODUCTION

1.1 Background

The most traditional steering system is to control the front wheels using a hand operated steering wheel that is located in front of the driver, via the steering column that may include universal joints, allowing it to deviate somewhat from a straight line. There have been several phases in the vehicle steering system, such as manual steering, hydraulic steering, electro-hydraulic steering, electrical power steering and by-wire steering (Tian, Tong, & Luo, 2018). Steering is a mixture of materials, linkages, etc. that helps the vehicle to follow the desired direction. The sole purpose of the steering system is to giving license or permission for the driver to navigate the vehicle along the exact route they want (Ruban, Sathishkumar, Shanmugavelan, Srinath, & Ramesh, 2017). Figure 1.1 below shows the basic steering components.

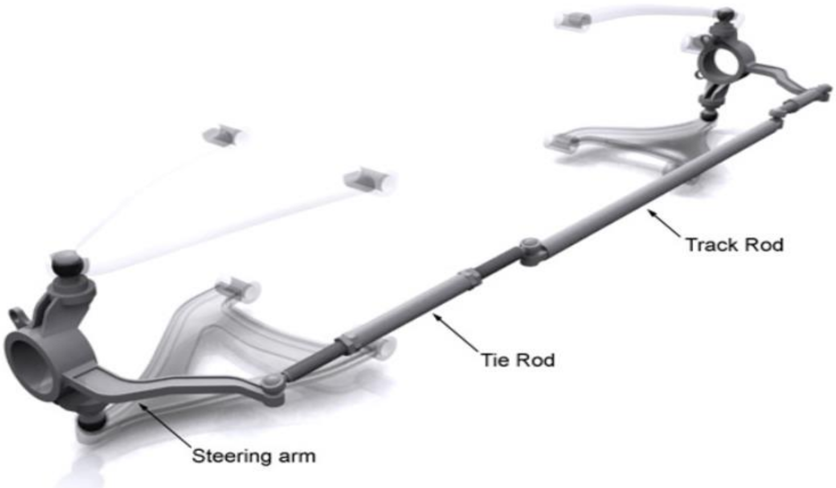

Figure 1.1: Basic steering components

There are various types of steering system such as steer-by-wire, four-wheel steering, rack and pinion, recirculating ball steering, etc. One of it is the four-wheel steering. Four wheel steering also known as independent steering system. Four wheel steering is an advanced control technique which can improve steering characteristics. A four wheel steering vehicle has the advantage of improving the ability of the vehicle to corner by steering the rear wheels according to the status of the vehicle and the lateral stability and overall handling efficiency of the vehicle can also be improved (Ronci, Ferrer Lng, Artuso Phd, & Bocci, 2011). The most sophisticated system consists of electric motors for each wheel and the development of this kind of system opens the possibility to use independent wheel torque control to steer the vehicle resulting in the removal of the mechanical steering linkage, greatly simplifying the mechanical design and allowing cost savings (W. Li, Potter, & Jones, 1998). Dynamic yaw-moment control (DYC) is a method for controlling the lateral motion of a vehicle with the input of the yaw moment produced by the difference in the left and right wheels torque (Sakai, Sado, & Hori, 1999). Figure 1.2 below shows the four wheel steering system.

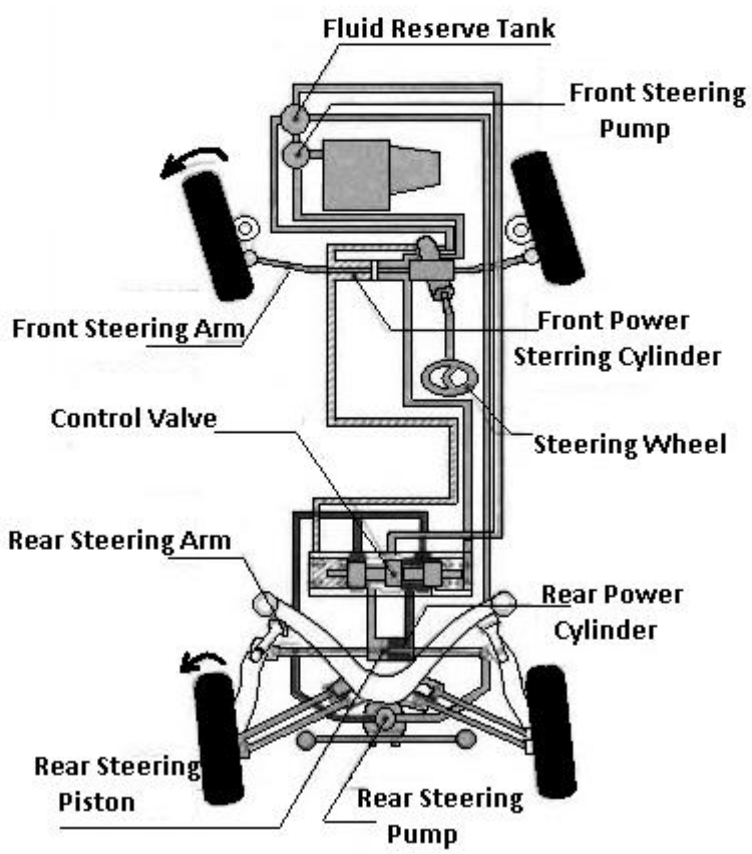

Figure 1.2: Four wheel steering system

An independent steering system or four wheel steering system is the most suitable type of steering system to be utilized when developing a pendular vehicle. A pendular vehicle is a tilting vehicle that is a result of combining the forces of gravity, centrifugal force and ground resistance of the wheels and places itself in equilibrium. This type of vehicle will have no actuator because of the slow respond of the actuator itself, which can mean delays in the tilt movement. This can lead to problems, especially in emergency situations. The driver's compartment and the wheels are mounted on longitudinal axes, allowing the driver's compartment to tilt on turns or a slope. This mechanism for lean in turn means the wheels are parallel to the angle of the driver's compartment hanging down while driving. Figure 1.3 below show an example of pendular vehicle.

Figure 1.3: Example of pendular vehicle

The sole purpose of an all-terrain vehicle (ATV) is off-roading. It is designed for very rough terrain such as the countryside, mountain, etc. All-terrain vehicle or also known as quad bikes consist of 4 wheel geared or non-geared systems. The only different between the normal all-terrain vehicles with the pendular vehicle is the existence of the pendulum mechanism. Pendular vehicle is an all-terrain vehicle that is combined with the pendulum mechanism. Pendular vehicle is a new mode of driving, good for all kinds of surrounding including hills, valleys, snow and sand. The nature of pendulum means that the vehicle is tilting on a bend and staying level on slopes. This means that the articulated legs splay out on the roughest terrain to keep the wheels in contact with the ground. All controls are grouped and easy to use around the steering wheel.

1.2 Problem statement

A problem statement is a concise summary of a problem to be solved or a situation to be changed. This defines the difference between a system or product's current state and the desired state.

The pendular vehicle is suitable for the off road or cross country vehicle that capable of operating across a wide variety of terrains. This kind of vehicle also suitable for peoples of reduced mobility because it is controlled only using hands and that making it very accessible. However there is a problem where the cradle is not strong enough to withstand the force from the suspension and not suitable for the long term used, thus, can affect the performance of the vehicle.

1.3 Objectives

- To investigate the suitable thickness of the cradle or subframe that can withstand the applied stress using Finite Element Analysis (FEA).
- To provide a complete analysis on the cradle or subframe and to propose engineering solutions.
- To determine the performance of the vehicle based on the analysis of the subframe.

1.4 Scope of project

The scopes of this project are:

- This report is to obtain the most suitable thickness for the cradle or subframe and can enhanced the performance of the vehicle. The variable that is to be manipulating in this project is the thickness of the cradle or subframe.
- The variable that is to be ignoring in this project is the material of the cradle which is concluded as the aluminium as the overall material for the component.
- The method that is used in this project is the final element analysis (FEA).

1.5 General methodology

The methodology is a way that is used in the project to collect the data and how to obtain the result with high accuracy.

1. The literature review: The journals, articles or any materials regarding the project.
2. Simulation: The simulation using the Final Element Analysis (FEA).
3. Analysis and proposed solution: Analysis will be presented on the thickness of the cradle that is suitable for the pendular vehicle to operate smoothly.
4. Report writing: A report on this study will be written at the end of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The steering system is the most important system in any vehicle. This lets the driver get full control over the car maneuver. The steering purpose is to guide the front wheel with the driving feedback so that the various types of terrain can be fully controlled

2.2 Type of steering system

There are various types of steering system such as steer-by-wire, four wheel steering, rack and pinion and the recirculating ball steering.

2.2.1 Steer-by-wire

There is no mechanical link between the steering wheel and the front wheel system in steer-by-wire system. It is completely different compared to the conventional steering system. Steer-by-wire system consist no steering shaft, column gear reduction mechanism, etc. By getting rid of the steering shaft, it will provide more space efficiency that enables a much better use of the engine compartment space, more fuel efficiency in term of functionality. Besides that, steer-by-wire system can also avoid oil leaking, offer a larger space in cabin that lead to freedom of interior design and also can minimise the injury during accident.

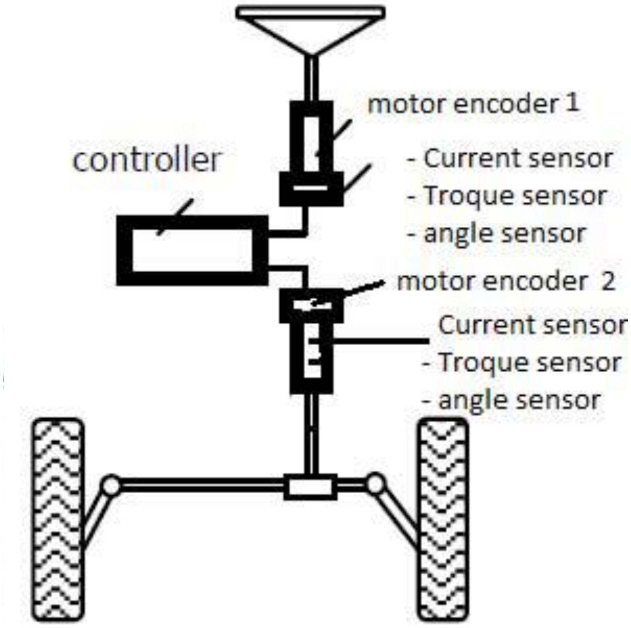

Figure 2.1: Steer-by-wire system

Attached to the steering wheel and front wheel assembly are sensors and actuators. The signal of the rotation angle is controlled by the electronic control unit (ECU) and sent to the front wheel actuators to turn the front wheels components in the same way as the action of the steering wheel. Steer-by-wire system can be broken down into three major subsystems which are steering wheel, front wheel and vehicle model system. Based on the Figure 2.1, the torque sensor, current sensor, steering angle sensor and motor encoded are situated within the steering wheel system. As for the front wheel system, it contains rack pinion gear, angle sensor, motor encoded and other related mechanism (Fahami, Zamzuri, Mazlan, & Zakaria, 2012).