TIE ROD ANALYSIS ON RACK AND PINION STEERING SYSTEM FOR SMALL CLASS VEHICLE

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A report submitted
In fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Tie Rod Analysis on Rack And Pinion Steering System for Small Class 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 (Automotive)

Signature : ….…….

Supervisor's Name : ……..

Date : ……..

DEDICATION

I dedicate this report to my beloved mother and father

ABSTRACT

Nowadays world demands car manufacture to produce a fuel efficient vehicle due to the consistently tightening regulation for protecting the environment. The use of lightweight automotive components can reduce fuel consumption and reduce carbon emission. This project is focuses on the design and material selection of a lightweight tie rod. To design a lightweight tie rod, a new material that has a lower density is needed. However, this new material could have a lower mechanical strength and causes the conflicting objectives during the design process. The objective of this project is to use Ashby's approach to solve conflicting objectives during design and material selection process of a lightweight tie rod. A suitable lightweight material will be determined by using CES Selector software. After the material was determined, the finite element analysis (FEA) will be conducted. The finite element analysis (FEA) is carried out to check its maximum stress and deformation. As a conclusion, trade-offs between low density and good mechanical strength will be considered for the new material.

ABSTRAK

Pada masa kini, dunia menuntut pembuatan kereta untuk menghasilkan kenderaan cekap bahan api kerana peraturan yang ketat secara konsisten untuk melindungi alam sekitar. Penggunaan komponen automotif ringan boleh mengurangkan penggunaan bahan api dan mengurangkan pelepasan karbon. Projek ini adalah memberi tumpuan kepada reka bentuk dan bahan pemilihan tie rod yang ringan. Untuk mereka bentuk tie rod yang ringan, bahan baru yang mempunyai ketumpatan yang lebih rendah diperlukan. Walau bagaimanapun, bahan baru ini boleh mempunyai kekuatan mekanikal yang lebih rendah dan menyebabkan objektif yang bercanggah semasa proses reka bentuk. Objektif projek ini adalah dengan menggunakan pendekatan Ashby untuk menyelesaikan objektif yang bercanggah semasa reka bentuk dan pemilihan bahan proses tie rod yang ringan. Bahan ringan yang sesuai akan ditentukan dengan menggunakan perisian CES Selector. Selepas bahan ditentukan, analisis unsur terhingga (FEA) akan dijalankan. Analisis unsur terhingga (FEA) dilaksanakan untuk memeriksa tekanan maksimum dan ubah bentuk. Kesimpulannya, keseimbangan antara kepadatan rendah dan kekuatan mekanikal yang baik akan dipertimbangkan untuk bahan baru.

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LIST OF ABBREVIATIONS

CNC	Computer Numerical Control
CATIA	Computer Aided Three-dimensional Interactive Application
FEA	Finite Element Analysis
CES	Cambridge Engineering Selector

LIST OF SYMBOLS

m	=	mass
A	=	Area
L	=	Length
ρ	=	Density
F	=	Force
σ_e	=	Fatigue constrain
M	=	Material index
ϕ_B^e	=	Shape factor in bending due to stiffness effect
ϕ_B^f	=	Shape factor relates the strength -efficiency
S	=	Stiffness cross section under consideration
S_o	=	Stiffness reference solid cross-section
I	=	Area moment of enertia
M_e	=	Limiting moment
X_o	=	output movement
X_i	=	Input movement
MR	=	Movement ratio
F_o	=	Load transmitted to the tie rod

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, the use of small class vehicle is highly in demand in Malaysia as it becomes the most used by the people as transportation in daily life. Most of the automobile manufacturers are trying to introduce lightweight component. This is due to the improve fuel consumption and performance because reduction of the weight of a component will reduce the overall weight of the car.

In this project, a new design of lightweight tie rod is studied. The tie rod is one of the most elementary parts of a steering mechanism, which has direct and crucial importance in terms of driving safety. Tie rod is part of steering system which connects center link to the steering knuckle in conventional suspension system and rack to the steering knuckle in McPherson suspension system. Tie rod generally gets force from rack and transfer it to the steering knuckle to turn the wheels. Tie rod is a circular rod with threaded part, Outer end and inner end. Tie rod is mostly made up of alloy steel. (Patil et al., 2013)

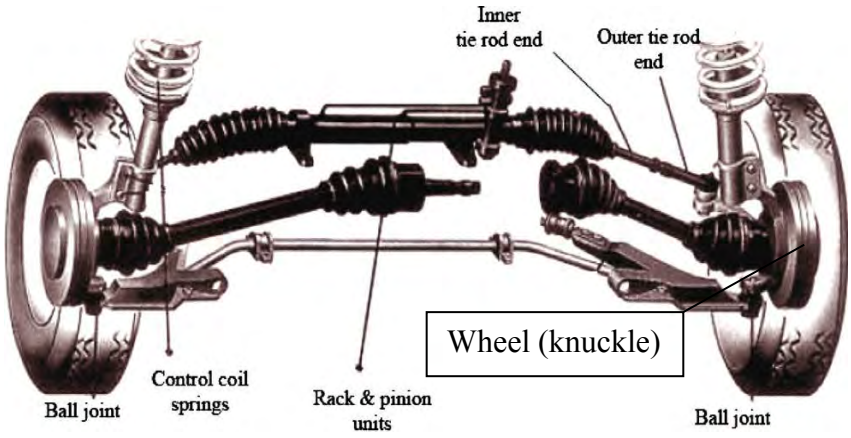

Figure 1.1: McPherson Suspension system (Patil et al., 2013)

Figure 1.2: tie rod

There have been many cases of lightweight structural design on body and chassis parts during the past decades (Park, Baek, Seo, Kim, & Lee, 2014). In this case of suspension and steering systems, there have been many studies on lightweight components, for example control arm or knuckle, but there were very few cases for the tie rod. This is because the outer tie rod is relatively much lighter than the other parts. However, along with recent trends, car makers and parts manufactures are interested in lightweight design of the outer tie rod.

Furthermore, consistent lightweight design is an essential means of extending the driving range. (Park et al., 2014)

Lightweight automobile parts can be developed by selecting steel substitutes, such as alloy, magnesium or aluminum. Based on design requirement, optimum selection of steel substitutes material will be using CES Selector software. The importance of lightweight design in the automobile industry has increased due to the consistently tightening regulation for protecting the environment. Other than that, using lightweight component also can reduce a car's fuel consumption.

To design lightweight component, one must consider conflicting objectives that may be associated with it. One of the conflicting objectives is between weight reduction and strength of the component. In fact, when the course materials with low density are use the strength will affect. As is known, the strength of a component decides how much load it can take before it breaks. In this case of lightweight tie rod, strength and mass are conditioning factor for the fuel efficiency.

1.2 Problem Statement

The problem that brought the idea of tie rod analysis on rack and pinion steering system for small class vehicle is because the tie rod are susceptible to bending, warping and breaking. Steel is conventionally used to produce tie rods due to its good mechanical properties such as high tensile strength and ductility. However, steel has high density and heavy. So, to minimize the weight of the tie rod, trade-offs must be made between lightweight and good mechanical strength. A suitable material will be proposed based on Ashby's approach using CES Selector and finite element analysis (FEA) using CATIA software.

1.3 Objective

The objective of this project are to use Ashby's approach to solve conflicting objectives during design and material selection process, and to conduct strength analysis of the tie rod using finite element analysis (FEA).

1.4 Scope of Project

This project will be focused on the finite element analysis (FEA) of the lightweight tie rod for small class vehicle. Second is to identify what is the conflicting objective. The design of the component will be carried out and analysis will be done using CATIA software. Based on the design requirement, optimum selection of lightweight material will be made based on analysis result using CES Selector software.

1.5 REPORT OUTLINE

In this project, the report will divide into five chapters. Chapter 1 describes about the introduction of tie rod end. This chapter also reviews about the problem statement of lightweight and its importance nowadays. Other than that, in this chapter also have objectives and scope of the project. Next, the Chapter 2 discusses about literature review which is referring to the journal and the book. From the journal research, we know that type of lightweight materials and its advantages and disadvantages. Other than that, using lightweight material can reduce fuel consumption and less carbon dioxide produce. Chapter 3 is a methodology which consist design analysis and design requirements. Beside that the

lightweight material will be determined using CES Selector software and the strength will be tested using finite element analysis (FEA). Next, Chapter 4 show the result and discussion. Lastly, Chapter 5 is the conclusion of the project and recommendation for the better material selection.

CHAPTER 2

LITERATURE REVIEW

2.1 Tie Rod End Working Mechanism

Tie rod end is the part of a tie rod. The tie rod is divided into two sections which is outer tie rod and inner tie rod. The function of the tie rod is a steering system connects the center link to the steering knuckle. Tie rod end generally gets force from the rack and transfer it to the steering knuckle to turn the wheels. The tie rod is a rod with threaded part, outer end and inner end. The tie rod is mostly made up of alloy steel. (Patil et al., 2013)

Figure 2.1: tie rod end

The current trend of the structural design of automobile parts is towards light weight design, light weight automobile part can be developed by selecting steel substitutes, such as plastic, aluminum, magnesium or composite materials.

2.2 Type of Lightweight Material

The lightweight materials may also be able to improve vehicle performance, such as acceleration or ride and handling. Other than that the selected material must have good mechanical strength to make sure the tie rod end is in good condition for a long period of time. Failure of tie rod end may cause instability of the vehicle and can cause an accident. Particularly, lightweight materials can be categorized into four groups (Source: advanced, lightweight materials development and technology for increasing vehicle efficiency (2008)).

1) High-strength steel
2) Aluminum
3) Magnesium
4) Composites

2.2.1 High-Strength Steel

High-strength steels are commonly used in automotive component because it has good durability and strength.

2.2.1.1 Properties High-Strength Steel

Table 2.1: High strength steel properties (Source: advanced, lightweight materials development and technology for increasing vehicle efficiency (2008)).

Material	High strength steel (A606)

Density, g/cm^3	7.87
yield strength, MPa	345
Tensile strength, MPa	483
Modulus of electricity, GPa	205

2.2.2 Aluminum

Aluminum is particularly strong in areas that require cast parts such as engine blocks, transmission casing and wheel. Nowadays, many cylinder blocks and another part are made from aluminum. Other than that, aluminum is easily worked using most machining methods such as milling, drilling, cutting, punching, bending and many more. One of the best known properties of aluminum is that it is light, with a density one third that of steel, 2.730 kg/m^3. The low density of aluminum accounts for it being lightweight but this does not affect its strength. Aluminum alloy commonly has a tensile strength of between 70Mpa and 700Mpa. Unlike most steel grades, aluminum does not become brittle at low temperature. Instead, its strength increase and at high temperature aluminum strength decrease.

2.2.2.1 Properties of Aluminum

Table 2.2: Aluminum properties (Source: aluminum design.net)

Material	Aluminum
Density, g/cm^3	2.73
yield strength, MPa	265
Tensile strength, MPa	295
Modulus of electricity, GPa	74