FATIGUE ANALYSIS OF STEERING KNUCKLE

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SUPERVISOR DECLARATION

"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
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DECLARATION

"I hereby declare that the work in this thesis entitle Fatigue Analysis of Steering Knuckle
is my own except for summaries and quotations which have been duly acknowledged."

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Special for my mum, Mrs. Ainon binti Zakaria and my dad Mr. Mohd. Razalli bin Abu Bakar, my oldest brother Ahmad Mourshedi bin Mohd. Razalli for everlasting supports, friends, and also lecturer Dr. Kamarul Ariffin bin Zakaria for preparation of this thesis.

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ABSTRACT

Generally, the steering knuckle works as a support in car which holds the tires besides ensuring a good handling, comfort and safety driving experience. Due to the problem occur on steering knuckle where design is not really reliable beside excessive material used on certain places where force in not present. An investigation and analysis is done by having the 3D CAD drawing and simulation using SolidWorks in order to determine the fatigue life behavior under various loading conditions. Forces that acted on the steering knuckle can either comes from the car or the road. The forces is not static and differ with time varying. SolidWorks is used to simulate as it has the ability to measure the fatigue life of a component by having a simulation based design. This helps to obtain all the data needed example like the life cycle, the reliability of the product, the identification of which the minimum stress is present and also the critical in steering knuckle where force is exerted in a huge amount. Perodua Myvi steering knuckle is choose in this project as it can help increase the handling and safety in that car. The results can be used in the future for further study.

ABSTRAK

Secara umumnya, sendi buku stereng berfungsi sebagai sokongan di dalam kereta yang memegang tayar selain memastikan kawalan kenderaan yang baik, keselesaan, dan juga keselamatan sewaktu pemanduan. Oleh kerana masalah yang datang pada sendi buku stereng di mana reka bentuknya tidak boleh di percayai selain berlaku lebihan bahan pada tempat yang tidak dikenakan sebarang beban. Sebuah kajian dan penyelidikan telah dijalankan bagi mengenal pasti tingkah laku hayat lesu sendi buku stereng apabila dikenakan beban dari pelbagai nilai dengan menggunakan simulasi dari SolidWorks. Beban yang dikenakan pada sendi buku stereng datang sama ada dari kereta mahupun jalan raya. Beban yang dikenakan tidak tetap dan berubah mengikut waktu. Simulasi SolidWorks digunakan untuk melihat hayat lesu bagi setiap komponen. Ini akan membantu dalam menghasilkan data seperti jangka hayat dan kitaran sesuatu bahan, keboleharapan, dan pengenalpastian di mana beban yang paling kurang dan juga beban yang paling maksimum yang akan dikenakan. Sendi buku Stereng Perodua Myvi di pilih dalam projek ini bagi membantu meningkatkan pengendalian dan keselamatan di dalam kereta. Keputusan yang diperoleh boleh digunakan untuk rujukan lanjut pada masa yang akan datang.

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LIST OF ABBREVIATIONS

DVVT	-	Dynamic Variable Valve Timing
CAD	-	Computer Aided Drawing
CATIA	-	Computer Aided Three Dimensional Interactive Application
FEA	-	Finite Element Analysis
PSM	-	Projek Sarjana Muda
PSB	-	Prolonged Sip Band
SAE	-	Society of Automotive Engineers
CNC	-	Computer Numerical Control

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Nowadays, the automobile industry becomes one of the assets for economic development. The automobile industry has grown rapidly since the production of the first car by Henry Ford. Cars have been improved dramatically from year to year in term of design, safety, technology and also performance. Steering module which related to handling is a piece of automobile suspension system which related to an exact vehicle stability and position. Steering knuckle is one of the automotive part on car and specifically been used in suspension system. The steering knuckle functions is to allow the wheels to turn. On cars with conventional suspension frameworks, the steering knuckle includes a spindle and connects the lower and upper ball joints. For modern cars which use MacPherson strut suspension systems, the steering knuckle connects the strut assembly to the lower ball joint.

Every vehicle will have four steering knuckle which located at the both rear and front-side in which on the front-side control arm joined together the left side of steering knuckle with the other side knuckle. Ball joint connect the steering knuckle with control arm. Ball joint helps lowering the unsprung mass of the suspension systems which would enhanced road holding. Both joint and pivot will experienced wear or crack after being exposed with movement and mechanism under a period of time. A lot of improvement was done by engineers and researches in order to produce the best design of the mechanism of steering knuckle which involved in steering system. Because of this scenario, in order to design a good and effective steering

knuckle, the right application should be consider and the analysis on reliability of the steering knuckle must be done. For future recommendation, this research need to analysed and study the fatigue life for various type and structure of steering knuckle.

1.2 PROBLEM STATEMENT

In today automobile vehicle, speed and handling plays an important factor in car construction. Because of this, steering knuckle need to have higher strength and stiffness but also must be lighter in weight and also size. In developing power output vehicle, the important goes to how to place the exact weight of linier and angular parts in steering knuckle. The overall performance of steering knuckle is affected by higher inertia force especially during driving which generated by the moving parts in the vehicle. This inertia comes from the uneven forces that act on the steering knuckle which can affect the lifetime and also the performance itself. Besides that, waste on material can also occur due to lack of knowledge and study in stress distribution on steering knuckle. Thus, an investigation on steering knuckle needs to be done In order to prevent any failure which can affect the car performance.

1.3 OBJECTIVE

The objective for this project are:

I. To apply 3D CAD modelling and Finite Element Analysis on steering knuckle.
II. To investigate the fatigue life behaviour of steering knuckle under various loading conditions.

1.4 SCOPES

There are several lists of scopes which will be applied thorough out the project. The scopes are:

I. To study the effect of steering knuckle under multiaxial load.

II. To analysed effect of acting force in steering knuckle using Finite Element Analysis.
III. To use SolidWorks Simulation as the simulation software to analysed fatigue failure.
IV. To identify the minimum stress area in steering knuckle.
V. To identify the critical part in steering knuckle when force is exerted.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In today manufacturing industry, the detail and specifications of steering knuckle comes in various design and shape for automobile vehicles. The configuration incorporates the specification vehicle whether it is suit or not with the vehicle itself. In addition, the design also emphasize the of reliability component whether the part can oblige the force that subjected on it. Although there are plenty of steering knuckle in the market today, the most important problem that occur in all automobile industry is the durability and reliability of the knuckle itself. Because of this problem, the understanding on stress and strain analysis and principle which experienced by the steering knuckle is needed in order to overcome the problem.

Steering knuckle can be names under part of suspension system, steering system, brake system and also as a part in wheel's assembly. Generally, the function of steering knuckle is to help in steering the car, brake and support the wheels. Steering knuckle also permits the front wheel to rotate and connect rotating components to suspension component beside helps distributing loads that comes from the road to body evenly. Inside a suspension systems, many parts are joined together to perform work which include steering knuckle. Parts like spring, shock absorbers, spindle, ball-joint and control arm are examples of suspension system. Steering knuckles have different shape for every different type of suspension system. Figure 2.1 shows the steering knuckle system that contain several part that attach to the steering knuckle such as disc

brake and the calliper. For Double Wishbone the knuckle is placed between upper and lower ball joints, while for MacPherson strut the lower ball joint with the strut itself.

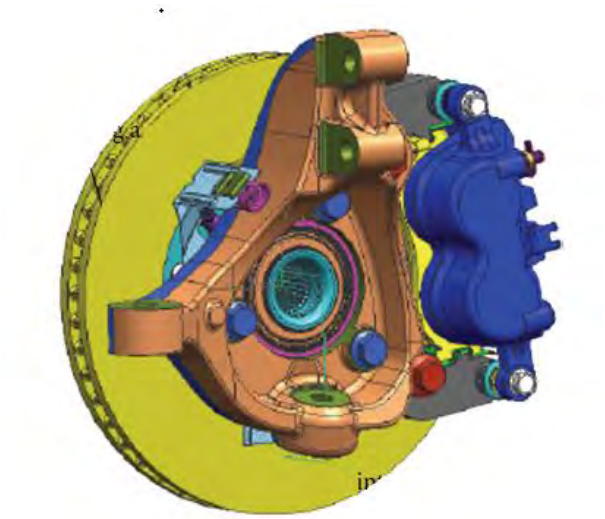

Figure 2.1: Steering knuckle system
(Source: Azrulhisham et. al, 2010)

2.2 FATIGUE LIFE

2.2.1 Introduction to Fatigue Life

Fatigue is the weakening of an element resulting from repetitively applied loads. It is the gradual and localized structural damage that takes place when an element is experiencing cyclic loading. The nominal highest stress values that result in such damage could be a lot less than the strength of the element generally set as the ultimate tensile stress limit or the yield stress limit. Fatigue takes place when a material is experiencing repetitive loading and unloading. If the loads are above the particular limit, microscopic cracks takes place to develop at the stress concentrators for instance the surface area, prolonged slip bands (PSBs), and also grain interfaces (Kim & Laird, 1978). Eventually when the crack reach a critical limit, the crack will generate suddenly, and the framework will begin fracture. The appearance of the structure will significantly influence the fatigue life example a square holes or sharp corners will

probably result in increased local stresses in which fatigue cracks can initiate while circular holes and smooth transitions or fillets will therefore raise the fatigue strength of the structure (Kim & Laird, 1978).

Fatigue life can be divided into four stages before the material begin to failure. The first stage is the crack initiation features the beginning of growth and development of fatigue damage that could be eliminated by an effective thermal anneal. Secondly, slip-band crack enhancement includes the deepening of the primary crack on planes of higher shear stress. This normally is known as stage one crack growth. Thirdly, crack growth on planes of higher tensile stress includes growing of distinct crack in direction normal to maximum tensile stress. Commonly known as stage two crack growth. Ultimate ductile failure happens when the crack actually gets to adequate length as a result the remaining cross section are unable to support the applied load.

2.2.2 Factor Affecting Fatigue Life

There are several factors which can affect the fatigue life of a material. Geometry for a material is important as the variation in cross section of a material can cause the stress to be focused in certain point where crack can occur. Fatigue life, along with the characteristic during cyclic loading, differs widely for numerous materials such as composites and polymers vary significantly from metals (eFunda, 2014). Extreme higher or lower temperatures may also reduce fatigue strength. For several typical types of loading, for example bending and also torsion, the maximum stress happens at the surface area. In addition, the surface area is exposed to severe surroundings that include corrosion, or unexpected loads like scratch and impact (eFunda, 2014). Furthermore, studies indicate that even the failing of axial loading generally starts at the surface area. Together with all the evidences indicating the surface area, it is necessary to fully understand the impact of surface area roughness and the solutions improving surface properties (eFunda, 2014). Table 2.1 shows the effect of surface roughness experiment done by using SAE 3130 steel specimens under stress at 655 MPa proves that a uniform and smooth surface can affect the fatigue life.

Table 2.1: Effect of surface roughness on fatigue life

Finish	Surface roughness (micron)	Median fatigue life (kilo-cycles)
Lathe-formed	2.67	24
Partial hand-polished	0.15	91
Hand polished	0.13	137
Ground	0.18	217
Ground and Polish	0.05	234
Superfinished	0.18	212

(Source: eFunda, 2014)

2.3 CAR SUSPENSION SYSTEM

There are many types of car suspension system. The most common one is the MacPherson strut suspension system. It can be seen on many cars on the road. Different types of suspension system give different experiences in term of handling. This is because some vehicles are made for racing, daily drive and many more.

2.3.1 Introduction

Steering knuckle is one of the suspension component which helps to hold car and tyres besides ensuring a smooth ride. The steering knuckle shape is mostly depends on how the suspension system will work and the component that will attached to it. Different type of suspension system can have different design of steering knuckle. The design can also differ according to the car even though the suspension system is the same. This ensure that the steering knuckle can fit exactly on it position. The most common suspension system is the MacPherson strut suspension which has been used widely in car.

2.3.2 Type of Suspension System

The suspension system have many design in which give different driving experience to the driver. However, all the suspension system are related to each other and provide the same function to the vehicle.

2.3.2.1 Solid Beam Axle

Getting into chronological order, the very first mass produced front part suspension design and style was the solid beam axle. In the same way that it looks, in the beam axle setup the two of the front wheels are linked to each other by a solid axle (Isaac-Lowry, 2004) as shown in figure 2.2. This design was brought over to the first automobiles from the horse driven carriages of earlier times and worked adequate to ensure that in the beginning no other suspension even necessary to be considered (Isaac-Lowry, 2004). As a matter of fact the beam axle can certainly still be discovered these days. New improvements in springs, roll bars, and shocks have kept the solid axle convenient for certain applications. This design continue used on semi-trucks as well as the large trucks due to the strength of the axle (Kilchermann, 2015).

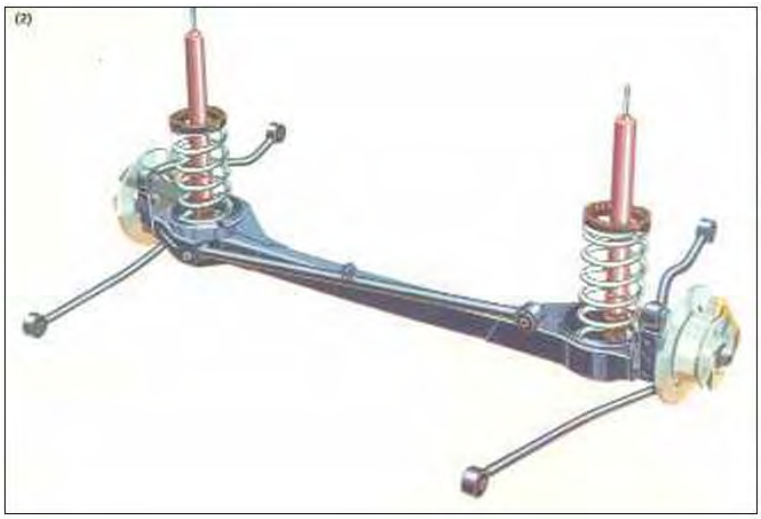

Figure 2.2: Beam axle design
(Sources: Isaac-Lowry, 2004)

2.3.2.2 Swing Axle Suspension

After designers had recognized the significant downsides of the solid axle front suspension, they proceed forward to create an initiative independent design of front suspension. One of those design is the swing axle suspension which is shown in figure 2.3. It is, as the term indicates, set up so that the axles pivot around a location at some place near the center of the vehicle and enable the tires to travel up and down throughout their specific arcs (Isaac-Lowry, 2004). This design was used by some sports car in the 50s such as the Mercedes 300SL Gullwing. However, the problem raised when applying this suspension is the unloading of the tires after encountering a bump in the road (Kilchermann, 2015). Soon, designers add a universal joint between the axle and the wheel which allowed the wheel to remain at its position whenever hit a bump.

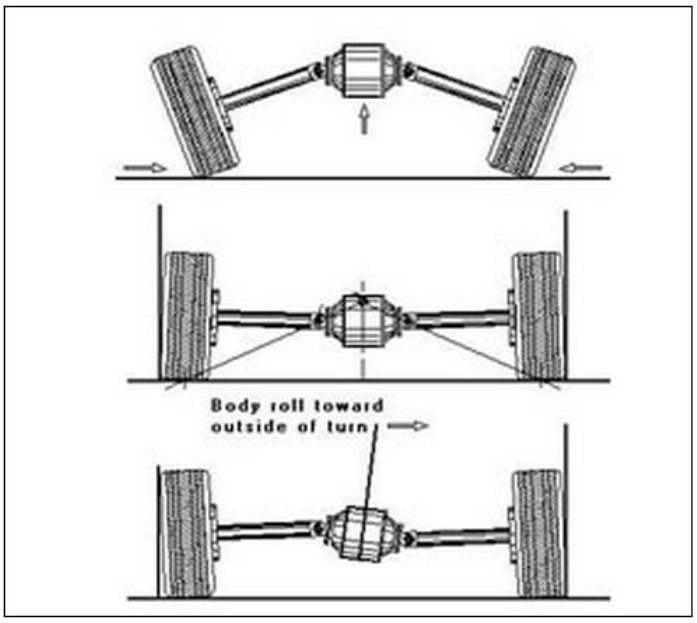

Figure 2.3: Swing axle suspension

(Sources: Isaac-Lowry, 2004)

2.3.2.3 Trailing Link Suspension

Another earlier type of front independent suspension is known as the trailing link suspension. This suspension design and style uses a number of arms positioned