SIMULATION OF FATIGUE LIFE ANALYSIS OF LOWER SUSPENSION ARM OVER DIFFERENT ROAD PROFILES

GOH CHEE HUI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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in fulfilment of the requirement for the degree of
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DECLARATION

I declare that this report entitled "Simulation of Fatigue Life Analysis of Lower Suspension Arm Over Different Road Profiles" 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 : ……

Name of Supervisor : ……

Date : ……

DEDICATION

To my beloved mother and father

ABSTRACT

Fatigue life is an important factor that cause failure in a component. Unlike other type of failure, fatigue failure has no warning or failure indication as it is caused by a microscopic crack and gradually grow into a macroscopic crack. Such failure often happens in a vehicle suspension system as suspension system experience numerous load application due to uneven road and imperfect road design. One of the common components that experience fatigue stress is lower suspension arm. Lower suspension arm is a hinge that connect the wheel and suspension system to the chassis of a car. Lower suspension arm experiences a lot of load as the car drive such as linear deflection, moment of roll, moment of yaw and moment of pitch. As the result of the repetitive loads, fatigue failure often found in lower suspension arm causing issue several issue to car such as instability and even wheel coming off when driving. Hence, this project focus on fatigue life analysis on lower suspension arm. The analysis is done by using strain-based analysis as it analyses the plastic deformation occur in a local region as opposed to stress-based analysis which is based on nominal stress as reference. The analysis is also done with uniaxial approach instead of triaxial approach. Uniaxial as the name suggest uses data on only one axis while triaxial uses data on three axes. Although triaxial approach is able to analyse non-proportional strain data and taking out-of-phase strain into account, uniaxial is more commonly used as it localized the strain acting on the lower suspension arm. In this study, finite element analysis is used to simulate the fatigue life of lower control arm in four different strain history. From the analysis, it is found that the fatigue life of lower suspension arm is 0.314×10^4 cycle when bracket strain history is applied, 69.056×10^4 cycle when suspension strain history is applied and 8.380×10^4 cycle when the transmission strain history is applied.

ABSTRAK

Jangka hayat lesu adalah salah satu faktor yang menyebabkan kegagalan dalam komponen. Kegagalan lesu adalah berbeza dengan kegagalan lain kerana kegagalan lesu tidak memberi amaran atau petunjuk sebelum patah. Kegagalan lesu bermula dari retakan mikroskopik dan bertumbuh sampai menjadi retakan makroskopik. Kegagalan tersebut sering berlaku di sistem gantungan kereta oleh sebab beban yang berulang apabila dipandu di jalan raya yang tidak rata. Salah satu komponen yang sentiasa mengalami kegagalan lesu ialah lengan kawalan bawah. Lengan kawalan bawah berfungsi seperti engsel yang menyambungkan roda dan sistem gantungan dengan casis kereta. Apabila kereta dipandu, lengan kawalan bawah mengalami banyak beban seperti lenturan linier, momen olengan, momen gulingan dan momen anggulan. Dengan mengalami beban tersebut berulang-ulang, kegagalan lesu sering berlaku di lengan kawalan bawah dan menyebabkan kereta tidak stabil dan roda terkeluar semasa memandu. Oleh itu, projek ini fokus kepada menganalisis jangka hayat lesu lengan kawalan bawah. Terdapat dua jenis analisis lesu iaitu melalui tegasan dan melalui terikan. Projek ini menggunakan analisis melalui terikan kerana analisis ini mengambil kira deformasi plastik yang berlaku di satu kawasan, analisis melaui tegasan pula mengambil tegasan nominal sebagai rujukan untuk berlakukan analisis. Analisis ini boleh dilaku melalui cara satu paksi iaitu menggunakan data dari satu paksi atau cara tiga paksi iaitu menggunakan data dari tiga paksi. Cara tiga paksi dapat menganalisi terikan yang bukan linier dan mengambil kira terikan luar fasa manakala cara satu paksi lebih biasa digunakan oleh sebab terikan dilokasi di tempat yang sama. Dalam projek ini, cara satu paksi dan analisis unsur terhingga telah digunakan untuk mengenal pasti jangka hayat lesu. Dari kajian ini, jangka hayat lesu lengan kawalan bawah adalah 0.314×10^4 *pusingan apabila terikan pendakap digunakan,* 69.056×10^4 *pusingan apabila terikan gantungan digunakan dan* 8.380×10^4 *pusingan apabila terikan transmisi digunakan.*

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LIST OF ABBREVAIATIONS

SWT	Smith, Watson and Topper
ESD	Effective strain damage
FE	Finite element
FEA	Finite element analysis
CAD	Computer-aided design

LIST OF SYMBOLS

σ	Stress
σ_a	Stress amplitude
σ_m	Mean stress
σ_{max}	Maximum stress
σ_{eq}	Equivalent stress
ε_a	Strain amplitude
ε_N	Normal strain
γ_{max}	Maximum shear strain
N_f	Number of cycles
σ_f'	Tensile strength fatigue coefficient
ε_f'	Fatigue ductility coefficient
E	Modulus of elasticity
ν	Poisson's ratio
α_{BM}	Brown-Miller fitting parameter
km	Kilometers
mi	Miles
Pa	Pascal
MPa	Mega Pascal
s	Seconds
mm	Millimeters
kg	Kilograms

N	Newton

CHAPTER 1

INTRODUCTION

1.1 Background

In a vehicle there are a lot of wear and tear component such as tire, brake pad, clutch pad engine mounting, these parts are prone to fail over time. Among that, lower suspension arm is a very common component in a car that will wear up overtime and require replacement after a period of time, typically $160\ 000km$ or lower (Tom, 2016). Lower suspension arm is a hinge that join the constantly moving wheel and suspension system to the statics vehicle's chassis. The wearing of lower suspension arm is caused by multiple loads such as tensile, compression and rotational moment apply on the component. These repeated stresses acting on the lower suspension arm cause the lower suspension arm to experience fatigue stress.

The failure of lower suspension arm can cause problem such as the wheel separating from the vehicle while driving, the vehicle ends up losing control as the wheel separate (Anonymous, 2019). The wear and of the lower suspension arm can be detected by several feedback experience by the driver such as steering wheel vibrating when driving, clunking sound at the wheel, the car misaligns and cause the car to wonder, uneven wear on the tire and instability when the car brakes (Anonymous, 2020)

Fatigue stress is the maximum stress that a component can withstands for a specific number of repetitions without failure. While most of the failed machine component found are caused by repeated or fluctuating stress (Budynas, 2011). The failure due to fatigue stress start from microscopic damage and worsen as the load applied repeatedly and the component

eventually fail (Dowling, 2013). Hence, fatigue stress is very important to be analysed as failure will not occurs at the first few stress tests of the component but it comes after thousands or millions of repeating applications of force.

There are a few approaches to analyse the fatigue life of the lower suspension arm. To list a few, uniaxial strain analysis had been performed by Husin et. al (2010), Rahul et. al (2014), Rahman et. al (2009), Abdullah et. al (2008), Naik et. al (2018) and Kale AR et. al (2018); while Essienubong et. al (2016), Savkin et. al (2017), Kulkarni et. al (2016) and Taksande et. al (2015) use triaxial strain analysis approach. Kong et. al (2020) on the other hand perform both uniaxial and triaxial strain analysis and compare their results.

Uniaxial strain analysis is a type of approach that only use data from one axis to make calculation. Commonly, Coffin-Manson, Morrow and Smith, Watson and Topper (SWT) method is used to perform uniaxial strain analysis (Husin, 2010). Uniaxial strain analysis is also commonly used in automotive field as it localized the strain acting on a component. Coffin-Manson approach is first used to relate the plastic strain to the fatigue life. Then Morrow approach adds the mean stress into the analysis and lastly, SWT method determine the mean stress by calculating the maximum stress acted in a time. Morrow and SWT Method are commonly used because of the existence of non-zero stress that can affect the fatigue behaviour of the component (Rahman, 2009). The loading data of uniaxial strain analysis can be analysed by obtaining the loading data of load-time history by using rain flow cycle method and convert into strain-time history (Husin, 2010). Another method is obtained by analysing the brake force which is assumed as maximum stress acting on the component (Rahul, 2014). The load data can also be calculated from multiple parameter such as mass and weight ratio of the vehicle (Jubri, 2015).

The uniaxial analysis is commonly used for automotive application due to simplicity however the result of uniaxial approach analysed by using Coffin-Manson, Morrow, SWT and Effective Strain Damage (ESD) are different even with the same load (Abdullah, 2008). The analysis with different application of load also result in different strain result (NitheshNaik, 2018). The difference also shown in real life experiment where the reading of strain gauge is different when installed at different position on the component (Ikpe Aniekan Essienubong, 2016). Besides, uniaxial strain analysis only performs at a single axis only, the component is assumed to be in an in-phase situation while the actual out of phase load is not considered (Kong, 2020). The conflict in uniaxial analysis can be overcome by using triaxial analysis where data of more than one axis is used in the analysis. This provide a more accurate analysis result compare to uniaxial analysis.

For triaxial strain analysis, the analysis is done on three different axes instead of one. Brown-Miller and Morrow mean stress approach are used in triaxial strain analysis. Brown-Miller approach introduce elements of normal strain and shear strain into the analysis equation (Kong, 2020). With that, analyse of fatigue stress is done with multiple elements of strain which are normal strain and shear strain. In other study, triaxial strain analysis is also done by combining the data of three different axes into one equivalent stress by using Mizes's hypothesis of specific energy deformation (Savkin, 2017). The data for triaxial strain can be obtained from putting a triaxial sensor on the component to measure the strain (Ambarish Kulkarni, 2016).

For this project, finite element analysis is first used to find the critical point which is describe as "the hotspot" by Sushilkumar P. Taksande (Taksande, 2015) where the stress is concentrated the most. After the critical point is determined, the analysis is then followed by fatigue analysis due to uniaxial strain. Although triaxial strain analysis take out of phase load

into consideration, the uniaxial strain analysis is used in this project instead as this approach is more commonly use in vehicle suspension analysis. The fatigue life is analysed by applying several different set of strain histories on the lower suspension arm to analyse the fatigue life of the lower suspension arm.

1.2 Problem Statement

As car has become a very common item everyone has, it is sometime considered as a necessity instead of wants by today standards. With that in mind, reliability of a car and service period of a car had become a very important factor to look into when designing a new car. Wear and tear component of a car become the focus of a lot of study as wear and tear parts with better quality will result in better longevity and improved reliability. One of the wear and tear component is the lower suspension arm.

Lower suspension arm functions as a connecting hinge between wheel and suspension system to the chassis of a car. The wheel and suspension system are constantly moving as the vehicle move, while chassis stay statics. As the result of irregular road surface that the car drives on, the wheel moves in every direction hence transmitting different load such as tension, compression, twisting moment, pitching moment and rolling moment to the lower suspension arm. Although suspension is designed to dampen the stresses, the lower suspension arm still transfers some of the load to the chassis making the rigid lower suspension arm experience as many stresses as the suspension system experience.

With the force repeatedly acting on the lower suspension arm, the lower suspension arm will eventually fail due to fatigue stress. Lower suspension arm may break and even cause the wheel to detach itself from the chassis. Such incident can cause a very serious impact especially when the car is driving. The component which are design to keep the car safe will become dangerous to the user and other road user if it fails. Hence, fatigue life analysis of lower suspension arm is very important.

Uniaxial strain analysis is used in the analysis of the fatigue life of the lower suspension arm instead of triaxial strain analysis. Although triaxial strain analysis provide a more complete data on multiple aspect of strain as it uses data from three different axes and supposedly provide a more accurate result, uniaxial strain analysis is more commonly used in automotive analysis as it focuses on the localised strain on the suspension component, which in this case, lower suspension arm. Therefore, uniaxial strain analysis is used to determined the fatigue life of the lower suspension arm.

1.3 Objective

The main objective of this project is:

1. Understand the uniaxial strain method and finite element analysis in fatigue life analysis.
2. Analyse the critical area and the fatigue life of lower suspension arm by using uniaxial strain method on finite element analysis.
3. Compare the difference between the analysis result on different strain history

1.4 Scope of Project

The scope of this project is:

1. Understand the structure and principle of lower suspension arm, theory behind fatigue life, strain analysis as well as the principle behind uniaxial strain analysis and finite element analysis.
2. Researching on different analysis approach on lower suspension arm.
3. Locate the critical point on lower suspension arm and analyse the fatigue life of lower suspension arm by using uniaxial strain approach on finite element analysis.