Faculty of Mechanical Engineering

EFFECT OF VARIABLE AMPLITUDE LOADING ON FATIGUE CHARACTERISTIC AND FAILURE PROBABILITY FOR AUTOMOBILE STEERING KNUCKLE

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DECLARATION

I declare that this thesis entitled “Effect of Variable Amplitude Loading on Fatigue Characteristic and Failure Probability for Automobile Steering Knuckle” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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 Master of Science in Mechanical Engineering.

Signature	:	…………………………………………
Supervisor Name	:	Dr. Kamarul Ariffin bin Zakaria
Date	:	…………………………………………

DEDICATION

Specially dedicated to my beloved parents,

Ad. Suhadak bin Nordin and Haslinda Hanim binti Jalil.

Not forgetting,

My family members for their love, supports and prayers.

ABSTRACT

Steering knuckle is an important compartment in a vehicle. It functions as a joint connecting the suspension and steering system where the steering arm could maneuver the automobile direction. While driving, the automobile steering knuckle is exposed to variable amplitude loading that is influenced by the conditions of the road surfaces. Traditionally, most of the fatigue life assessment is performed using constant amplitude loading. However, in operation most of the engineering components are subjected to stresses which varies with time. Therefore, the study of fatigue life under variable amplitude loadings is an important subject. The main objective of this study is to investigate the fatigue life behavior and fatigue failure probability based on the variable amplitude loading. In this study, the actual variable amplitude loadings are obtained from steering knuckle of 1300 cc national automobile. The fatigue strain signals, which acts as a variable amplitude loading are captured using a 2 mm strain gauge and a data acquisition system while the vehicle is driven onto different road surfaces. The fatigue strain signal sample is recorded for 60 seconds. Four types of road are used in this study which are the residential area road, rural road, country road and highway road. The fatigue strain signal behaviors are then determined using global statistical analysis. Prior to capturing the fatigue strain signals, the position of the strain gauge on automobile steering knuckle is determined using finite element analysis. For simulation purposes, the automobile steering knuckle is modeled using a 3D scanner, Faro Laser Scan Arm to provide an accurate dimension. Then, the finite element model is created using a commercial finite element software. The model is meshed using tetrahedral element type. Loadings are applied on strut mount and lower ball joint with consideration of the weight of the car with passenger and driven at constant speed. The fatigue damage behavior of automobile steering knuckle is simulated using Glyphwork® software. The obtained fatigue damaged is correlated with the fatigue strain signal behavior. Then, the fatigue failure probability that contributed from the different road surface condition is determined. Results indicated that the fatigue strain signals behavior, fatigue damage, fatigue life of automobile steering knuckle are influenced significantly by the different type of road surfaces profile. Residential road recorded the highest strain signal range, vibration energy and power content of steering knuckle. It also contributed to the most damage as compared to the rural, country and highway road on automobile steering knuckle. The failure probability that is in consideration of different type of road surfaces also contributed to the prediction of fatigue life. Morrow approach recorded a higher fatigue life of steering knuckle than SWT approach and it is found that Morrow approach is more suitable to be applied in steering knuckle case. This is due to the type of loading condition and material used in steering knuckle which is more suitable for Morrow approach.

ABSTRAK

Sendi buku stereng adalah komponen penting dalam kereta. Ia berfungsi sebagai sambungan bersama antara stereng dan lengan stereng yang boleh mengawal arah pergerakan kereta. Semasa memandu, sendi buku stereng kereta terdedah kepada pembebanan pelbagai amplitud yang dipengaruhi keadaan permukaan jalan. Tradisinya, sebahagian besar daripada penilaian hayat lesu dilakukan menggunakan pembebanan amplitud malar. Walau bagaimanapun, dalam perkhidmatan sebenar sebahagian besar daripada komponen kejuruteraan dikenakan tegasan yang berbeza dengan masa. Oleh itu, kajian hayat lesu di bawah pembebanan pelbagai amplitud adalah penting. Objektif utama kajian ini adalah untuk menyiasat kelakuan hayat lesu dan kebarangkalian kegagalan lesu berdasarkan kepada pembebanan pelbagai amplitud. Dalam kajian ini, pembebanan pelbagai amplitud sebenar telah diperolehi daripada sendi buku stereng kereta kebangsaan 1300 cc. Isyarat terikan lesu, yang bertindak sebagai pembebanan pelbagai amplitud telah dicerap menggunakan tolok terikan bersaiz 2 mm dan sistem pengumpulan data semasa dipandu di atas permukaan jalan yang berbeza. Sampel isyarat terikan lesu telah direkodkan selama 60 saat. Empat jenis jalan digunakan dalam kajian ini iaitu jalan kawasan perumahan, jalan luar bandar, jalan negeri dan lebuh raya. Kelakuan isyarat terikan lesu kemudiannya ditentukan menggunakan analisis statistik umum. Sebelum isyarat terikan lesu dicerap, kedudukan tolok terikan pada sendi buku stereng kereta telah ditentukan menggunakan analisis unsur terhingga. Bagi tujuan simulasi, sendi buku stereng kereta telah dimodelkan menggunakan pengimbas 3D, Faro Laser Scan Arm untuk memberikan dimensi yang tepat. Kemudian, model unsur terhingga telah dibuat menggunakan perisian unsur terhingga komersil. Model ini telah dijaring menggunakan elemen jenis tetrahedral. Pembebanan keatas sendi buku stereng kereta dikenakan pada 'strut mount' dan 'lower ball joint' dengan mengambil kira berat berat kereta bersama penumpang dan pada kelajuan malar. Kelakuan kerosakan lesu bagi sendi buku stereng kereta telah disimulasi menggunakan perisian Glyphwork®. Kerosakan lesu yang diperolehi telah dikorelasi dengan kelakukan isyarat terikan lesu. Kemudian, kebarangkalian kegagalan lesu yang disumbang oleh keadaan permukaan jalan yang berbeza telah ditentukan. Keputusan menunjukkan bahawa kelakuan isyarat terikan lesu, kerosakan lesu dan hayat lesu sendi buku stereng kereta dipengaruhi dengan ketara oleh profil permukaan jalan yang berbeza. Jalan kawasan kediaman mencatatkan skala isyarat tarikan, tenaga getaran dan kandungan kuasa sendi buku stereng yang paling tingggi. Ia juga menyumbang kepada kerosakan lesu yang paling banyak berbanding jalan luar bandar, jalan negeri dan lebuh raya. Kebarangkalian kegagalan yang mengambil kira jenis permukaan jalan yang berlainan juga menyumbang kepada peramalan hayat lesu. Pendekatan Morrow mencatatkan hayat lesu sendi buku stereng yang lebih tinggi daripada pendekatan SWT dan pendekatann Morrow didapati lebih sesuai diaplikasi dalam kes sendi buku stereng . Hal ini disebabkan jenis keadaan pembebanan dan komposisi bahan yang digunakan dalam sendi buku stereng itu lebih sesuai unuk pendekatan Morrow.

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LIST OF ABBREVIATIONS

3D	-	3 Dimension
ASTM	-	American Society for Testing and Materials
CAL	-	Constant Amplitude Loading
DAQ	-	Data Acquisition System
EDX	-	Energy- Dispersive X- Ray Spectroscopy test
EN	-	Strain Life
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
FKM	-	Fakulti Kejuruteraan Mekanikal
MMC	-	Metal Matrix Composite
OL	-	Over Load
PSD	-	Power Spectrum Density
S-N	-	Stress-Life
SAE	-	Society of Automotive Engineers
SEM	-	Scanning Electron Microscope
SWT	-	Smith-Watson-Topper Mean Stress Correction
UL		Under Load
UTS	-	Ultimate Tensile Strength
VAL	-	Variable Amplitude Loading

WRP	-	3D Modelling File
YS	-	Yield Strength

LIST OF SYMBOLS

σ	-	Stress value
σ_a	-	Stress amplitude
σ'_f	-	Fatigue strength coefficient
σ_m	-	Mean stress
σ_{max}	-	Maximum stress
σ_{min}	-	Minimum stress
ε	-	Fatigue strain
ε'_f	-	Fatigue ductility coefficient
ε_a	-	Strain amplitude
a	-	Material constant
b	-	Fatigue strength exponent
B	-	Length of grip section
c	-	Fatigue ductility exponent
D	-	Fatigue damage
D_{Morrow}	-	Fatigue damage Morrow
D_{SWT}	-	Fatigue damage SWT approach
E	-	Elastic modulus
G	-	Gauge length
j	-	Number of sample function

k	-	Strain hardening coefficient
L	-	Overall length
l	-	Length of reduced section
N	-	Number of data
n_i	-	Number of applied data
N_{ic}	-	Number of cycles to failure at *i*th stress level
$r_{i,lb}$	-	Radius of inner lower ball joint
$r_{o,lb}$	-	Radius of outer lower ball joint
r_{sm}	-	Radius of strut mount hole
R_f	-	Radius of fillet
R	-	Stress ratio
$r.m.s$	-	Root mean square
SD	-	Standard deviation
t	-	Thickness
W	-	Width
w_g	-	Width of grip section
w_{sm}	-	Width of strut mount joint
$\bar{x}$	-	Mean data

LIST OF PUBLICATIONS

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