UNIVERSITI TEKNIKAL MALAYSIA MELAKA	UNIVERSITI TEKNIKAL MALAYSIA MELAKA CENTRE FOR RESEARCH AND INNOVATION MANAGEMENT
	PROJECT COMPLETION REPORT

PERHATIAN:

1. Laporanakhirprojekhendaklahdihantarke**CRIM dua (2)**bulanselepasprojektamat.
2. Silalampirkandokumen yang berkaitanseperti yang dinyatakan.
3. Senaraisemak:

No.	Perkara	Tandakan (√)
1.	Borang RND13lengkap	☐
2.	PerakuanPengarah CRIM	☐
3.	SertakanTemplate Profile Penyelidikan.	☐
4.	Salinan Softcopy (CD).	☐

A. PROJECT DETAILS

Principal Researcher : Dr. KamarulAriffin Bin Zakaria

Faculty/Centre : FakultiKejuruteraanMekanikal

Project Title :Investigation on fatigue life characteristic and failure probability subjected to variable amplitude loadings

Project No.: FRGS/2/2014/TK01/FKM/03/F00234

CoE : CARe

RG : HiPS

Project Duration : Starts Date 01 Dec 2014Final End Date:30 Nov 2017

Budget Approved: RM 119,500Amount Spent Up to this period:RM 114,943.60

Project Members : MultidiciplinaryMul ☐ ty√ ☐

B. PROJECT ACHIVEMENT AND PERFORMANCE

OVERALL	**0 – 50%**	**51 – 75%**	**76 – 100%**
Work completion (please state %)			95 %
Financial Utilization (please state %)			96.2 %
RESEARCH OUTPUT			
I. PUBLICATION (Recorded at UTeMeRepository)	UTeM Press	Index Scopus/ISI	Others
a. No. of Journal Publication (Please attach the first page of publication)		4	
b. No. of Conference Proceeding (Please attach the first page of publication)		2	
c. No. of Other type of publication eg. monograph, books, chapters in book			

II. PROTOTYPE DEVELOPMENT	National	International
a. No. of Intellectual Property Rights		
b. Attended product exhibition & competition		
c. No. of Industrial Collaboration MoU/NDA/MoA)		

III. HUMAN CAPITAL DEVELOPMENT

Number of Human Capital		On-Going		Graduated	
		Malaysian	Non-M	Malaysian	Non-M
1	PhD Student				
2	Master Student	1			
3	Undergraduate Student (SRA)			3	
Total		1		3	

IV. ASSETS AND INVENTORY PURCHASED (Cost more than RM 3000 per item)

1. NI Data Acquisition System (RM 18,974 including GST)
2. 4 yrs license nCodeGlyphworks Software (RM 6648.32 including GST)
3. 4 yrs license nCodeDesignLife Software (RM 6648.32 including GST)
4.
5.

DECLARATION OF PRINCIPAL RESEARCHER

I acknowledged UTeM in providing the fund for this research work. (For University Grant only)

I certify that the information given in this final project report is true to the best of my knowledge.

Principal Researcher Signature :

Official stamp :
Name :
Designation :
Date :

ENDORSEMENT BY DIRECTOR OF CRIM
(Please state /comment on the performance of the project)

____

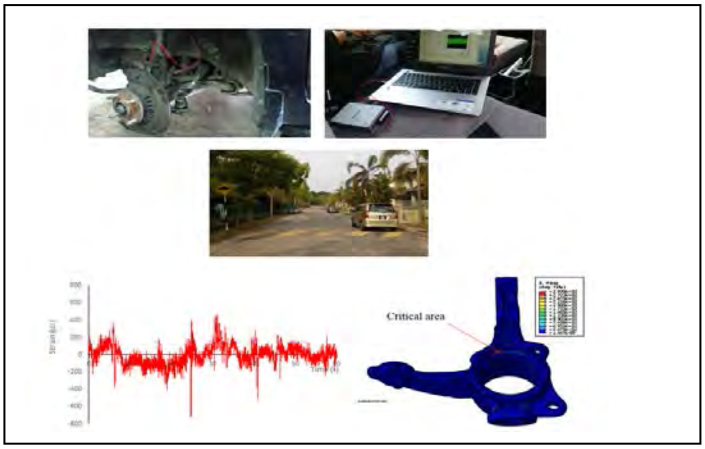
____

Signature & Official Stamp   Date

CRIM Revised date: 9 June 2017

LAMPIRAN A

RESEARCH PROFILE / TECHNICAL REPORT



TITLE OF RESEARCH

Investigation on fatigue life characteristic and failure probability subjected to variable amplitude loadings

PROJECT NO

FRGS/2/2014/TK01/FKM/03/F00234

NAME OF RESEARCHERS

Dr. Kamarul Ariffin Zakaria
Prof. Ir. Dr. Shahrum Abdullah (FKAB UKM)
Dr. Mohd Basri Ali (FKM UTeM)
Dr. Mohd Asri Yusuff (FKM UTeM)
Dr. Mohd Shahir Kassim (FKP UTeM)
Pn. Siti Norbaya Shaadan (FKM UTeM)

IPTA / FACULTY / RESEARCH GROUP

Faculty of Mechanical Engineering,
Centre for Advanced Research on Energy (HiPS group), UniversitiTeknikal Malaysia Melaka.

PROJECT DURATION

01 Dec 2014 – 30 Nov 2017

DATE OF REPORT

18 Jan 2018

EXECUTIVE SUMMARY / ABSTRACT

Traditionally, most of the fatigue life characterisation is performed using constant sinusiodal loading. However, the great majority of engineering components are subjected to variable amplitude loadings. The study on fatigue life under the variable amplitude loading is more complex due load interaction and sequence effects, and less reported. Besides, the material properties of components used in the fabrication cannot be exactly consistent due to uncertainties associated with the size effect, machining and manufacturing conditions. These uncertainties factors should be considered as random variables that results in variation of the fatigue life curves. The fatigue life probability based on variable amplitude loadings need to be developed and worthy to an accurate life prediction based on signal processing approach. Therefore, the main objective of this research is to propose a fatigue failure probability model based on strain signal characteristics. In this study, strain gauges were attached to an automobile steering knuckle connected to the data acquisition set in order to capture actual strain signals when driving onto different road profiles. The strain signals were analysed statistically to determine their behaviour and correlate with fatigue damage that evaluated using finite element commercial software.Experimental fatigue lives were performed to develop the stress life curves. A variety of fatigue strain signals that affected by different road surfaces condition is then used to predict the fatigue failures probability. The expected outcomes of the fatigue failures probability from experimental and simulation can be used to predict the actual failure of the components.

1. INTRODUCTION

In design features reliability, the behavior of materials around the feature itself needs to be thoroughly understood to preserve the safety and integrity of the structure or its components, especially when they are subjected to stress of variable amplitudes. Fatigue failure and its mechanism associated with variable amplitude loading (VAL) are important in quantifying fatigue crack growth rate and fatigue life, which is becoming increasingly more complex. An accurate fatigue life prediction requires an adequate evaluation of the load interaction effects that exist in the VAL.

In this research, variable amplitude loading is captured from the automobile steering knuckle as a case study. Steering knuckle is one part of the vehicle’s steering and suspension system which undergoes time-varying loading during its service life. This system provides a means whereby driver can place his vehicle accurately where he wants it to be on the road. This system also means in keeping the vehicle stable on course regardless of irregularities in the surface over which the vehicle is travelling. Any failure in these components results immediately in loss of the orientation of the vehicle.

Signal processing is performed to collect information in certain signals. For example, signal processing technique was used in analysis fatigue strain signal, vibration signal, ultrasonic signal and acoustic signal. For fatigue analysis, signal processing technique used to analyze fatigue strain that varies their amplitude with time. Signal processing technique is used to relate the fatigue signal and fatigue damage.

The fatigue life of structures or components is a function of many variables, which may produce scattered results. The material properties of components used in the fabrication cannot be exactly consistent due to uncertainties associated with the size effect, machining and manufacturing conditions. These uncertainties factors should be considered as random variables that results in variation of the fatigue life curves. Besides, the scattered in loading variables may also produce variable fatigue life. This problem leads to the necessity of performing statistical analyses during designing and manufacturing for the safe utilization of materials.

2. OBJECTIVES OF RESEARCH

Structural or engineering components are prone to fatigue failure when subjected to a certain number of cyclic loading, which is normally occurs below the ultimate strength of material. Fatigue failure usually occurs without warning after a progressive degradation of the material subjected to cyclic loadings. Fatigue failure may ensue in a wide range of application, from simple objects to complex structures such as automotive, marine, and aircraft components. Therefore, the fatigue life assessment of engineering applications is highly important.

The majority of the fatigue life characterization of a material is performed using a constant sinusoidal loading, which is easier to accommodate with most of the fatigue testing machine's capabilities and to simplify the analysis. However, in actual applications most of the engineering components are subjected to stress amplitude that varies with time. Thus, the failure mechanism associated with VAL is important to understand in order to quantify the crack growth rate and fatigue lifetime under the VAL condition. Predicting of fatigue life and crack propagation becomes increasingly more complex under variable amplitude loadings due to load interaction and history effects.

In term of automotive applications, the fatigue life of their components is a function of many variables including the variability of the loading conditions. This problems leads to the necessity of performing the fatigue life prediction based on fatigue data of the real road profiles. Furthermore, probability of failure based on statistical analysis need to be developed in assisting the fatigue life prediction during designing and manufacturing for the safe utilization of materials.

Therefore, the objective of the present study is to investigate the fatigue strain signal behavior of automobile steering knuckle while driving on different road profiles, correlates the signal pattern with fatigue damage and propose a fatigue failure probabilitybased on signal processing of the strain signal characteristics.

3. RESEARCH METHODOLOGY

(a) Capturing fatigue strain signal history from automobile steering knuckle.
(b) Analyze of fatigue strain signal behavior using statistical method.
(c) FEA based fatigue life – determine the critical area, fatigue damage & fatigue life.
(e) Experimental fatigue life
(f) Fatiguefailure probability study

4. RESULTS / FINDINGS

In this study, the critical area on the steering knuckle is successful determined using commercial finite element software.The steering knuckle is modeled using computer-aided design software, in which the dimensions are assigned according to 3D scanning files.Results indicated that the maximum stress occurred at the point under the strut mount. This area is identified as a critical area for the steering knuckle where fatigue failure may occur. The strut mount is essentially connected with the shock absorber, which supports the majority of the car weight. Furthermore, the induced force also comes from the VAL generated from the uneven surface of the road condition.

A set of VAL data is then obtained using a strain gauge fixed on the steering knuckle of the 1300 cc automobile. The fatigue strain signal is captured while traveling on four different types of road surfaces, i.e. residential area road, rural road, country road and highway. The fatigue strain signal behavior were determined using statistic approach. Statistical values such as maximum, minimum, mean, range,r.m.s., kurtosis and PSD are successful differentiate the signal behaviors. Residential area road showed the highest values of signal range, r.m.s, kurtosis and PSD. This high strain range indicates that the steering knuckle experienced a significant displacement when the automobile is driven on the road bumper. The magnitude of displacement or elongation is at a specified and localized area on the steering knuckle, which is measured by the strain gauge in the form of time series history. Meanwhile, highway road showed the lowest since their road surface is smoother compared to others.

The fatigue strain signals areused as the VAL in the fatigue damage simulations of automobile steering knuckle. Fatigue failure occurs a material weakens due to repeated load application. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. In this case, fatigue damage may initiate at the critical area on the steering knuckle before propagating enough failures. Results of simulation from four types of fatigue strain signals showed the same location of fatigue damage, which is located at the neck of the strut mount. The simulation reveals that residential area road strain signal contributed to the highest fatigue damage with 7.28×10^{-4}, followed by rural road strain signal 2.02×10^{-4}, country road strain signal 1.15×10^{-4} and highway strain signal 4.16×10^{-5}. The fatigue damages are also analyzed and compared using different type of fatigue damage models. The damaged values arethen significantly correlated with the statistical signal behavior values.

The last part of the study is to propose a fatigue failure probabilitybased on signal processing of the strain signal characteristics. In term of automotive applications, the fatigue life of their components is a function of many variables including the variability of the loading conditions. This problems leads to the necessity of performing the fatigue life prediction based on fatigue data of the real road profiles. Damage data from the studies are compiled and analyzed to obtain the probability percentage. The probability graphs based on different damage models and different road surfaces condition are successful developed. From that, fatigue life of the automobile steering knuckle can be predicted and justified.

5. CONTRIBUTIONS OF RESEARCH

In this study, actual fatigue strain signal is captured from the steering knuckle of a 1300 cc national automobile while traveling on a residential road surface. This VAL is then used as input loading for fatigue analysis. Previously, there is no fatigue strain signal pattern of automobile steering knuckle reported. Thus, the obtain fatigue strain signals for different road surfaces can be used as a referenceVAL of the automobile steering knuckle. The fatigue strain signals were successful correlated with fatigue damage, which can be further used as an indicator based on the signal processing approach. The fatigue life probability of the automobile steering knuckle also contributed to a better prediction of the fatigue life by considering different condition of the road surfaces.

6. ACHIEVEMENT

i. Name of articles/ manuscripts/ books published

1. Fatigue strain signal characteristic and damage of automobile suspension system. 2018. ARPN Journal of Engineering and Applied Sciences 13(1): 221-225. (Scopus).
2. Influence of mechanical properties on load sequence effect and fatigue life of aluminium alloy. 2017. Journal of Mechanical Engineering and Sciences 11(1): 2469-2477. (Scopus).
3. Preliminary study on fatigue strain signal of automobile steering knuckle. Proceedings of Mechanical Engineering Research Day 2017: 310-311.
4. Fatigue damage analysis of automobile steering knuckle using finite element analysis. 2017. ARPN Journal of Engineering and Applied Sciences 12(14): 4225-4228. (Scopus).
5. Influence of Elevated Temperature on the Fatigue Fracture Surface Hardness of AA6061. 2016. Journal of Engineering and Applied Sciences 11(10): 2130-2135. (Scopus).

ii. Title of Paper presentations (international/ local)

1. Fatigue Damage Simulation of Automobile Steering Knuckle Subjected Variable Amplitude Loading (Oral presentation).
2. Preliminary study on fatigue strain signal of automobile steering knuckle. (Poster presentation).
3. Influence of mechanical properties on load sequence effect and fatigue life of aluminium alloy. (Oral presentation).
4. Fatigue damage analysis of automobile steering knuckle using finite element analysis. (Oral presentation).
5. Influence of Elevated Temperature on the Fatigue Fracture Surface Hardness of AA6061 (Oral presentation).

iii. Human Capital Development

1. One master student by research – on going
2. Three undergraduate students – graduated

iv. Awards/ Others

7. CONCLUSION

From the study on fatigue strain signal behavior of automobile steering knuckle,correlation of the signal pattern with fatigue damage and the fatigue failure probability, the fatigue life can be predicted based on signal processing of the strain signal characteristics. Furthermore, the obtained fatigue strain signal pattern from different road surface conditions can be used as a reference for further investigation of fatigue life under the VAL.

REFERENCES

[1] R. I. Stephens, A. Fatemi, R. R. Stephen and H. O. Fuchs, "Metal Fatigue in Engineering Second edition", New York John Wiley & Sons, 2001.

[2] A. L. M. Carvalho, J. P. Martins and H. J. C. Voorlwad, "Fatigue damage accumulation in aluminium 7050-T7451 alloy subjected to block program loading under step down sequence", Proc. Eng., vol. 2, Apr 2010, pp. 2037-2043.

[3] N. L. Post, S. W. Case and J. J. Lesko, "Modeling the variable amplitude fatigue of composite material: A review and evaluation of the state of the art for spectrum loading", Intl. J. of F., vol. 30, Dec 2008, pp. 2064-2086.

[4] Y. H. Zhang and S. J. Maddox, "Fatigue life prediction for tow ground welded joints", Intl. J. of F., vol. 31, July 2009, pp. 1124-1136.

[5] P. Dumbre, A. K. Mishra, V. S. Aher and S. S. Kulkarni, "Structural analysis of steering knuckle for weight reduction", Intl. J. of Adv, Eng. Res. and Stud. Vol. 4, June 2014, pp. 552-557.

[6] M. Zoroufi and A. Fatemi, "Fatigue life comparison of competing manufacturing processes: An experimental study of steering knuckle", SAE Tech. Pap., 2004, pp. 1-11.

[7] P. P. Tagade, A. R. Sahu and H. C. Kutarmare, "Optimization and finite element analysis of steering knuckle", Intl. J. of Comp. App., 2015, pp. 17-21.

[8] M. P. Sharma, D. S. Mevawala, H. Joshi and D. A. Patel, "Static analysis of steering knuckle and its shape optimization", IOSR J. of Mech. and Civil Eng., 2014, pp. 34-38.

[9] M. Zoroufi and A. Fatemi, "Fatigue performance evaluation of forged versus competing manufacturing process technologies: a comparative analytical and experimental study", Forg. Ind. Tech. Confer., vol. 24, 2002, pp. 1-20.

[10] Y. Uematsu, M. Akita, M. Nakajima and K. Tokaji, "Effect of temperature on high cycle fatigue bahaviour in 18Cr–2Mo ferritic stainless steel", Int. J. Fatigue, vol. 30, Apr 2008, pp. 642–648.

[11] V. R. Kulkarni and A. G. Tambe, "Optimization and finite element analysis of steering knuckle", Altair Tech. Conf., 2013, pp. 1-8.