UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

INVESTIGATION OF IMPACT STRAIN SIGNAL CHARACTERISTICS FOR MATERIAL BEHAVIOUR PREDICTION FROM CHARPY TEST

Nurlaela binti Muhammad Said

Master of Science in Mechanical Engineering

2019

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INVESTIGATION OF IMPACT STRAIN SIGNAL CHARACTERISTICS FOR MATERIAL BEHAVIOUR PREDICTION FROM CHARPY TEST

NURLAELA BINTI MUHAMMAD SAID

A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

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DECLARATION

I declare that this thesis entitled "Investigation of Impact Strain Signal Characteristics for Material Behaviour Prediction from Charpy Test" 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.

Signature : ....

Name : Nurlaela binti Muhammad Said

Date : 18.11.2019

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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. Mohd Basri bin Ali
Date	:	18. 11. 2019

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DEDICATION

To my lovely husband, Mohammad Afnan Emy bin Mazlan and my beloved parents, Muhammad Said bin Menjong and Bungatia binti Barohe

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ABSTRACT

This thesis investigates impact strain signal analysis during Charpy impact test. Impact strain signals were used to examine strain signal patterns under various parameters. It is includes the correlation between energy absorbed with power spectrum density (PSD) and area under strain-time graph at different material, impact speed and thickness of material. Thickness effect on impact duration is presents as well. Besides that, stress-strain curve is relates with the impact strain signal. Recently, the number of accident on highway has been increased due to loss of structure integrity to withstand high impact load. Therefore, materials that have ability to provide adequate protection to passengers from harmful and improve occupants' survivability during crash event are needed. Tough material with high energy absorption capability is required to reduce damage on structure when high impact energy is applied. Impact test is often performed to determine toughness of material by determine the amount of energy absorbs. However, most of energy absorbed is not accurate and only calculated as an estimation value. This scenario brings an idea to correlate the energy absorbed with strain energy by installing strain gauge to striker hammer that connected to data acquisition system (SOMAT eDAQ). Besides that, mechanical testing of tensile test is carried out to obtain the material behaviour and to identify the material properties that being used in calculation of impact duration. Results indicate a great correlation is observed between energy absorbed with strain energy. Strain energy is directly proportional to the energy absorbed. In term of material's type, Aluminium 6061-T6 shows a good energy absorber compared to the Magnesium AM60 because aluminium is more ductile than magnesium. Impact duration of experiment, theory and previous study shows a same pattern where it was increased if material's thickness is increased but decreased when applied speed is increased. Relation of strain signal from Charpy test and stress-strain curve from tensile test shows a great finding where the material deforms and fracture points is identified through the strain pattern and stress-strain curve. Aluminium 6061-T6 has the highest of energy absorbed, maximum strain and strain energy under PSD graph compared to Magnesium AM60. This concludes that characteristics of strain signal from Charpy test needs to be classified as an alternative method to predict properties of a material.

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ABSTRAK

Tesis ini mengkaji analisis isyarat terikan impak ketika ujikaji Charpy. Isyarat terikan impak digunakan untuk mengenalpasti corak isyarat terikan dengan pelbagai parameter. Ia termasuklah korelasi di antara tenaga serapan dengan kuasa kepadatan spektrum (PSD) dan kawasan di bawah graf terikan-masa pada jenis bahan, kelajuan impak dan ketebalan bahan yang berbeza. Kesan ketebalan bahan kepada tempoh impak juga dibentangkan. Selain itu, lekuk tegasan-terikan dihubungkaitkan dengan isyarat terikan. Pada masa kini, bilangan kemalangan di lebuh raya telah meningkat disebabkan kehilangan struktur integriti untuk menahan beban impak yang tinggi sangat diperlukan. Oleh itu, bahan yang mempunyai keupayaan untuk memberikan perlindungan yang mencukupi kepada penumpang daripada keadaan membahayakan dan meningkatkan daya hidup penumpang semasa berlakunya kemalangan. Bahan yang kuat dan mempunyai keupayaan penyerapan tenaga yang tinggi sangat diperlukan untuk mengurangkan kerosakan pada struktur apabila dikenakan tenaga impak yang tinggi. Ujian impak kerap kali dilakukan untuk menentukan kekuatan bahan dengan menentukan jumlah penyerapan tenaga. Walau bagaimanapun, kebanyakan tenaga yang diserap tidak tepat dan hanya dikira sebagai nilai anggaran. Senario ini telah memberi idea untuk menghubungkaitkan tenaga yang diserap dengan tenaga terikan dengan memasang tolok terikan pada tukul mesin Charpy yang disambungkan dengan sistem pemerolehan data (SOMAT eDAQ). Selain itu, ujian mekanikal iaitu ujian tegangan dijalankan untuk untuk mengenal pasti tingkah laku mekanikal dan sifat-sifat bahan yang digunakan dalam pengiraan tempoh impak. Keputusan menunjukkan korelasi yang baik dapat diperhatikan di antara tenaga serapan dengan tenaga terikan. Tenaga terikan berkadar terus dengan tenaga serapan. Jenis bahan menunjukkan Aluminium 6061-T6 adalah penyerap tenaga yang baik berbanding dengan Magnesium AM60 kerana aluminium lebih mulur daripada magnesium. Oleh itu, aluminium mempunyai kawasan elastik dan plastik yang banyak sebelum patah. Keputusan tempoh impak daripada eksperimen, teori dan kajian terdahulu menunjukkam corak yang sama di mana ia meningkat apabila ketebalan bahan meningkat manakala menurun apabila halaju yang dikenakan meningkat. Hubungkait di antara isyarat terikan daripada ujian Charpy dan lekuk tegasan-terikan daripada ujian tegangan menunjukkan keputusan yang baik apabila titik bentuk dan titik patah bahan dapat dikenalpasti melalui isyarat terikan dan lekuk tegasan-terikan. Aluminium 6061-T6 mempunyai tenaga serapan, terikan maksimum dan tenaga terikan di bawah graf PSD yang tertinggi berbanding Magnesium AM60. Disimpulkan bahawa ciri-ciri isyarat terikan daripada ujian Charpy perlu diklasifikasi sebagai kaedah alternatif untuk meramal sifat-sifat bahan.

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ACKNOWLEDGEMENTS

Firstly, I would like to express my deepest appreciation to all those who encouraged and supported me to complete this thesis report. First and foremost, a special gratitude I give to my main supervisor, Dr. Mohd Basri bin Ali for his contribution in suggestions, guideline, supervision and encouragement to coordinate my research study especially in writing this report. Futhermore, I would also like to acknowledge with much appreciation to Dr. Kamarul Ariffin bin Zakaria as my co-supervisor for sharing his knowledge and constant advises to inspire me throughout this study.

Particularly, I would also like to express my gratitude to all the laboratory technician, Encik Wan Saharizal bin Wan Harun for his helpful and guideline to completed my experimental testing.

I gratefully acknowledge to my financial funding from the Ministry of Higher Education (MOHE) for sponsoring this research work under FRGS/2/2013/TK01/FKM/03/3/F00173 research grant and scholarship from MyBrain15 through the duration of my study.

Last but not least, many thanks go to my lovely husband and parents who have provided me through moral and emotional support in completing this study. I am also grateful to my other family members and friends, Rosmia binti Mohd Amman, Siti Nur Rabiatutadawiah binti Ramli, Zailinda binti Abdullah, Fadrah Hanim binti Ad Suhadak and Noor Dina binti Ghazali who have supported me along the way. Thanks for all your encouragement.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
CNT	-	Carbon nanotube
CVN	-	Charpy V-notch
DBT	-	Ductile-brittle transition
EA	-	Energy absorbed
FBG	-	Fibre Bragg grating
FEA	-	Finite element analysis
FEM	-	Finite element method
FFT	-	Fast Fourier Transform
GF	-	Gage factor
GFRP	-	Glass fibre reinforced plastic
HAZ	-	Heat Affected Zone
ISO	-	International Organization for Standardization
KCV	-	notch toughness
LYS	-	Low yield strength
PSD	-	Power Spectrum Density
PVC	-	Polyvinyl chloride
PZT	-	Piezoelectric ceramic material
TRIP	-	Transformation induced plasticity
UKM	-	Universiti Kebangsaan Malaysia

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USE	-	Upper shelf energy
UTM	-	Universal Testing Machine
VA	-	Variable amplitude

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LIST OF SYMBOLS

A	-	Area
c	-	Damper of viscous damping coefficient
C_t	-	Total compliance
ε	-	Strain
E	-	Young Modulus
$E_{abs\ tot}$	-	Total energy absorbed
E_b	-	Bending energy
E_c	-	Contact energy
E_d	-	Deformation energy
E_{del}	-	Delamination energy
E_{frac}	-	Fracture energy
E_k	-	Kinetic energy
E_m	-	Membrane energy
E_{petal}	-	Petaling energy
E_s	-	Shear energy
F	-	Force
$G(j\omega)$	-	Frequency spectrum
J	-	Impulse
k	-	Spring stiffness
k_b	-	Bending spring constant

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k_c - Contact spring constant

k_{eq} - Equivalent spring constant

k_m - Membrane spring constant

k_s - Shear spring constant

M - Total mass

ms - miliseconds

N - Shape parameter

P - Instantaneous crushing load

p - Linear momentum

P_m - Mean crushing load

P_{max} - Maximum load

P_{xx} - Power spectral density

R - Radius of spherical impactor

r_o - Scale parameter

r_{xx} - Autocorrelation function

s - Car crush

t - Impact duration

t_c - Contact time

T_p - Crash pulse duration

ν - Poison's ratio

v - Velocity

V_c - Closing velocity

w - Vertical deflection

γ - Surface potential

ρ - Density

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