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UNIVERSITI PUTRA MALAYSIA

VIBRATION-INDUCED STRESS ANALYSIS OF NATURAL GAS VEHICLE

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FK 2008 58

VIBRATION-INDUCED STRESS ANALYSIS OF NATURAL GAS VEHICLE

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirement for the Degree of Master of Science
June 2008

Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfilment
of the requirements for the degree of Master of Science.

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June 2008

Chairman: **Professor Ir. Barkawi Bin Sahari, PhD**

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The automotive industry has been exploring alternative vehicle fuel for decades as petrol reserve for the future is reducing. Natural gas is found to be the most suitable alternative choice, but the natural gas storage tank that is to be located in the vehicle requires specific space. Thus, a dedicated natural gas vehicle platform is designed and during the initial design stage of vehicle platform, the study of the self-excited vibration and the affected stress to the vehicle platform structure were analyzed.

There have been little studies about the effects of the vehicle structure natural frequency to the structural stress. Vibration is known as a source of energy that induces structural and mechanical oscillations, self-excited vibration is an unwanted occurrence. Other than resonance, high stresses caused structural failure thus their values are investigated.

In this research, there are three models of compressed natural gas (CNG) vehicle platforms designed from the modification of the conventional petrol fuelled

PROTON Waja’s vehicle platform and they are CNG 3T, CNG 4T and CNG 5T Platforms. Finite element analyses were done to these platforms models with the conventional petrol fuelled platform being the benchmark platform.

The modal analysis in searching for the natural frequency values below 50Hz are performed first and the induced stresses due to the natural frequency mode shape deformation is determined through static analysis. The frequencies, mode shape and vibration-induced stress results for all the analyzed platforms are presented.

The analysis results showed that the CNG 3T, CNG 4T and CNG 5T Platforms have a maximum stress of 53.3MPa, 36.0MPa and 43.9MPa accordingly when induced by natural vibrations of frequencies below 50Hz. The maximum stresses are below the yield stress of the applied material. The natural vibration mode shape have been identified to be the main factor of the induced stresses, while the platform’s geometry has affected the natural vibration frequency values as the modifications made has increased the platform’s stiffness.

However, the relationship between frequency and the induced stress could not be determined due to the inability to predict the natural vibration mode shape that has been the main factor of the vibration-induced stress analysis. Nevertheless, the results obtained will serve as a base for future vibration-induced stress study to structures.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANALISIS TEGASAN SEBAGAI HASIL GETARAN KENDERAAN GAS ASLI

Oleh

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Memandangkan sumber petroleum sebagai bahan bakar kenderaan semakin berkurangan, industri automotif giat mencari bahan bakar alternatif sejak berabad lamanya. Gas asli dipersetujui sebagai bahan bakar kenderaan yang paling sesuai. Namun begitu, tangki penyimpanan gas asli memerlukan ruangan khusus di dalam kenderaan. Maka, lantai kenderaan gas asli khusus direka dan di peringkat awal rekaan, penyiasatan ke atas getaran tabii lantai kenderaan dan penghasilan tegasan daripada getaran tabii tersebut dilakukan.

Akibat daripada getaran tabii struktur kenderaan kepada tegasan tidak banyak dibincangkan. Namun getaran yang diketahui sebagai sumber tenaga dan pengayunan menyebabkan getaran tabii tidak diingini. Selain daripada salunan, nilai tegasan yang tinggi juga akan mengakibatkan kegagalan sesebuah struktur.

Pada penyiasatan ini, tiga buah model lantai kenderaan gas asli telah direka berdasarkan lantai kenderaan yang menggunakan bahan bakar petroleum keluaran

PROTON Berhad, iaitu Waja dan lantai kenderaan tersebut ialah lantai CNG 3T, CNG 4T dan CNG 5T. Analisis elemen tidak terhingga dilakukan ke atas kesemua model lantai tersebut dan lantai kenderaan yang menggunakan bahan bakar petroleum menjadi nilai tara yang dirujuk.

Analisis ragam telah dilaksanakan bagi menentukan nilai frekuensi tabii di bawah 50 Hz. Seterusnya, nilai tegasan hasil daripada getaran yang diperolehi, didapati dari analisis statik. Nilai frekuensi, bentuk mode dan nilai tegasan hasil daripada getaran untuk kesemua model lantai diperolehi dan dibincangkan.

Daripada keputusan yang diperolehi menunjukkan lantai CNG 3T, CNG 4T dan CNG 5T menghasilkan tegasan maksimum iaitu 53.3MPa, 36.0MPa dan 43.9MPa masing-masing apabila lantai-lantai tersebut bergetar dengan nilai frekuensi kurang daripada 50 Hz. Nilai tegasan maksimum tersebut adalah jauh lebih rendah daripada nilai tegasan bagi bahan yang digunakan. Selain itu, geometri yang berbeza dikenalpasti sebagai punca perbezaan nilai frekuensi lantai gas asli rekaan berbanding nilai tara yang dirujuk kerana peningkatan nilai kekakuan lantai.

Walaubagaimanapun, perkaitan antara nilai frekuensi dengan tegasan yang terhasil tidak dapat dipastikan kerana bentuk ragam yang menjadi faktor utama pengahsilan tegasan tidak dapat diramalkan. Namun begitu, segala keputusan yang diperolehi dapat dijadikan asas kepada kajian ke atas tegasan sebagai hasil getaran struktur kenderaan di masa akan datang.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude and deep thanks to my supervisor, Professor Ir. Dr. Barkawi Bin Sahari for his kind assistance, support, advice, encouragements and suggestions throughout this work and during the preparation of this thesis.

I would also like to express my appreciation to Associate Professor Dr. Wong Shaw Voon for his suggestions and constructive criticisms given at different stages of this study.

My heartfelt appreciation also goes to all my colleagues for their useful ideas and critical but constructive comments to work on. Our fruitful discussions would never go unmentioned.

Finally, I would like to express my indebtness to my family for their moral support through this long journey.

I certify that an Examination Committee met on 26th June 2008 to conduct the final examination of Siti Marhainis Binti Abu Mansor on her Master of Science thesis entitled "Vibration-Induced Stress Analysis of Natural Gas Vehicle" in accordance with the Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

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DECLARATION

I declare that the thesis is based on my original work except for the quotations and citation which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for any other degree at UPM or at any other institutions.

Siti Marhainis Binti Abu Mansor

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LIST OF ABBREVIATIONS

NGV	Natural gas vehicle
MOSTI	Ministry of Science, Technology and Innovation of Malaysia
PROTON	Perusahaan Otomobil Nasional Berhad
CNG	Compressed natural gas
CAE	Computer aided engineering
VLFS	Very large floating structures
LSFD	Least square-based finite difference
MDOF	Multi degree-of-freedom
CAD	Computer aided design
FEA	Finite element analysis
CNG 3T	Compressed natural gas vehicle with three tanks
CNG 4T	Compressed natural gas vehicle with four tanks
CNG 5T	Compressed natural gas vehicle with five tanks
M_x	Resultant moment in x-direction
M_y	Resultant moment in y-direction
E	Young’s Modulus
D	Plate stiffness
ρ	Density
υ	Poisson’s ratio
h	Thickness of plate
ω	Angular frequency
M, m	Mass
K, k	Stiffness
x	Displacement
$\ddot{x}$	Acceleration
T	Kinetic energy
U	Potential energy
σ	Direct stress
ε	Direct strain

τ	Shear stress
γ	Shear strain

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CHAPTER 1

INTRODUCTION

Vibration is a source of energy that can induce structural and mechanical oscillations to structures and self-excited vibration of structures due to natural frequency is an undesirable phenomenon (Singiresu, 1995). Since the fatigue life of most material is proportional to the stress occurrence(Geradin, 1997), there is a need in understanding the role of self-excited vibration that induces stress as a result of the structure vibration oscillations.

The study of stress-induced vibration of vehicle structure is important to predict the strength and durability of the vehicle structure in the design stage. So far, there has been little studies about the effects of vibration of the vehicle to the structural stress. Several studies have produced accountable results in obtaining the vehicle’s natural frequency through the modal analysis, but there is still insufficient data for the effects of the vibration mode shape deformation to the stress of the vehicle structure.

Most of the studies in the modal analysis of a vehicle structure have only focused in obtaining the natural frequency and its mode shape and not the structural stress as a result of vibration especially at the fundamental frequencies. Since high stresses can