ANALYTICAL INVESTIGATION OF THE DYNAMIC PROPERTIES OF PASSIVE ENGINE MOUNTING

BY

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A dissertation submitted in fulfilment of the requirement for the degree of Master of Science in Automotive Engineering

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ABSTRACT

Engine mount is an automotive component that is essential in supporting the engine static state in order to prevent engine bounce from shock excitation and to isolate engine vibration caused by engine disturbances in the complete speed range. The main objective of this study is to analyze the dynamic properties which are the natural frequencies and modeshapes of different types of passive engine mounts. In this study, four passive (rubber) engine mount models were considered. The modal analysis were computed by using finite element software, ABAQUS and the results obtained were the modeshapes of the engine mounts. Modeshapes are the deflection shapes taken on by a system when excited at one of its natural frequencies. The corresponding modeshapes of all the rubber engine mount models were computed both in presence and absence of the engine's weight and the results are compared with the results from impact test which has been conducted to one of the engine mount. The computer simulated model of these mounts was analyzed and later the effect of the load applied on the engine mounts were compared with the engine mounts without the load. The results from the modal analysis demonstrated variety in the natural frequency values for all types of passive engine mounts. The modeshapes results showed the trend of bending mode, torsion mode and also the mixture of both. From the modehshapes results, the most deformed spot in the engine mounts can be identified. The results showed that the engine mounting with more metal contact will have the highest frequency of 987.56 Hz when analyzed without the engine weight while the engine mount with less metal contact will have the highest frequency of 1456.20 Hz when analyzed with the engine weight. This shows that rubber engine mounts with the least metal contact design had the highest frequency value of all and this signifies that it can provide the best damper for the engine weight. As a conclusion, the natural frequency of the passive engine mount depends strongly on the applied load although theoretically the natural frequency of a system should not be affected by the applied load. The variations happen because of the rubber viscoelastic nature. Besides that, the natural frequency of the rubber engine mounts also depend on their designs as the least metal contact design showed higher natural frequency value. The results of this study will open up a passage to researchers to study and improve the elastomeric engine mounts.

خلاصة البحث

إن نظام تصعيد المحرّك يجب أن يدعم الحالة الساكنة للمحرّك، يمنع إرتداد المحرّك من إثارة الصدمة ويعزل الاهتزاز الناجم عن إضطرابات المحرّك في مدى السرعة الكاملة. في هذه الدراسة، تم إعتبار أربعة أنواع من المحركات. الاشكال المقابلة للمحركات والمصنّعة من المطاط تم احتسابها في حالتي وجود وعدم وجود وزن المحرّك ومقارنة النتائج لفحوصات التأثيرعلى واحد من المحرّكات التي تم اعتمادها. وتم حساب محاكاة الحاسوب باستخدام برنامج محدد العنصر، نوع (أي بي أي كيو يو أس) والحصول على النتائج التي كانت في التذبذبات الطبيعية. تم تحليل نتائج محاكاة الحاسوب وتم مقارنة تأثير الحمل المسلّط على المحرك في حالة وجود حمل أو عدمه. وأخيراً، بعد مقارنة هذه النتائج، تبين وبعد تغيير التذبذبات إن التذبذبات الطبيعية لمحركات المطاط قد تأثرت بالحمل المسلّط على نظام المحرّك. هذا البحث يفتح الطريق للباحثين لدراسة وتطوير المحرّك المرن.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Automotive Enginering.

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Waleed Fekry Faris
Supervisor

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Automotive Engineering.

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This dissertation was submitted to the Director, Advanced Engineering and Innovation Centre and is accepted as a fulfilment of the requirement for the degree of Master of Science in Automotive Engineering.

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Agus Geter E. Sutjipto
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Amir Akramin Shafie
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Fazidah bte Saad

Signature……………………….. Date…………………………..

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

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Affirmed by Fazidah binti Saad

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Signature Date

This dissertation is dedicated to:

My late father Saad Bin Hussain,

My mother Fatimah Binti Abdullah

&

My beloved husband Zulkarnain Bin Abdul Latiff

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In the name of Allah, the Most Compassionate and the Most Merciful. All praise due to Allah SWT and peace and blessings be upon His prophet Muhammad SAW.

This dissertation is an outcome of two years research work and many people have contributed throughout my work in different ways. I express my sincere gratitude and respect to my supervisor Dr. Waleed F. Faris for his continuous guidance. Special thanks to Mdm. Ismaliza Binti Ismail from RRIM for her intensive support and guidance throughout this project. This dissertation would not have been the same if it had not been guided and maintained by my supervisors. Also thank to AEIC, International Islamic University Malaysia for various supports.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
CAE	Computer Aided Engineering
EDS	Engineering Data Sheet
FEA	Finite Element Analysis
FRF	Frequency Response Function
RRIM	Rubber Research Institute Malaysia
USM	University Science Malaysia

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Generally, the vehicle engine mounting system consists of an engine as the vibration source and several mounts connected to the vehicle structure. The modern engine mounting systems have been successfully used to isolate the driver and passenger from both noise and vibration generated by the engine. However, there is still a need to improve the performance of engine mounting systems because of the requirements of vibration and noise level isolation for passenger cars and also because of the modern car designs that need a lighter bodies and more power-intensive engines. Such a weight reduction and increased power requirements will often have adverse effects on vibratory behavior that it will increase the vibration and noise level. So, a study on the improvement in the performance of engine mounting systems definitely plays an important role in resolving the conflicting requirements of the reduction weight vehicle that is having power-intensive engines with the requirements of vibration and noise level isolation for passenger cars.

Several types of engine mounting systems are conventional elastomeric engine mounting, passive hydraulic engine mounting, semi-active engine mounting and active engine mounting. This study attempts to analyze the dynamic properties of the current elastomeric engine mounts of different geometry.

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

There are many types of passive engine mounts with different shapes and material that are available in the market. However, these engine mounts, do not meet all the requirements to isolate vibrations caused by engine disturbance forces in all engine speed range. Therefore, there is some improvements to the properties of elastomeric mounts in order to maximize their functions can be made. To date, there is no empirical study of different types of engine mounts have yet been conducted. Hence, this study focuses on the analyze of the natural frequency as well as the frequency modes of different types of passive engine mounts.

Theoretically, the natural frequency for a model or a system should not be affected by the load applied on it. Consequently, this project will analyze the engine mounts in two conditions; with and without the engine's load applied to the engine mounts system in order to prove the mentioned theory.

1.3 RESEARCH OBJECTIVES

The objectives of this study are:

1. To analyze the dynamic properties of different geometry of passive engine mounts.
2. To develop geometric models for these engine mounts and run finite element simulation.
3. To characterize the dynamic properties of elastomeric engine mount.

1.4 RESEARCH METHODOLOGY

After establishing the objectives for the dynamic properties characterization of an engine mounting system, the parameters to be studied are determined.

Basically the study will include the following:

1. Literature review
2. Identification of the problem statement
3. Deciding the parameters to be studied
4. Choice of the analytical tools for the research
5. Carrying out investigation
6. Results analysis and discussion

Figure 1.1 shows a flowchart for the research methodology.

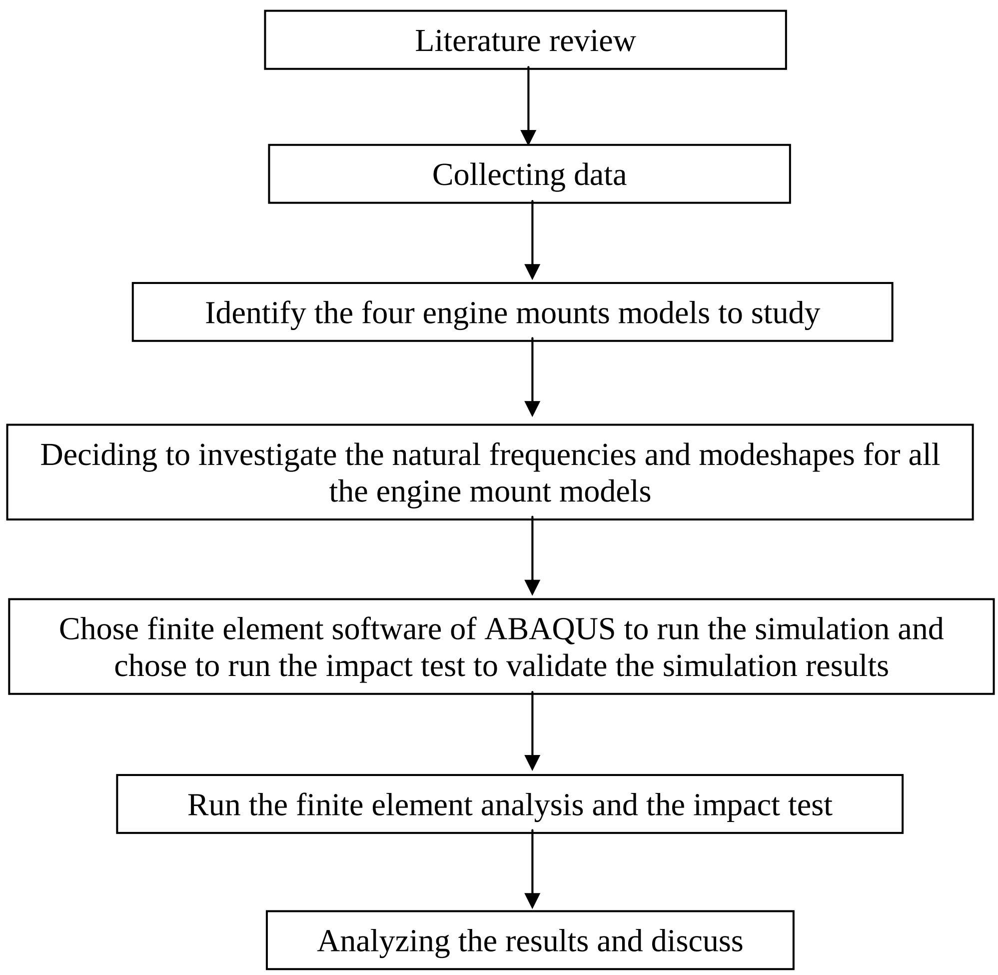

Figure 1.1 Flowchart for the research methodology

1.5 RESEARCH SCOPE

One of the major limitations of this study is that eventhough the Finite Element Analysis of four different types of elastomeric engine mounts were carried out but only one experimental validation was done on one of the engine mounts. The experiments could not be conducted on all four types of engine mounts as the studied specimens were not allowed to taken out from Rubber Research Institute Malaysia (RRIM) for testing. The experiment was unable to be carried out in the facility as apparently the facilities was not equip sufficiently. Thus, only one engine mount was tested at University Science Malaysia (USM).

1.6 DISSERTATION ORGANIZATION

The dissertation is organized as follows:

Chapter 1 consists of introduction. This chapter comprises of the background of the research, objectives and research methodology.

Chapter 2 consists of literature review. In this chapter, the previous study and analysis in the field of engine mounting, particularly on rubber engine mounting is presented and discussed.

Chapter 3 covers the methodology of the study which involves the modal analysis of the engine mounting systems and also the impact test that was carried out to the engine mount. This chapter discusses the development of finite element model as well as the analysis of calculating the natural frequencies and mode shapes of the engine mounts models.

Chapter 4 consists of the results obtained from analyses for all the four different models of engine mounts. Also the results obtained from the impact test are presented. This chapter also presents discussions of analyses result as the frequency values and all are provided comparison between them.

Chapter 5 gives the conclusions and recommendations for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The primary function of an engine mounting system is to support the weight of the engine and to isolate the unbalanced engine disturbance force from vehicle structure. For an internal combustion engine, there are two basic dynamic disturbances, which are the firing pulse due to the explosion of the fuel in the cylinder and the inertia forces and torques that are caused by the rotating and reciprocating parts in the engine such as connecting rods, pistons and crankshafts.

To isolate the vibration caused by the engine unbalanced disturbances, low elastic stiffness and low damping are needed as the force transmitted to the structure is proportional to the stiffness and damping of the mounts.

The most common means of providing isolation for engines is with a simple form of padding or matting material. In this type of isolator, the materials ranged from cork to rubber or neoprene. The second type of mount used in the isolation of the engine consisted of rubber, in the form that is commonly known as rubber-in-shear isolator.

Based on a research done by Yunhe (2001), for a four-cylinder engine, the main disturbing frequencies are in the range of 20 to 200 Hz. The corresponding deformation amplitude for the engine mounts is in the range 0.05 to 1mm.In a normal practice, a traditional rubber isolator is considered to be a massless spring, which is acceptable at low frequencies of excitation. In contrast, Snowdown (1979) stated that, when a mount is excited at frequencies above 200 Hz, standing waves within the rubber become significant.

A strong trend toward smaller and lighter vehicles powered by four-cylinder engines, and coupled with lighter and more flexible vehicle frames have led to an increase in frame vibration levels. Primarily these vibrations are transmitted through the engine mounts. Temperature fluctuations are wide in the engine. In addition, cost, maintenance, reliability and the durability of the mounts are key considerations in the design of the engine mount. It is a common practice to design isolators largely on the basis of analytical and computer simulations, and from the engineering judgment.

As summary, the important duties and principal functions of engine mounts are as follows:

1) To support the weight of the engine
2) To prevent fatigue failure of the engine and gearbox support points, which occur if they are rigidly attached to the chassis or body structure
3) To isolate the unbalanced engine disturbance force from the structure of the vehicle
4) To reduce the amplitude of engine vibrations that are transmitted to the body structure
5) To reduce noise that occurs if engine vibrations are allowed to transfer directly to the body structure
6) To reduce human discomfort and fatigue by partially isolating the engine vibrations from the human body by means of an elastic medium such as rubber or hydraulic

LIST OF SYMBOLS

v	Poisson ratio
K_a	Bulk Modulus, MPa
$//_0$	Shear Modulus, MPa
D	Temperature-dependent material parameters, MPa
Z),	Temperature-dependent material parameters, MPa
$C,_0$	Coefficient in strain energy function, MPa
$U(e)$	Strain energy potential, MPa
U	Strain energy per unit of reference volume, MPa
I',	First deviatoric strain invariant
1_2	Second deviatoric strain invariant
/L.	Principal stretches, MPa
J	Total volume ratio
J^{el}	Elastic volume ratio
N	Material parameter, MPa
A_m	Locking stretch, MPa
a	Global interaction parameter, MPa
$(3$	Invariant mixture parameter, MPa
F	Load applied, kg
A	Contact area, mm
P	Distributed force, MPa