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CLASSIFICATION	SYSTEM NUMBER 507238
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TITLE

MINIMIZATION OF VIBRATION TRANSMISSION THROUGH ENGINE ISOLATION MOUNTS

System Number:

Patron Number:

Requester:

Notes: Paper #35 contained in Parent Sysnum #507203

DSIS Use only:

Deliver to: DK

#507238 (35)

Minimization of Vibration Transmission Through Engine Isolation Mounts

by

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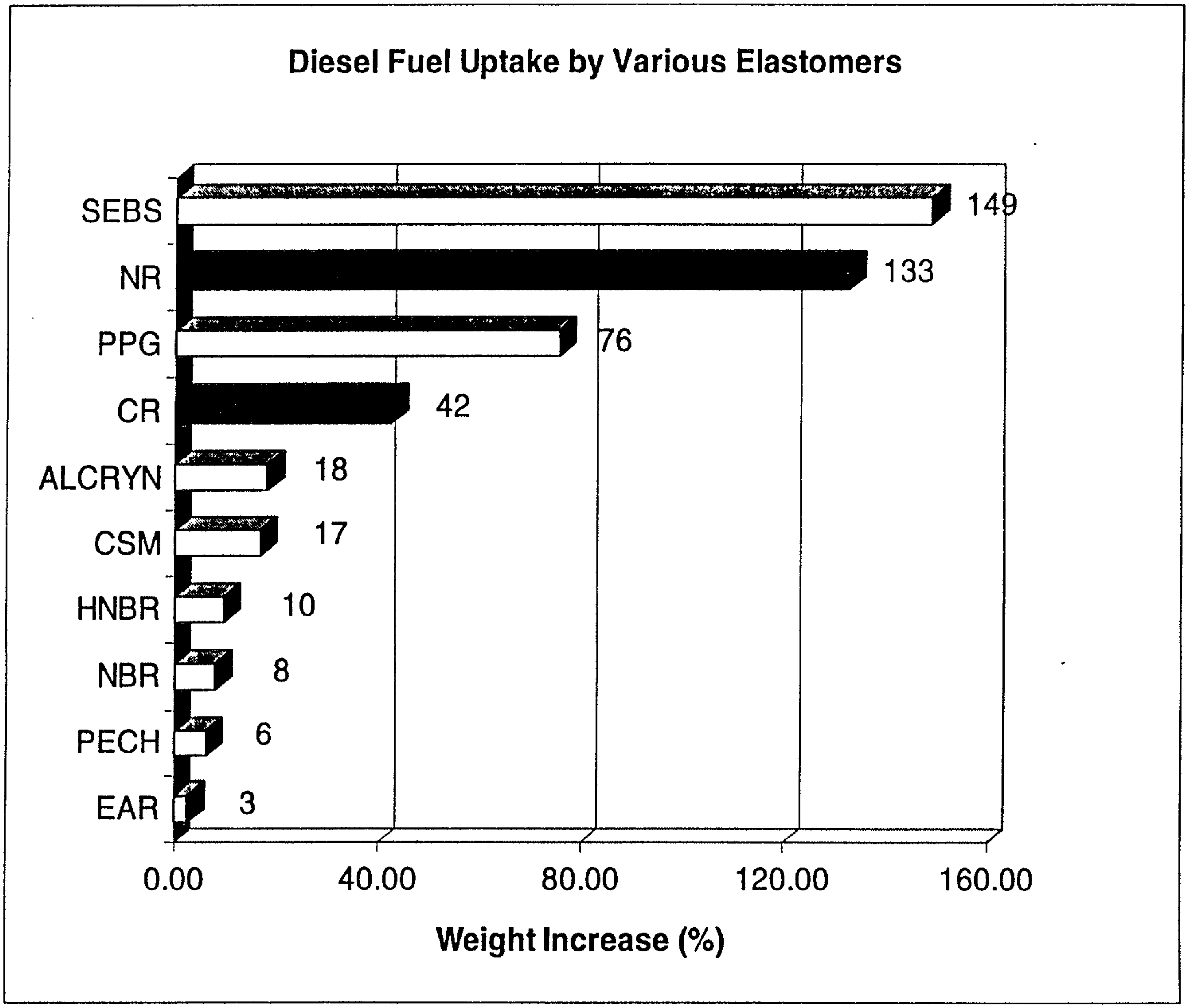
ABSTRACT

Engine isolation mounts should be designed to provide optimum isolation of the vibrational energy produced by engine operation. In order to achieve such a goal effective modeling of the complete system would be of assistance. Such modeling must include the three dimensional nature of the problem, the vibration characteristics of the engine and its supports and an accurate representation of the response characteristics of the isolator mounts.

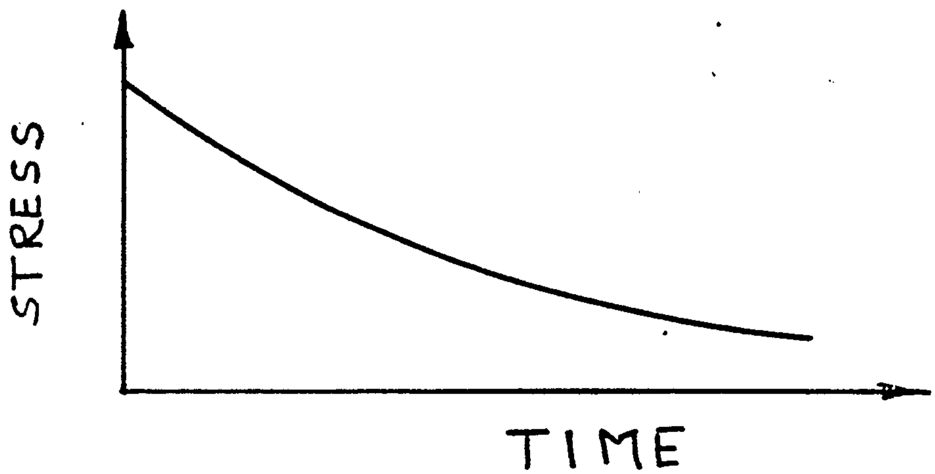
The present paper reviews the development of such a model and pays particular attention to the experimental measurement and modeling of isolator characteristics. A comprehensive finite element model is developed by using viscoelastic modeling of the isolators and numerical tools are developed that assist in the choice of optimal isolators for a given installation.

CONTENTS


Diesel Fuel Uptake by Various Elastomers
SEBS
NR
PPG
CR
ALCRYN
CSM
HNBR
NBR
PECH
EAR
149
133
76
42
18
17
10
8
6
3
0.00
40.00
80.00
120.00
160.00
Weight Increase (%)

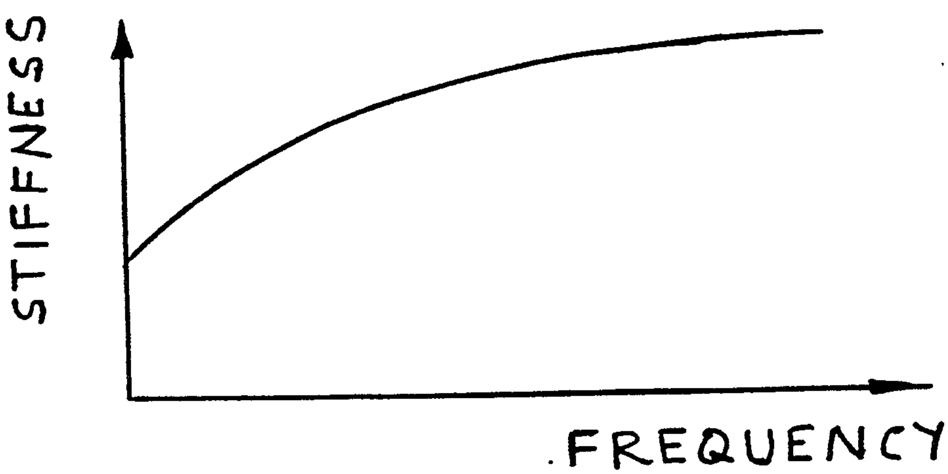
MODELLING OF ISOLATOR MATERIALS:

1. FOR UNIAXIAL TEST WITH SUDDENLY APPLIED STRAIN



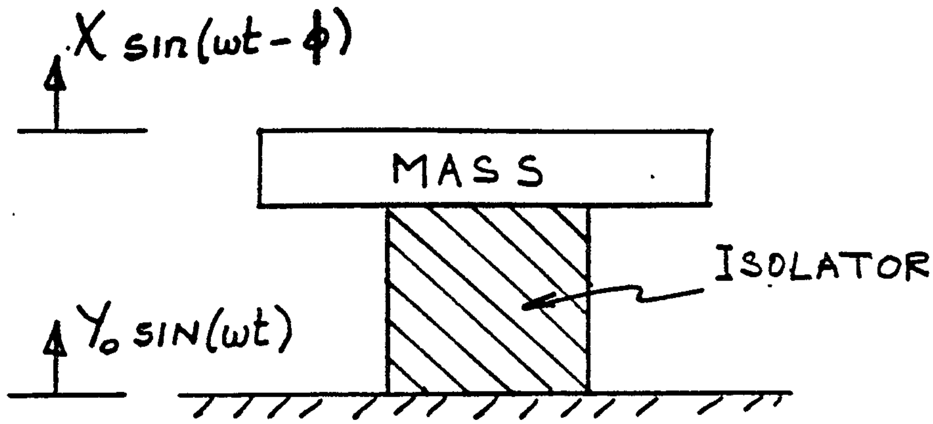
STRESS/STRAIN RELATION IS TIME DEPENDENT

2. FOR UNIAXIAL TEST WITH A HARMONIC EXCITATION F_0SINWT

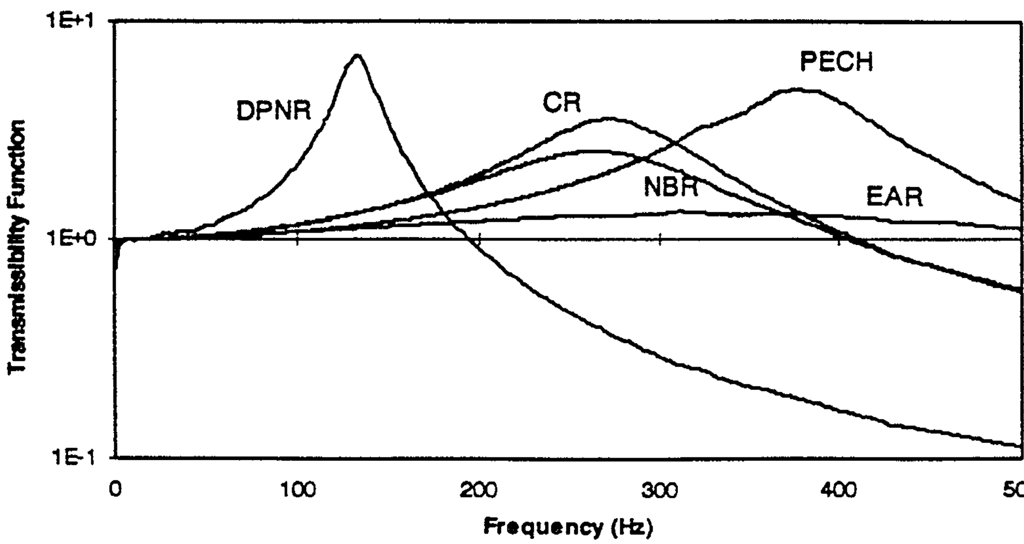


STRESS/STRAIN RELATION IS FREQUENCY DEPENDENT

ISOLATION OF A SDOF SYSTEM



$$|\text{TRANSMISSIBILITY}| = \left|\frac{X}{Y_0}\right|$$



AT LOW FREQUENCY REQUIRE HIGH DAMPING BUT AT HIGH FREQUENCY REQUIRE LOW DAMPING (FOR SDOF SYSTEM)

VISCOELASTIC CONSTITUTIVE MODELS

1. GENERAL ONE DIMENSIONAL STRESS/STRAIN LAW:

$$a_1\sigma + a_1\frac{d\sigma}{dt} + \cdots \quad a_n\frac{d\sigma}{dt^n} = b_0\varepsilon + b_1\frac{d\varepsilon}{dt} + \cdots \quad b_n\frac{d^n\varepsilon}{dt^n}$$

or

$$\sigma(t) = E\left(\varepsilon(t) - \int_0^t \Gamma(t-\tau)\varepsilon(\tau)d\tau\right)$$

where $\Gamma(t-\tau) =$ RELAXATION KERNEL

$$= \sum_{i=1}^{n} c_i \, exp\left[-\alpha_i(t-\tau)\right]$$

where c_i and α_i must be determined experimentally

2. FOR HARMONIC EXCITATION AT w R/S

$$\varepsilon = \varepsilon_0 \, exp[iwt] \quad i = \sqrt{-1}$$

and $\sigma = E^*\varepsilon_0 \, exp[iwt]$

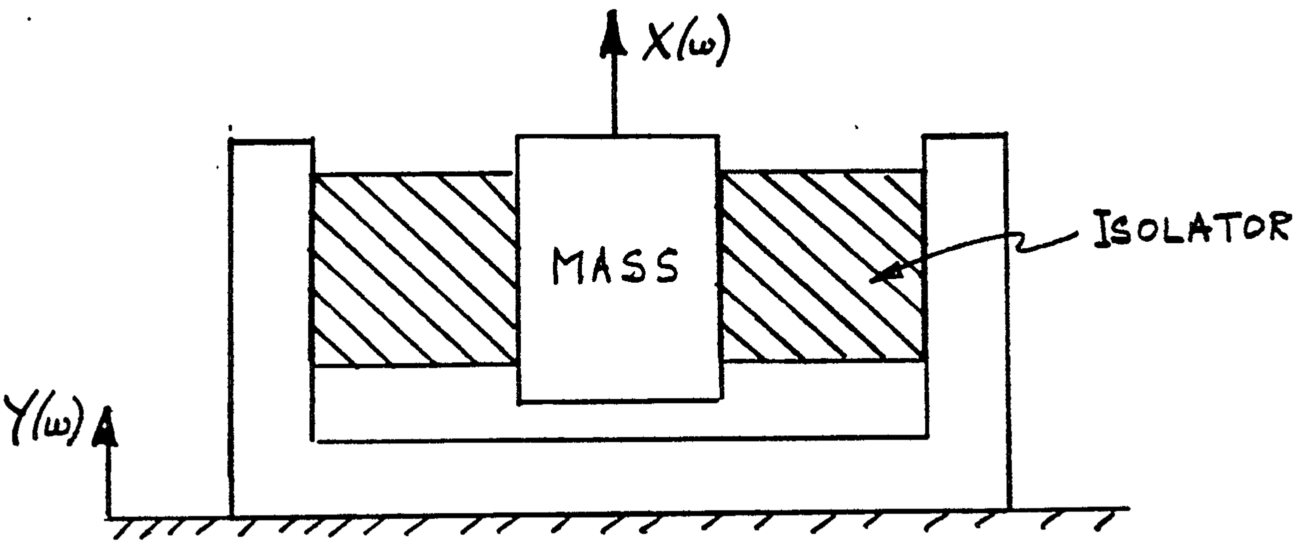
where $E^*(w) = E_1(w) + i\,E_2(w) =$ COMPLEX YOUNG'S MODULUS

$E_1(w) =$ STORAGE MODULUS

$E_2(w) =$ LOSS MODULUS

NEED TO MEASURE $E^*(w)$ OVER FREQUENCY RANGE OF INTEREST TO BE ABLE TO CONDUCT ANALYSIS

EXPERIMENTAL DETERMINATION OF VISCOELASTIC CHARACTERISTICS



$Y(w)$ = INPUT EXCITATION
$X(w)$ = OUTPUT RESPONSE

1. TRANSMISSIBILITY = $\left|\frac{X}{Y}\right| = T^*(w) = T_1(w) + i\,T_2(w)$

2. DEPENDS UPON E^* COMPLEX YOUNG'S MODULUS
   G^* COMPLEX SHEAR MODULUS
   GEOMETRY OF TEST SAMPLES

3. USING FINITE ELEMENT ANALYSIS OF GEOMETRY AND KNOWING $T^*(w)$ CAN CALCULATE E^* AND G^*

CAN EXPERIMENTALLY DETERMINE $E^*(w)$ AND $G^*(w)$ OVER WIDE FREQUENCY RANGE

SPECIFICATION OF ISOLATION CRITERIA FOR MARINE DIESEL ENGINES SUPPORTED ON A FLEXIBLE FOUNDATION

The following factors need to be considered:

1. The Excitation Forces Produced by the Engine

2. The Three Dimensional Nature of the Engine Vibration Response

3. The Three Dimensional Nature of the Isolator Mounts

4. The Material Characteristics of the Mounts

5. The Response Characteristics of the Flexible Foundation

REQUIRE AN ACCURATE PREDICTIVE CAPABILITY TO INVESTIGATE THE ABOVE CHARACTERISTICS

VIBRATION ANALYSIS OF ENGINE ON VISCOELASTIC MOUNTS

1. We have developed a closed form solution to the free vibration response of viscoelastic materials for the case when the relaxation kernel is expressed as a sum of exponentials. This means we do not have to use expensive time stepping numerical integration schemes

2. We have developed a complete three dimensional dynamic analysis of engine forces that includes time dependent inertia terms not previously considered. Under conditions of high unbalance these terms can lead to the occurrence of unstable parametric resonances.

3. We have developed computer programs that

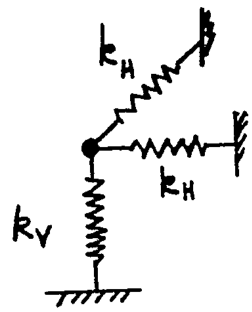
   a) uses finite elements (VAST) to analyse steady state response of an engine supported by viscoelastic isolators on a flexible foundation

   b) uses the engine model to (i) analyze the effect of different engine and isolator properties on response when the isolators are rigidly supported; and (ii) optimize the loss modulus as a function of frequency for given low frequency constraints on isolator displacements.

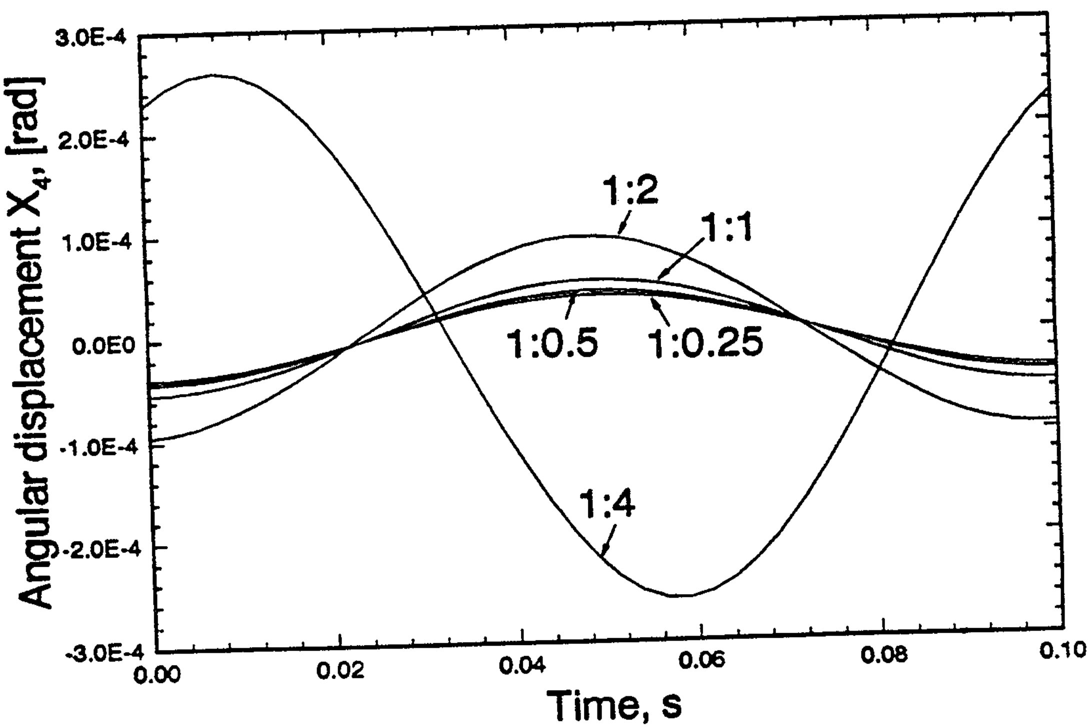
NUMERICAL RESULTS

EFFECT OF MOUNT GEOMETRY ON ENGINE VIBRATION RESPONSE

Engine Mount Stiffness Model:



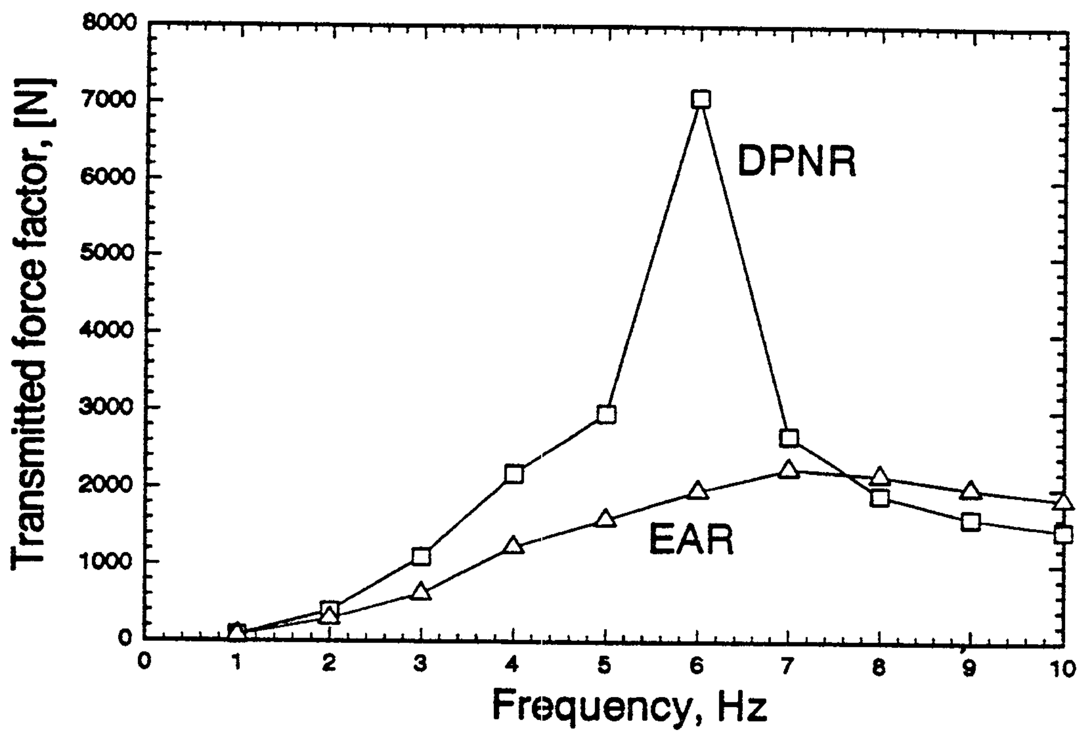
What is the effect of $\lambda = \frac{k_H}{k_V}$?



THE THREE DIMENSIONAL CHARACTER OF THE ISOLATION MOUNT MUST BE INCLUDED IN THE ANALYSIS

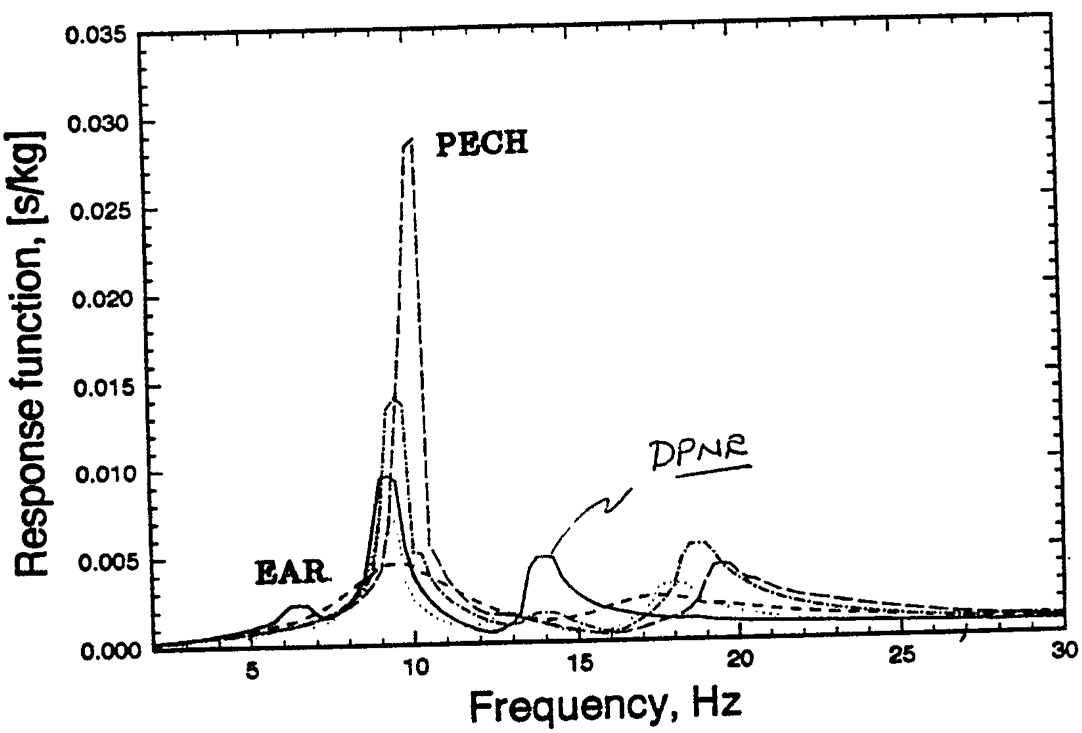
NUMERICAL RESULTS

EFFECT OF MATERIAL CHARACTERISTICS ON ENGINE VIBRATION RESPONSE



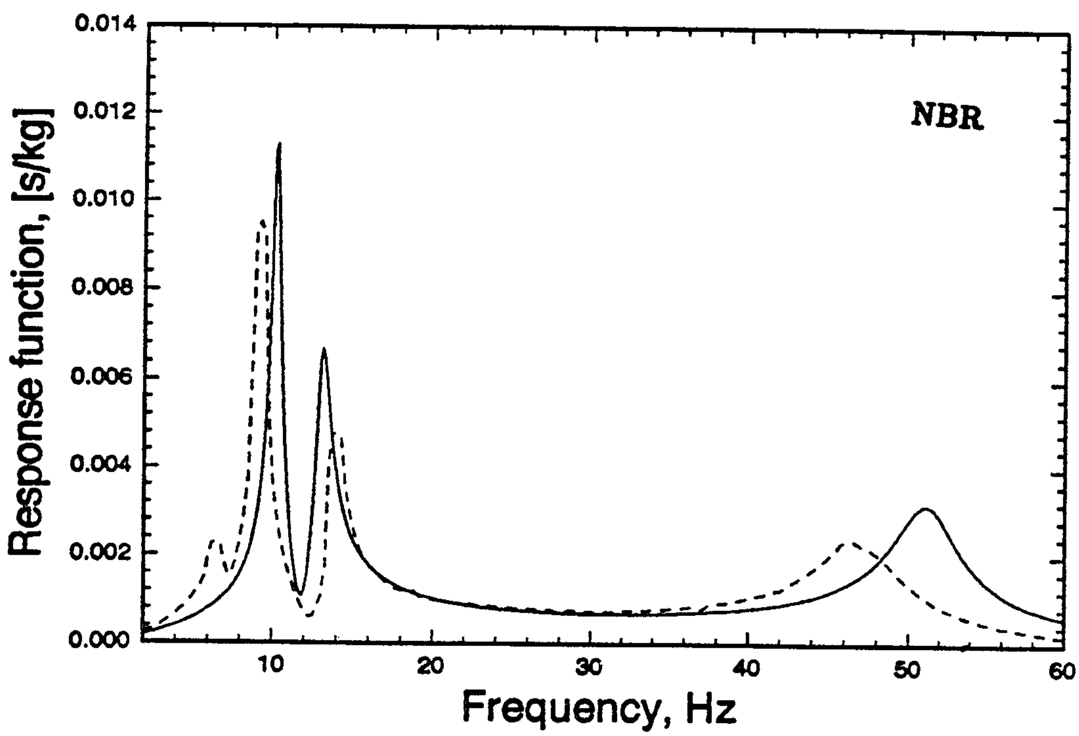
EXPERIMENTAL MODEL TESTING

EFFECT OF MATERIAL CHARACTERISTICS ON VIBRATION VELOCITY MEASURED ON FLEXIBLE FOUNDATION DUE TO SINE FORCE EXCITATION APPLIED TO ENGINE



EXPERIMENTAL MODEL TESTING

COMPARISON OF NUMERICAL AND EXPERIMENTAL RESULTS



SUMMARY

In order to conduct an analysis of the vibration transmission through engine mounts the following are required:

1) Details of the engine geometry and its inertia characteristics

2) Accurate complex moduli data for the isolators

3) Geometric details of the isolator mounts

4) Foundation support structural details

5) Constraints upon maximum mount vibrations

6) Knowledge of other resonant vibrations that may exist

The work that has been conducted in the present contract has provided fundamental understanding of the issues involved and has developed the basic tools required to compare the behaviour of different mount materials