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Dynamic Analysis on Vibration Isolation of Hypersonic Vehicle Internal Systems

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ABSTRACT

Severe vibration levels can cause machinery failures. The present work in this paper is to investigate theoretical and simulation analysis of isolated systems subjected to external excitation. Systems having rotating may cause vibrations and noise when they mounted on a roof, or on a floor above the ground floor. The problem is usually most apparent in the immediate vicinity of the vibration source. However, mechanical vibrations can transmit for long distances, and by very circuitous routes through the structure of any hypersonic vehicles, sometimes resurfacing hundreds of feet from the source. This research investigates the importance of isolation for the reduction in the force transmitted to foundation, transmissibility and effectiveness of the isolator using commercial analysis software.

Keywords: Vibration, Source, Isolation, Transmissibility, Effectiveness.

Nomenclature:

m	=	mass of the source in kg
u	=	displacement in m
F_o	=	vibrating force in N
k	=	stiffness in N/m
c	=	viscous damping in N-m
ω	=	forced frequency in rad/sec
ω_n	=	natural frequency in rad/sec

f_n = natural frequency in Hz

f = forced frequency in Hz

r = ω / ω_n

T = transmissibility

E = effectiveness in dB

F_T = Force transmitted to foundation in N

INTRODUCTION

Vibration isolation of machinery to prevent the transmission of vibration and noise has become one of the important phases of hypersonic vehicles. Light weight construction and locating mechanical equipment on elevated foundations, adjacent to quiet areas, increases the requirement for vibration control. The use of isolation is primarily for reducing the effect of the dynamic forces generated by moving parts in a machine into the surrounding structure. Every machine by its very function of operation creates a vibration or shock of varying intensity or amplitude (1). The requirements for isolating this vibration depend upon the local conditions of installation. Three principle factors control the selection of an isolator for a particular machine. The first is the weight to be supported, the second is the disturbing frequency of the machine and the third is the rigidity of the structure supporting the machine. Vibration is a force and establishing an opposed force can effectively reduce its transmission. This is accomplished by incorporating a truly resilient material, which when subjected to a static load, deflects and by so doing establishes the natural frequency of the isolation system. When the natural frequency of the isolation system is lower than the operating or disturbing frequency of the supported machine, each cycle of vibratory force finds the resilient material in the returning phase of its cycle. The effectiveness of the isolation then, is a function of the distance of return travel remaining at the time of impact. A vibration problem can also be nicely described by the same source – path – receiver model to characterize the noise control problem.

- Source: A mechanical or fluid disturbance, generated internally by the machine, such as unbalance, torque pulsations, gear tooth meshing, fan blade passing, etc. These typical occur at frequencies which are integer multiples of the rotating frequency of the machine.
- Path: The structural or airborne path by which the disturbance is transmitted to the receiver.
- Receiver: The responding system, generally having many natural frequencies which can potentially be excited by vibration frequencies generated by the source.

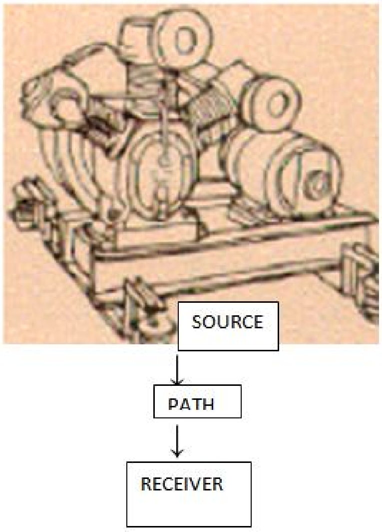


Fig: 1 Source-Path-Receiver model hierarchy

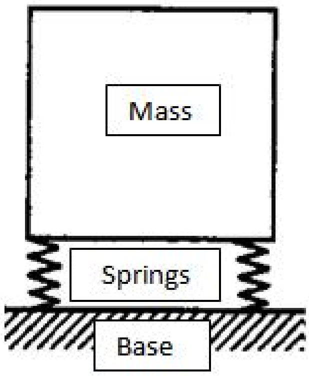


Fig:2 Setup of a Model for Simulation

Suppose when the vibrating force is 100 N, a 90% efficient isolator with 10% transmissibility will transmit 10N force to the foundation or base structure as transmission to structure varies as a function of magnitude of vibrating force (2). The transmissibility as a function of frequency ratio Vibration isolation (defined as $T<1$) occurs when the excitation frequency is greater than1.4fn. For minimum transmissibility (maximum isolation), the excitation frequency should be as high above the natural frequency as possible.

- Problem Description: A typical engine step-up gear box weighing 500 kg, running at 1200 rpm and is installed using vibration isolator springs four in number having the total stiffness of 5 N/m. All the materials are made of steel having the density of 7450 kg/m^{3,} Poisson's ratio 0.3 and Young's modulus 2e11 N/m^2.
- Mathematical Model: Considering only vertical motion, the model can be described mathematically by a single degree of freedom, lumped element system

$$m\ddot{u} + c\dot{u} + ku = F_o(t) \qquad \text{Eq.(1)}$$

If we neglect damping, the vertical motion of the system, u(t) can be shown to be

$$u(t) = \frac{[(Fo/k)]}{1-r2} \sin\omega t \qquad \text{Eq.(2)}$$

where $r = (\omega/\omega_n) = (f / f_n)$

$$F_T = ku \qquad \text{Eq (3)}$$

$$\text{Transmissibility, } T = F_T / F_o = \frac{1}{(r2-1)} \qquad \text{Eq (4)}$$

The effectiveness of the isolator, expressed in dB is :

$$E = 10 \log_{10} (1/T) \qquad \text{Eq (5)}$$

The effectiveness of the isolator, expressed in percent is:

$$\% \text{ Isolation} = (1- T)*100 \qquad \text{Eq (6)}$$

FEM Model: A finite element model with typical solid and combination spring damper element is chosen for the discretization considering all aspects of the approaches.

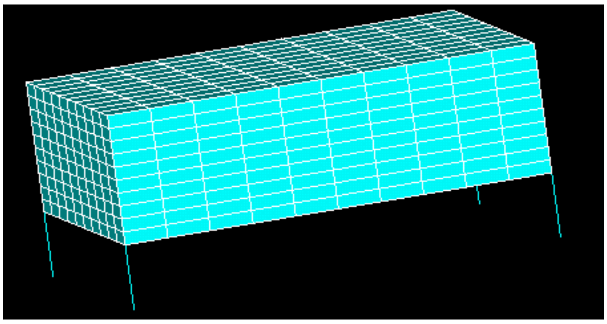


Fig: 3 A typical fem model

Results & Discussions:

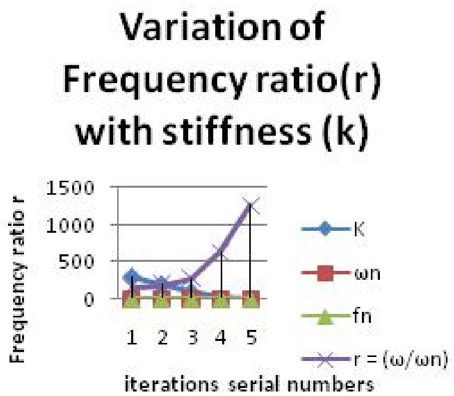
- Simulated results of undamped model supported with 4 springs is considered to calculate the natural frequency of the vibrating mass carrying the rotating equipment like scramjet engine used for hypersonic vehicle running at 1200 rpm approximately.
- The numerical results evaluated from the mathematical model are tabulated by varying the total stiffness of the springs to calculate the transmissibility, effectiveness in dB and the % of isolation.
- The results are compared with graphs to evaluate the effect of change in stiffness influencing the depending variables like transmissibility, effectiveness in dB and the % of isolation.

Table 1: Stiffness and frequency ratio

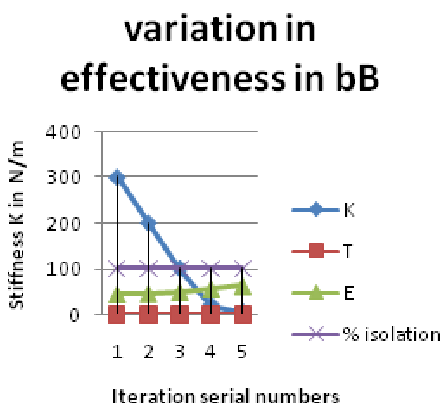
S. No	K	ω_n	f_n	$r = (\omega/\omega_n)$
1	300	0.77	0.12	163.2
2	200	0.63	0.101	198.6
3	100	0.45	0.071	280.9
4	20	0.2	0.032	628.3
5	5	0.1	0.015	1256.6

Table 2 : Stiffness, transmissibility, effectiveness and % isolation.

S. No	K	T	E in dB	% isolation
1	300	3.735e-5	44.25	99.9960
2	200	2.53e-5	45.96	99.9970
3	100	1.26e-5	48.96	99.9980
4	20	2.53e-5	55.96	99.9997
5	5	6.33e-5	61.98	99.9999



Graph1: frequency ratio(r) with variation in stiffness (k)



Graph: 2 Effectiveness in dB with stiffness

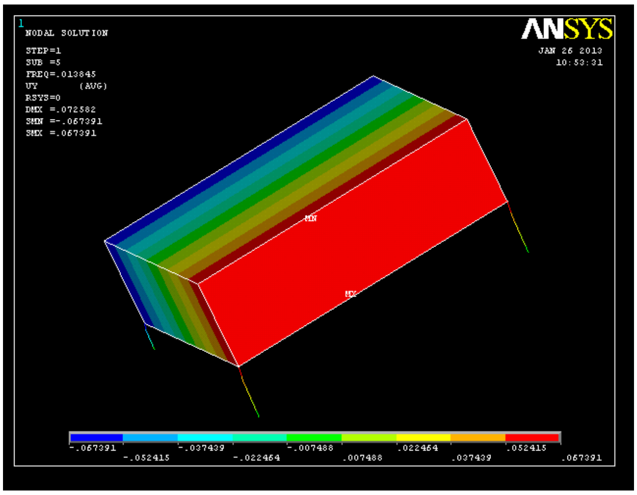


Fig: 4 Natural frequency at mode5

Conclusions:

- The natural frequency of the simulated model is in good understanding with the numerically evaluated value of 0.015 Hz from fig(4) with Sl. No 5 in table1.
- When the stiffness value is varying from 300 N/m to 5 N/m, the value of frequency ratio is increasing from 163.2 to 1256.6Hz.
- The effectiveness in dB is increasing from 44.25 to 61.98 Hz when the value of stiffness is decreasing.
- A little variation is observed in the values of % of isolation from 99.996 to 99.999.

References:

[1] ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineering) Applications Handbook, 1999.
[2] Cyril M. Harris, Handbook of Acoustical Measurements and Noise Control, McGraw Hill, 1991.
[3] L. Beranek editor, Noise and Vibration Control Engineering,, John Wiley and Son, 1992, pp 429-450.
[4] www.ansys.com
[5] www.wikipedia.com
[6] S. Graham Kelly, Fundamentals of Mechanical vibrations, Second Edition, McGraw Hill, 2000.