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A Critical Investigation of Force Transmissibility Characteristics in various Isolator materials using Force Transmissibility Apparatus

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Abstract: *In this paper, an apparatus/experimental facility developed to study the force transmissibility characteristics of various isolator materials, has been described. It is demonstrated that this set up can serve as a useful and handy equipment for the industry to test the suitability of possible isolator materials in regard to their force transmissibility. Experimental and theoretical results of force transmissibility, in case of some metal springs, have been compared. Also, for transmissibility characteristics of other isolator materials such as coir, rubber, belt etc. (and also their combinations) are compared, based on the experimental results obtained on this experimental facility. The results of this reported study will help facilitate the parameter design and performance analysis of a vibration isolation system.*

Keywords: Vibrations, Force Transmissibility, Exciter, load cell, Isolator, Frequency coefficient

I. INTRODUCTION

Vibration and noise control play a central role in the industrial machineries. Intensive research has been done in this arena which has drawn attention of researchers. The vibration isolation has assumed importance in the design of machine mountings, isolator mounts of instruments. Since noise and vibration isolation performance are key parameters in the design of vibration control systems, an accurate calculation of transmissibility has become increasingly important in the design process. This calls for studying the suitability of existing and newer materials as possible isolator materials in regard to their force and motion transmissibility characteristics.

II. LITERATURE REVIEW

Noise and vibration isolation performance are key parameters in the design of vibration control systems, an accurate calculation of transmissibility has become increasingly important in the design process [1-5]. In this regard, Tapia-Gonzalez et al. experimentally studied the shock and vibration transmissibility of dry friction isolators,.[6].Sahu et al. actively controlled transmitted sound through a double panel partition using a weighted sum of spatial gradients.[7] Caiazzo et al. reported on the active control of the turbulent boundary layer sound transmission into a vehicle's interior.[8] Zhoul and Wenlei reported on the study of the vibration and noise transmissibility characteristics of a gear transmission system.[9].The inerter is a recently proposed concept and device that allows an applied force at two terminals to be proportional to the relative acceleration between them.[10,11]

III. METHODOLOGY

The primary objective of the present study was, therefore, to design and develop an experimental facility/apparatus on which, especially the force transmissibility characteristics of such isolator materials can be determined. For this purpose

- An inertia type vibration exciter has been designed and developed to provide a force of variable amplitude (0 to 42 kgf.) and variable frequency of (O to 16 Hz)
- A suitable mounting system has been developed, and a strain gauge-proving-ring type force transducer is designed to sense the force transmitted through isolator material under test. It is connected to suitable recording/display system using digital strain bridge/oscilloscope (storage type).

First the frequency response of vibration exciter developed, as obtained and was compared with its theoretical response.

Secondly, few spring isolators were tested on this apparatus for their force transmissibility and these results were compared with the theoretical values, of force transmissibility. Also, the force transmissibility characteristics of rubber, foam rubber, cork, coir, felt, thermocole and (for some of their combinations) were determined on this apparat us and based on these results their relative capability as force isolator were compared, to demonstrate that the apparatus thus developed can serve as a useful tool for industries to test the possible isolator materials and to have a feel of relative isolation characteristics of isolator materials.

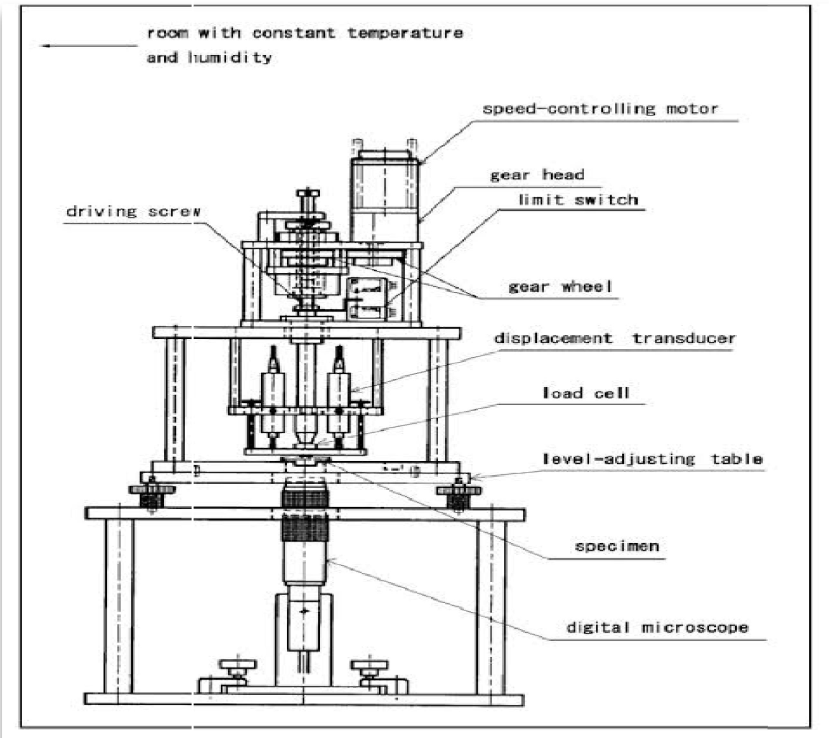

Figure 1: Force transmissibility Apparatus

3.1 Development of Exciter

For the type of vibration exciter sought to be developed, principle of rotating out of balance masses is taken into consideration thus simulating the of actual type of forces that are met within rotating machinery for which the isolators are employed. The simplified schematic system transmitting a known force to the load cell, through an isolator element is shown in Fig. 2.

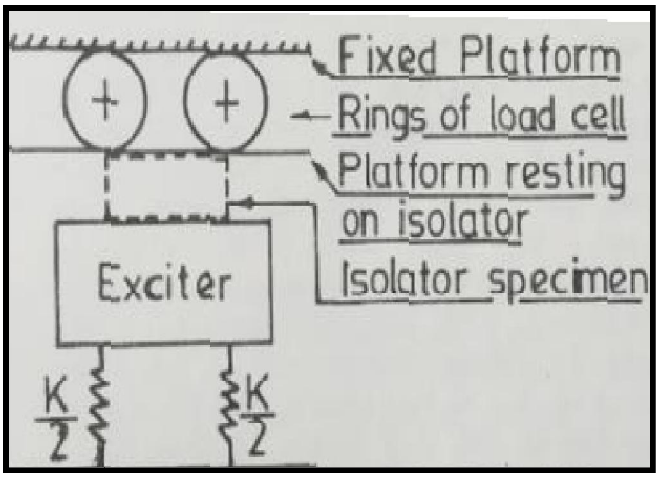

Figure 2: Experimental set up of Exciter

The isolator element under test is shown by dotted rectangle. From this exciter, a force variation of 0 to 42 kgf with a variation of frequency from 0 to 16 Hz can be obtained.

3.2 Measurement of Force

The isolator transmits force depending upon the magnitude and frequency of excitation. To measure this force transmitted, a load cell capable of measuring forces of dynamic nature was designed and developed. This cell consists of four aluminium rings connected in between two parallel aluminium plates. The strain gauges were mounted as shown in fig. 3.

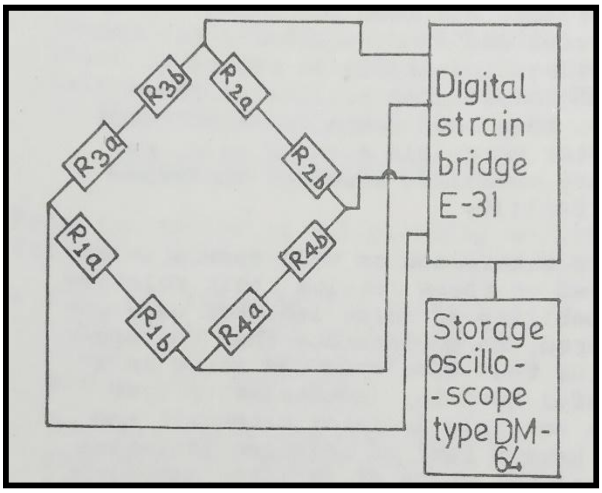

Figure 3: Instrumentation of Experimental set up

On each ring one gauge on inner side and one on the other side. The force to be measured is vertical and hence for maximum bending effects, gauges were mounted at right angled direction. These are oriented with their major axes circumferentials. This minimizes the effects of axial strain. All the strain gauges are connected in a Wheat stones bridge, gauges sensing like strains in opposite arms and those sensing opposite strains in adjacent arms.

The output of the strain gauges was given to a digital strain bridge storage oscilloscope for recording/display of force transmitted through the isolator material mount under test. The load cell was calibrated under static compression type of loading. The arrangement for mounting isolator material is as shown in fig.6. A Variable speed d.c. shunt motor of 0.5 hp, 1500 r.p. m is mounted the end of the foundation. The motor drives the exciter central driver gear shaft by a flexible shaft under a safely guard.

IV. Formulae And Calculations

Let us denote force transmissibility as FT. In fig.1 if the dotted rectangle represents a metal spring of stiffness K_I (axis of spring perpendicular both the platform base) and if X is the amplitude of exciter platform response at excitation frequency ω, then the force transmissibility FT of a metal spring, can be given by

$$FT = \frac{K_I \xi}{M_e \omega^2} \quad \text{--- (1)}$$

where μ = ratio of total eccentric mass (m) to mass of the vibration exciter (M).

Let the stiffness of exciter support spring and that of the load cell rings are represented by K and K_I and K respectively. Since K_I is designed to be very large as compared to K_I,the combined stiffness of isolator spring and load cell spring can be approximated as K_I itself. Then K_I and K would be in parallel and forms single domain frequency system with natural frequency given by ω_n

If $\beta = \frac{\omega}{\omega_n}$

$$where\ \omega_n = \sqrt{\frac{(K_I + K)}{M}} \quad \text{----(2)}$$

Then

$$\xi = \frac{\mu e\, \beta^2}{1-\beta^2} \quad \text{---(3)}$$

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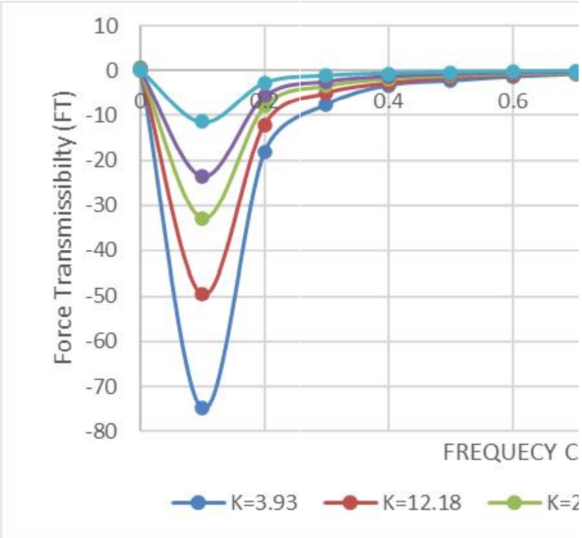
Hence final expression becomes

$$FT = \left(\frac{K_I}{K_I+K}\right)\left(1-\frac{1}{\beta^2}\right) \text{ --- -(4)}$$

Following helical springs with values of stiffnesses (kgf. per cm) equal to 3.93, 12.18, 24.5, 39 and 94 were used as isolators and their theoretical values of FT's were calculated using equation (4), for different values of excitation frequency these were tested experimentally, for typical spring isolator (with K_I =12.18 Kgf per cm.) results are depicted in fig. 3 It shows fairly good agreement between experimental and the theoretical values of force transmissibility.



Graph. 1 Graph showing the variation of Force Transmissibility (FT) with frequency constant for steel springs with fixed value of stiffness

On the same set up, values of other isolator materials Such as (1) rubber, cork, coir, felt thermocole foam rubber and (2) combination of foam rubber and coir, felt and coir and felt and foam rubber, was experimentally obtained.

TABLE I: The variation of FT with forcing frequency for typical cases

S. No	Material of isolator (In Compression)	Maximum value of Fracture Toughness (FT)
1	Rubber	6.73
2	Felt	7.32
3	Foam Rubber	3.29
4	Coir	3.23
5	Cork	1.78
6	Thermocole	5.73
7	Felt and Foam Rubber composite	2.03
8	Felt and Coir composite	2.69

TABLE III: The variation of Force Transmissibility with forcing frequency for typical cases

β	Felt	Rubber	Foam Rubber	Felt and Foam
0	0	0.45	0.42	0.62
0.4	0.88	0.63	0.44	0.73
0.8	1.76	1.22	0.63	0.82
1.2	3.54	6.74	2.88	1.72
1.3	5.27	6.32	2.25	1.86
1.4	7.32	3.76	1.48	2.03
1.5	3.47	1.34	0.76	0.78
1.6	1.26	1.17	0.58	0.66
1.7	0.44	0.88	0.36	0.62
1.8	0.18	0.53	0.31	0.57

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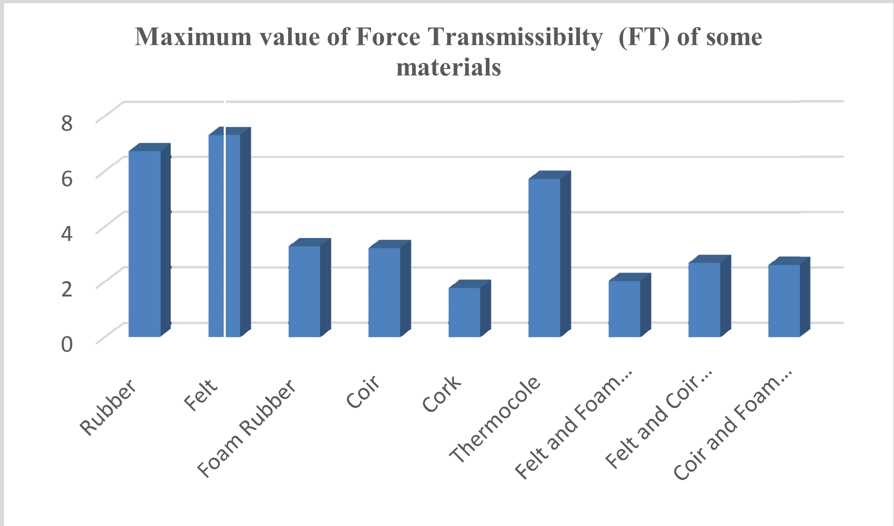
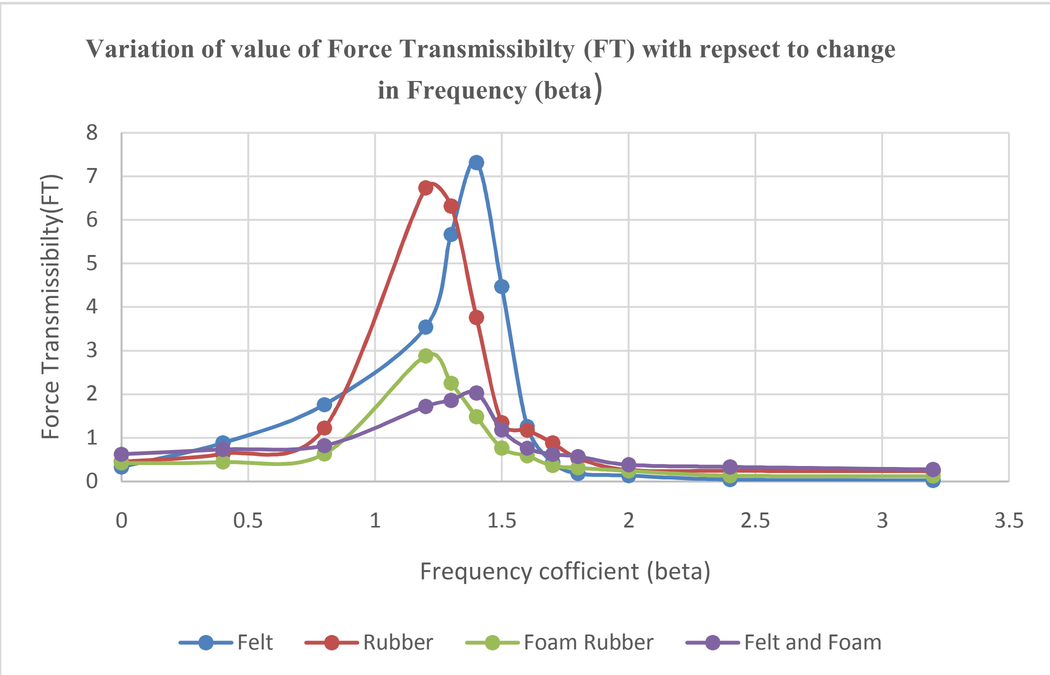
2.0	0.13	0.26	0.24	0.38
2.4	0.04	0.24	0.13	0.33
3.2	0.02	0.23	0.12	0.27



Graph. 3 Graph showing the maximum values of Force Transmissibility (FT) for some materials



Graph. 4 Graph showing the variation of Force Transmissibility (FT)with change in frequency coefficient(β)

V. CONCLUSION

The research paper was aimed to develop an experimental facility for determination of force transmissibility of certain isolator materials and giving results with fairly good accuracy with theoretical ones. First frequency response of vibration exciter was obtained and was compared with its theoretical response, then force transmissibility characteristics of rubber, foam, felt and its combinations were calculated and compared showing its utility in finding relative isolation characteristics of different isolator materials. The variation of FT with forcing frequency for typical materials are shown in graphically and in tabular form. From the data available following inference can be made:

- Highest value of force transmissibility is obtained in case of Felt and foam composite, hence is regarded best vibration isolator material
- With increase in frequency ratio, transmissibility goes on decreasing.
- Transmissibility ratio attains its maximum value for different material and their combinations at a particular frequency ratio

VI. FUTURE SCOPE

This research can be useful to find force transmissibility of different isolator materials and in future can be put to use in

- In the dynamics of machines laboratory to demonstrate and study the principle of vibration isolation and damping
- With little modifications, as per the needs of industry for testing the suitability of possible isolator materials for the industrial applications.
- With some arrangements in the existing set up, we can study the effects of temperature variation, moisture, oil etc., on the force transmissibility characteristics of these isolator materials.

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