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Analyze the Transmissibility of Various Materials Using Vibration Analysis

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Abstract

Vibration is a to and fro motion of a body about its mean position. It is desirable or undesirable, it depends on our work, but necessarily produce during operation of any machine. To minimize vibration level, isolators are equipped for getting minimum transmissibility. This paper deals with the comparison and analysis of various materials for vibration isolation. Transmissibility and properties on different materials gives idea about getting maximum vibration isolation values of Transmissibility have been taken for different materials (Aluminium, Mild Steel, Cast Iron, Marble, Rubber, Wood, Nylon, and Cork) & analysis has been done to get a better vibration isolation.

Keywords: Vibration apparatus, samples of materials, Vibration meter (Digital).

Introduction

The isolation of machinery to prevent the transmission of vibration and noise has become one of the important phases of modern building engineering. Lightweight construction and locating mechanical equipment on upper floors, 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.

The purpose of vibration isolation is to control unwanted vibration so that its adverse effects are kept within acceptable limits. Vibrations originating from machines or other sources are transmitted to a support structure such as a facility floor, causing a detrimental environment and unwanted levels of vibration. If the equipment requiring isolation is the source of unwanted vibration, the purpose of isolation is to reduce the vibration transmitted from the source to the support structure. Conversely, if the equipment requiring isolation is a recipient of unwanted vibration, the purpose of isolation is to reduce the vibration transmitted from the support structure to the recipient. An isolator is a resilient support, which decouples an object from steady state or forced vibration. To reduce the transmitted vibration, isolators in the form of springs are used. Common springs used are pneumatic, steel coil, rubber (elastomeric) and other pad materials. [1]

Literature review

J.M. Krodkiewski, [1], if the equipment requiring isolation is the source of unwanted vibration, the purpose of isolation is to reduce the vibration transmitted from the source to the support structure. Conversely, if the equipment requiring isolation is a recipient of unwanted vibration, the purpose of isolation is to reduce the vibration transmitted from the support structure to the recipient. An isolator is a resilient support, which decouples an object from steady state or forced vibration. To reduce the transmitted vibration, isolators in the form of springs are used. Common springs used are pneumatic, steel coil, rubber and other pad materials.

Natural frequency and damping are the basic properties of an isolator, which determine the transmissibility of a system designed to provide vibration and/or shock isolation. Additionally, other important factors must be considered in the selection of an isolator/isolation material.

Vibration isolation

A.G. Ambekar [2], Machines which transmit substantial static or dynamic forces through their pedestal, are required to be installed on foundation. Attempts are made to reduce out of balance force in a machine has to installed in structure where vibration is undesirable. For instance, A.C. motor may be installed in a hospital or a hotel in connection with elevators. Similarly, an I.C. engine, which is inherently source of

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vibration, is requiring installing in an automobile. In all such cases, an engineer is required to mount the machine in such a manner objectionable feature of such vibration is that they are transmitted to other locations through the structures and can cause other machines to vibrate. There is yet another category of problem requiring vibration isolation. In some of the machines (e.g. aircraft, rocket etc.), vibration of structure must not be transmitted to the radio receiver and the instruments on control panels. In all such cases, vibrating objects are required to be isolated from rest of the parts of the machine or structure. Problems of both the types can be solved by isolating the equipment from the support.

Force transmissibility

[2], Universal solution to the isolation problem consists in mounting the machines on properly designed springs and effectiveness of vibration isolation is measured in the terms of ratio of force/motion transmitted through the isolator to the amplitude of excitation force / motion. This is called Transmissibility. Lesser the amplitude of force being transmitted through the isolator, for a given excitation force, greater is isolation. To develop a clear understanding about the problem of vibration isolation, one must know the different roles played by each of the two components, namely the spring and the viscous damper.

$$T.R. = \frac{\sqrt{1+(2\zeta r)^2}}{\sqrt{(1-r^2)^2+(2\zeta r)^2}} \quad \ldots\ldots\ldots (1)$$

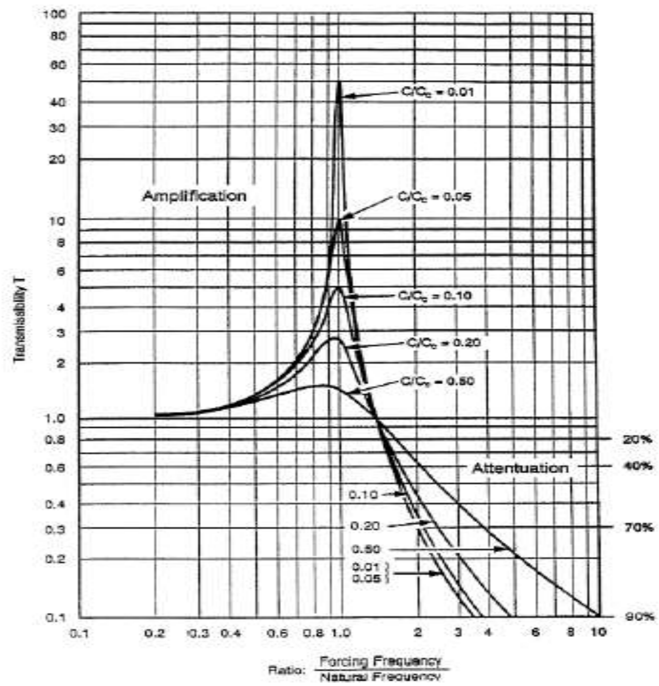

Figure 1.1 Transmissibility v/s frequency ratio for several values of damping, [4]

Experimentation

In the project work, a fabricated vibration apparatus has been selected for the experimental work. Materials like, ALUMINIUM, M.S, C.I, MARBLE, RUBEER, WOOD, NYLON, CORK were used in the tests, and regulator is available to get variation in vibration level on top and bottom plate. A photograph of the experimental set-up is shown in Fig.2. In this apparatus an electric vibrator is used, which applies five varying loads, mounted on an aluminum plate working on AC supply providing point vibrations to the sample placed between two Aluminium plates. The sensor is placed on lower and upper

Aluminium plate, which is further connected to the Vibrometre providing us the value of acceleration at these different speeds. Acceleration provide values of excitation and transmitted force and by using equation (1), values of transmissibility at different speeds are calculated.

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Figure 02, Experimental Set-Up

The experiment is carried out in two stages. In the first stage, the piezoelectric sensor is placed on lower Aluminium plate which is in direct connection with the Vibrator, it gives the values of force transmitted by vibrator to lower Aluminium plate (neglecting the damping due to Aluminium), and readings are shown in Table no. 1. And in the second stage, the piezoelectric sensor is placed on upper Aluminium, after placing sample material between both plates, it gives the transmitted values of force which is always less than the lower Aluminium plate due to provision of isolating materials. The values of damping ratio or factor (ζ) is consulted through [7]

Results & discussions

The table (01-08) and Figure1.3 shown below gives a clear view on effect on Transmissibility by changing the Isolation material.

Table 01 Transmissibility analysis of Aluminium (ζ=0.004)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.85	0.519	48.1
II	3.56	1.89	0.532	46.8
III	4.64	2.84	0.612	38.8
IV	5.72	3.65	0.638	36.2
V	8.24	5.58	0.678	32.2

Table 02 Transmissibility analysis of Mild Steel (ζ=0.008)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.62	0.456	54.4
II	3.56	1.62	0.456	54.4
III	4.64	2.16	0.466	53.4
IV	5.72	3.02	0.528	47.2
V	8.24	4.37	0.530	47.0

Table 03 Transmissibility analysis of Marble (ζ=0.017)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.85	0.519	48.1
II	3.56	2.03	0.570	43.0
III	4.64	2.84	0.612	38.8
IV	5.72	4.37	0.764	23.6
V	8.24	6.57	0.798	20.2

Table 04 Transmissibility analysis of Cast Iron (ζ=0.02)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.53	0.430	57.0
II	3.56	1.53	0.430	57.0
III	4.64	2.34	0.505	49.5
IV	5.72	3.02	0.528	47.2
V	8.24	4.59	0.557	44.3

Table 05 Transmissibility analysis of Wood (ζ=0.035)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.13	0.316	68.4
II	3.56	1.13	0.316	68.4
III	4.64	1.89	0.408	59.2
IV	5.72	2.57	0.449	55.1
V	8.24	4.14	0.503	49.7

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Table 06 Transmissibility analysis of Rubber (ζ=0.05)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	0.36	0.101	89.9
II	3.56	0.36	0.101	89.9
III	4.64	0.77	0.165	83.5
IV	5.72	1.22	0.213	78.7
V	8.24	2.79	0.339	66.1

Table 07 Transmissibility analysis of Nylon (ζ=0.070)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.71	0.481	51.9
II	3.56	1.76	0.494	50.6
III	4.64	2.75	0.592	40.8
IV	5.72	3.69	0.646	35.4
V	8.24	6.08	0.738	26.2

Table 08 Transmissibility analysis of Cork (ζ=0.127)

SPEED	EXCITATION FORCE (F_0), kg.mm/s^2	TRANSMITTED FORCE (F_t), kg.mm/s^2	$T.R. = \frac{F_t}{F_0}$	EFFECTIVENESS OF ISOLATION (1 - T.R.) X 100 (%)
I	3.56	1.98	0.557	44.3
II	3.56	1.98	0.557	44.3
III	4.64	2.57	0.553	44.7
IV	5.72	3.74	0.654	34.6
V	8.24	5.63	0.683	31.7

The tables (01-08) are in ascending order of their damping ratio (ζ**)**, which shows that:-

- ❖ The Transmissibility for all materials belongs to (0.10 to 0.90).
- ❖ The rubber provides minimum value of transmissibility = 0.101 and the marble, cork provides maximum value of transmissibility = 0.557.
- ❖ As we know, if transmissibility increases the effectiveness of vibration isolation decreases and vice-versa. Therefore, by the analysis it is found that rubber is best possible choice for vibration isolation
- ❖ If the average value of vibration isolation is taken into consideration, rubber is providing 81% reduction in transmitted force, whereas, marble is providing only up to 34% which is the least value amongst all.
- ❖ The value of frequency ratio (r) is decreases with increase in transmissibility
- ❖ The value of r for all materials belongs to (1.5 to 3.4).
- ❖ The marble has minimum value of r = 1.5 and the rubber has maximum value of r = 3.4.
- ❖ As mentioned, at r>$\sqrt{2}$ the transmissibility is less than 1, this statement is justified by above readings.

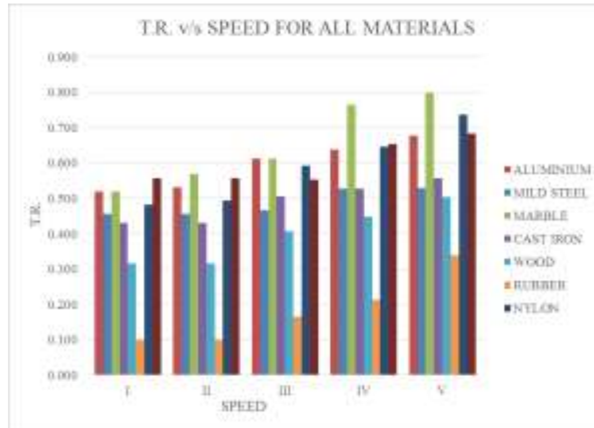

Figure. 03, Transmissibility v/s Intensity of vibration (speed of Regulator)

The plot in Figure 03 throws light on:-

- ❖ If we see the graphs plotted between transmissibility v/s speed, the common factor is, as speed of regulator increases transmissibility also increases and,
- ❖ For Aluminium, C.I, Wood and Cork the increment in transmissibility with speed is quite less as compared to remaining. This makes them suitable option for vibration isolation for varying load machines.
- ❖ M.S., Rubber, Nylon provides great fluctuations after speed iii, it makes them suitable for slow speed machines.
- ❖ For least and max. Transfer of force with varying speed, the M.S. provide minimum value (transmissibility) = 0.08 & Nylon provides max. Value (transmissibility) = 0.257, which is a very high difference makes it not suitable for vibration isolation for fluctuating loads.
- ❖ The plots between transmissibility and frequency ratio **(r)** gives quite similar results as we get in fig no.1. So, we can say that these above analysis are verified theoretically as well as experimentally.

Conclusions

- The main aim for doing this project to get a best possible solution for vibration isolation amongst materials under observation.
- This also gives an idea which materials suites the best for the given operating conditions.
- Rubber shows a consistent and good performance from speed I to V. Therefore amongst all rubber is a good isolator.
- Mean effectiveness of rubber is up to 82% which is very high compared to other materials.
- While, the mean effectiveness of marble is up to 35% only, which is very amongst all.
- This analysis belongs to compare the transmissibility for better vibration isolation, the study, and selection materials and through various experiments it has found that, if we arrange mean effectiveness of isolating materials under observation. These are,

Marble < Cork < Aluminium < Nylon < Cast Iron < Mild Steel < Wood < Rubber.

- This analysis also enables to understand that, effectiveness of isolation vary according to the nature of intensity of vibration, irrespective of damping ratio (ζ).
- Isolation of materials decreases with increase in speed or intensity of vibration, the maximum reduction is effectiveness of isolation is found to be:-

Aluminium (16%), Mild steel (8%), Marble (30%), Cast Iron (13%), Wood (19%), Rubber (24%), Nylon (26%), Cork (13%).

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