Bull. Ind Soc. Earthq. Tech., Paper No. 277, Vol. 26, No. 4, Dec. 1989, pp 39-48

BASE ISOLATION OF EQUIPMENT AND SYSTEM

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ABSTRACT

The increased dependence of the society on machines provides no room for failure and inturn demands equipment and systems with higher performance reliability. Vibration problems, since decades, have been drawing attention of the scientists and engineers world over to find ways and means to minimise the failures of machines. Though, improvements in manufacturing technology has provided machines with better tolerance and thereby controlled behaviour, the vibration problems are still persisting. Use of isolation devices for rotating machines appears to be a possibility to minimise vibration related problems. An effort has been made in this paper to list down the isolation requirements for rotating machinery both from the point of vibration isolation as well as seismic/shock isolation. Salient details of a case study regarding base isolation have been presented.

INTRODUCTION

The concept of vibration isolation, though well known for several decades, has been in use only in limited areas. Not only lack but a total disregard of the awareness of harmful effects of vibration as well as absence of legal enforcements are the primary causes responsible for such a slow rate of development in use of isolation devices in India. High initial cost, non-availability of indigenous isolation devices and lack of quantitative feed back data are some of the other factors responsible for virtual non-existent practice of vibration isolation.

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Need based isolation devices were in use even several decades ago when the mathematical concepts of vibration isolation were virtually non-existent. For example, use of springs under seat cover of a cycle was adopted to minimise the effect of vibration on the rider. Tremendous development has taken place in the design and engineering of shock absorbers for use in automobile industry, and this has, no doubt, added to increased roadworthiness of the vehicles besides providing better riding comforts. Similarly, in case of machines like forging hammers, isolation in the initial stages was achieved by cutting trenches all around the foundation and filling the same with sand. However, various isolating devices are now available with better results in reducing the harmfull effects of vibrations.

Although the present paper primarily aims at seismic base isolation, it may not be out of place to include other aspects of isolation, namely, vibration and shock for equipment and systems. In broader sense, these include:

a. control of vibration amplitudes/velocities because of dynamic forces generated by the machine itself.

b. Isolation of vibration generated by the machine and its effect on the adjoining structures and equipment.

c. Isolation of equipment from the vibration effects of the adjoining system.

d. Isolation from the seismic forces.

e. Isolation from shok which need special attention in industrial environment.

PRESENT STATUS

Isolation devices made of materials, like, rubber, cork, steel springs, viscous dampers and fabric plate, have been developed and are being manufactured in some of the advanced countries on commercial scale. These devices have been extensively used in those counries for vibration isolation of equipment. However, their application is limited so far as Indian industries are concerned. Efforts have been made by some organisations to design and manufacture vibration isolation devices in India for small machines and these are being used on large scale because of their low initial cost. For heavy machinery, like turbo generators, heavy duty compressors, motors, pumps, etc., it is possible to achieve the vibration isolation using the principles of dynamics applied to machines and their foundations. The problem is drawing more attention with the increased rating of machines as the direct and indirect losses on account of outages due to excessive vibration may be many fold of the initial cost of the vibration isolation devices. It is interesting to note that the ratio of initial cost of isolation devices to the capital cost of machines is decreasing with the increase in rating of the machines and use of isolation devices may prove to be cost effective.

PRINCIPAL OF ISOLATION

Isolation primarily means reduction in the transmissibility in the exciting force from the foundation to the equipment or vice-versa. Consider two single degree spring mass and dashpot systems as shown in Figure 1.

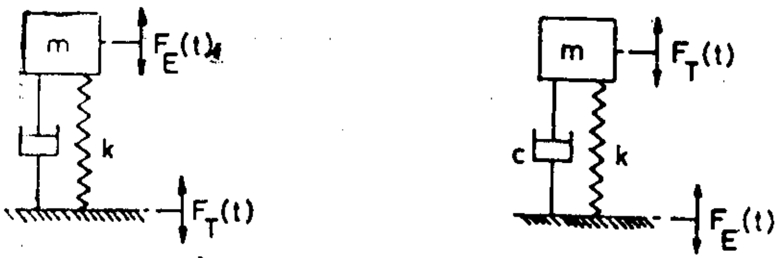

FIGURE - 1

where

k represent the stiffness.
c represent the damping.
m represent the mass.
F_E (t) represents the force of excitation.
F_T (t) represents transmitted force.

The transmissibility ratio 'TR' and the efficiency of isolation 'η' are definded as:

$$TR = F_T / F_E$$

$$\eta = (1 - TR) * 100$$

It is obvious that lesser the TR, better the efficiency of isolation.

For excitation force to be periodic having a frequency w_e and natural frequency of the system be w_n, the frequency ratio 'β' is:

$\beta = w_e / w_n$

Solution to equation of motion for each system indicate that the transmissibility factor 'TR' is same for both the systems and is given by the relation:

$$TR = \frac{\sqrt{1 + (2\xi\beta)^2}}{\sqrt{(1-\beta^2)^2 + (2\xi\beta)^2}}$$

where

ξ is % of critical damping.

Figure 2 shows a plot between TR and β for various damping ratios. It is seen from the figure that isolation is possible only for $\beta > \sqrt{2}$ i.e. natural frequency should be less than 0.7 times the excitation frequency.

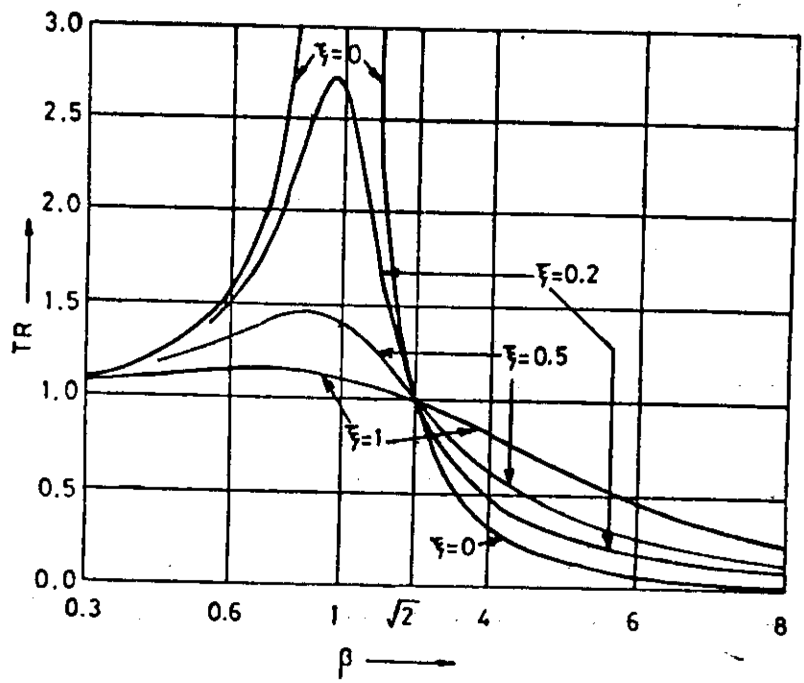

FIGURE - 2

For excitation force being pulse type, the variation of 'TR' with the pulse duration and natural frequency of the system is shown in Figure 3

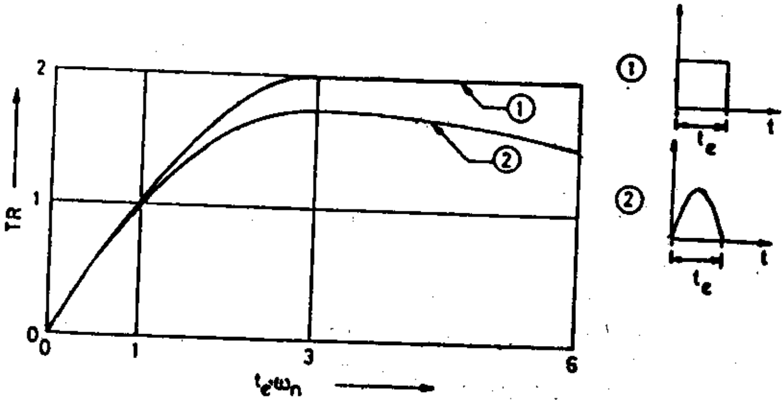

FIGURE - 3

where

t_e is the pulse duration

It is seen from the Figure 3 that for effective isolation, the product of t_e and w_n should be much less than unity i.e. system should have very low natural frequency.

SELECTION OF ISOLATION DEVICES

Although the equipment in industrial environment include rotating machines, stationary equipment, pipings etc., the focus in this paper is made primarly on rotating machines. Selection of isolation devices not only depends upon equipment but also on its environmental conditions. Choice of material and type of isolation device is faced with the following problems :

a. The isolation device should be able to withstand the environmental effects, like, high temperature, leakage of oil, moisture, steam etc. without loosing its properties.

b. It should require least maintenance.

c. It should be accessible for maintenance if need be.

d. Time required for maintenance, repair or replacement should be least so as to reduce the outage time and thereby reduce direct and indirect losses.

e. It should provide uniform stable deflection in order to ease the alignment process.

f. There should be no permanent ettlement.

Having selected the isolation devices, the response of the system is computed separately for each of the dynamic load condition, namely, vibration, earthquake and shock. A check is required to be made at this stage to ensure that the output parameters, are well within the allowable limits. If any of the output parameters, like, vibration amplitudes under normal operating conditions, deflections under earthquake or shock conditions, transmitted force, relative deflection under earthquake or shock conditions, transmitted force, relative deflection at the interface of the equipment and associated systems, etc., are non-permissible, the complete analysis needs to be redone by changing the characteristics of isolation devices till acceptable results are obtained.

Often, for the interconnected equipment systems relative deflection may pose a severe constraint and it may not be possible to achieve high efficiency of isolation. The use of low frequency isolation devices. though, provide better isolation effeciency, the corresponding deflections are relatively large. Figure 4 shows the variation of transmitted force and associated deflection as a function of frequency of isolation device.

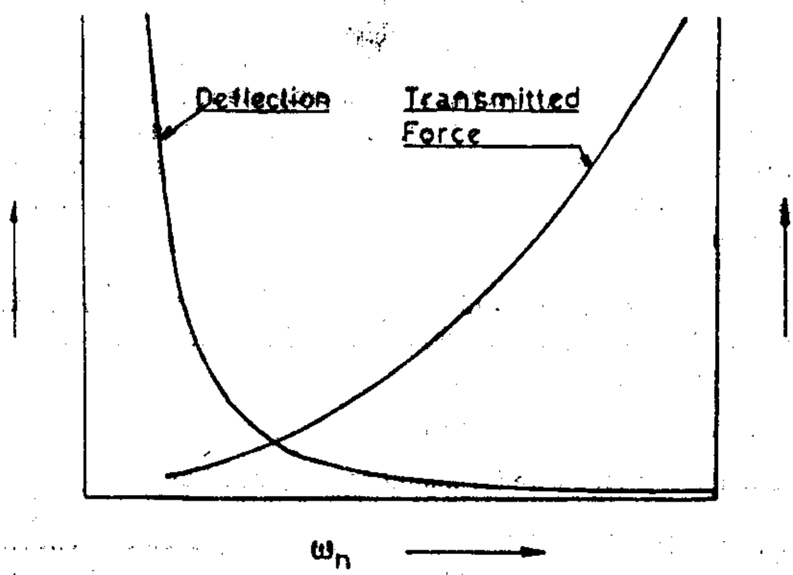

FIGURE - 4

The variation shown in this figure is only qualitative. Quantification of this, however, depends upon specific application. It is seen from the plot that higher the frequency of isolation mounts, force transmitted is higher whereas deflections are lower. It thus becomes necessary to so select the isolation device so as to be effective in vibration isolation of the machine as well as isolation of force like earthquake, shock, etc. It is worthwhile to mention that an isolation device good for vibration isolation may or may not be suitable for seismic isolation as the exciting frequency of the two forces may be different. For example vibration isolation of a machine operating at 50 Hz frequency can very well be achieved by isolation mounts of 6-8 Hz frequency, but this may amplify the seismic forces in the event of an earthquake. On the other hand seismic isolation of the machine may very well be achieved using isolators of frequency 1-2 Hz, but the deflection at the interface with connected equipment may be prohibitive. It is this aspect which makes the machine/equipment different than building structure so far as isolation is concerned.

APPLICATION

In the industrial environment in India use of isolation devices was practically absent in the past. Very recently isolation mounts have been used for 500 MWe Turbogenerator system as well as Boiler Feed Pump driven by Stem Turbine. Figure 5 shows schematic arrangement of isolation mounts for Boiler Feed Pump. These isolation mounts are supplied by M/S GERB, West Germany. These isolation mounts have been provided mainly for vibration isolation. More details, if needed can be had directly from M/S GERB.

The authors consider it appropriate to share their experiecne of isolating equipment and foundation system from the adjoining structures using cork as an isolation material. The two equipments where building foundation has been isolated are:

1. Hyper Comressor
2. Gas Turbine

In both the cases need for vibration isolation arose from layout constraints. At the time of plant layout the space envelope earmarked

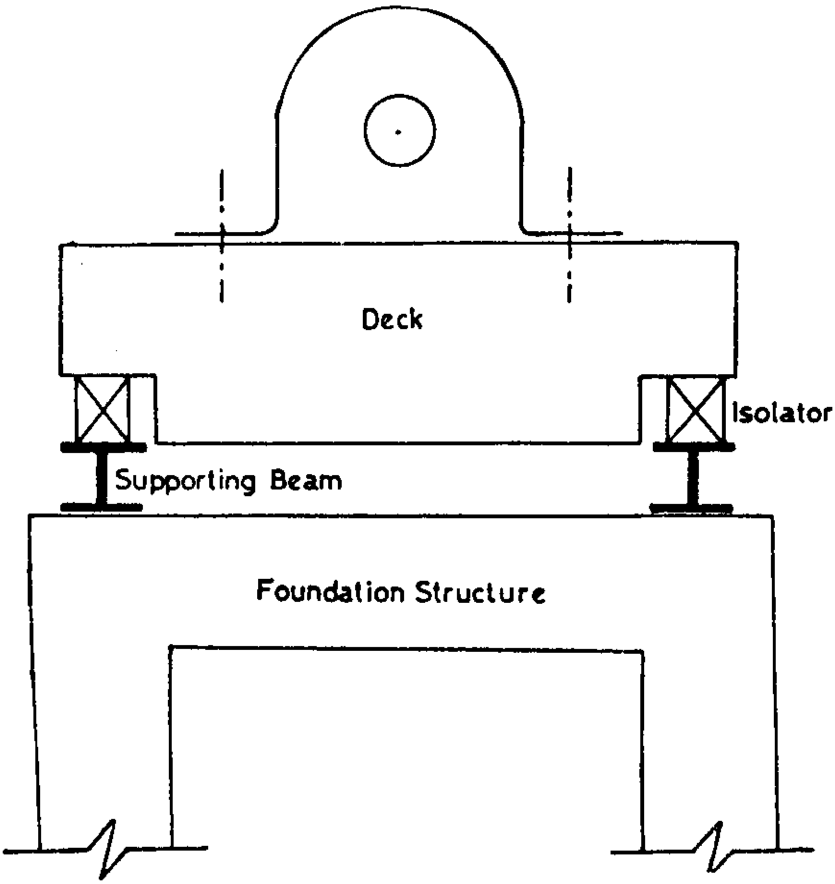

Figure-5

for the building housing the equipment was inadequate to provide independent foundations both for the building and the machine. It became imperative to isolate the machine vibration transmitted to the building structure and the same was achieved by using 40mm thick cork sheet underneath the machine foundation. Figure 6 provides details of the cork placement between building foundation and machine foundation. With this arrangement, both vibration amplitudes of the machine and the transmitted force to the adjoining structure were brought within acceptable limits. The Hyper Compressor is in position for last about 15 years and the feedback regarding the vibration amplitudes of the machine as well as the force transmitted to the structure is encouraging The Gas Turbine has not yet been fully commissioned and feedback, is awaited.

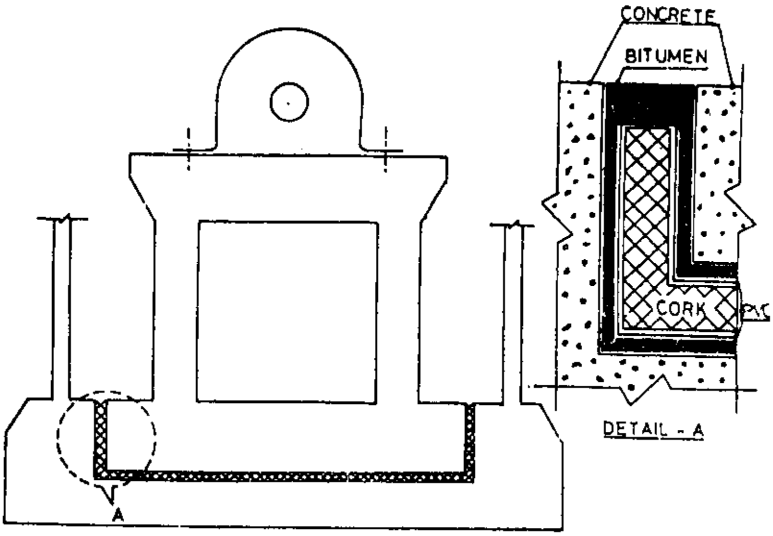

FIGURE - 6

OBSERVATIONS

From the foregoing discussion, the following observations aremaed :

1. Use of isolation devices for equipment and system, in general, is desirable, if it is not cost prohibitive. However, their use for machines of higher rating is recommended as the ratio of the cost of isolation to the capital cost of equipment would be relatively low,

2. For rotating machines, the prime objective is to achieve the desirable performance under normal operating conditions. Therefore main emphasis should be placed on vibration isolation rather than seismic or shock isolation.

3. Inhouse R&D work is much needed for design and development of isolation devices. The knowhow should then be transferred to appropriate industry for manufacture of the same within the country.

ACKNOWLEDCEMENTS

The authors wish to express their deep sense of gratitude to Bharat Heavy Electricals Limited for permission to present this paper.

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