International Convention on Surface Engineering

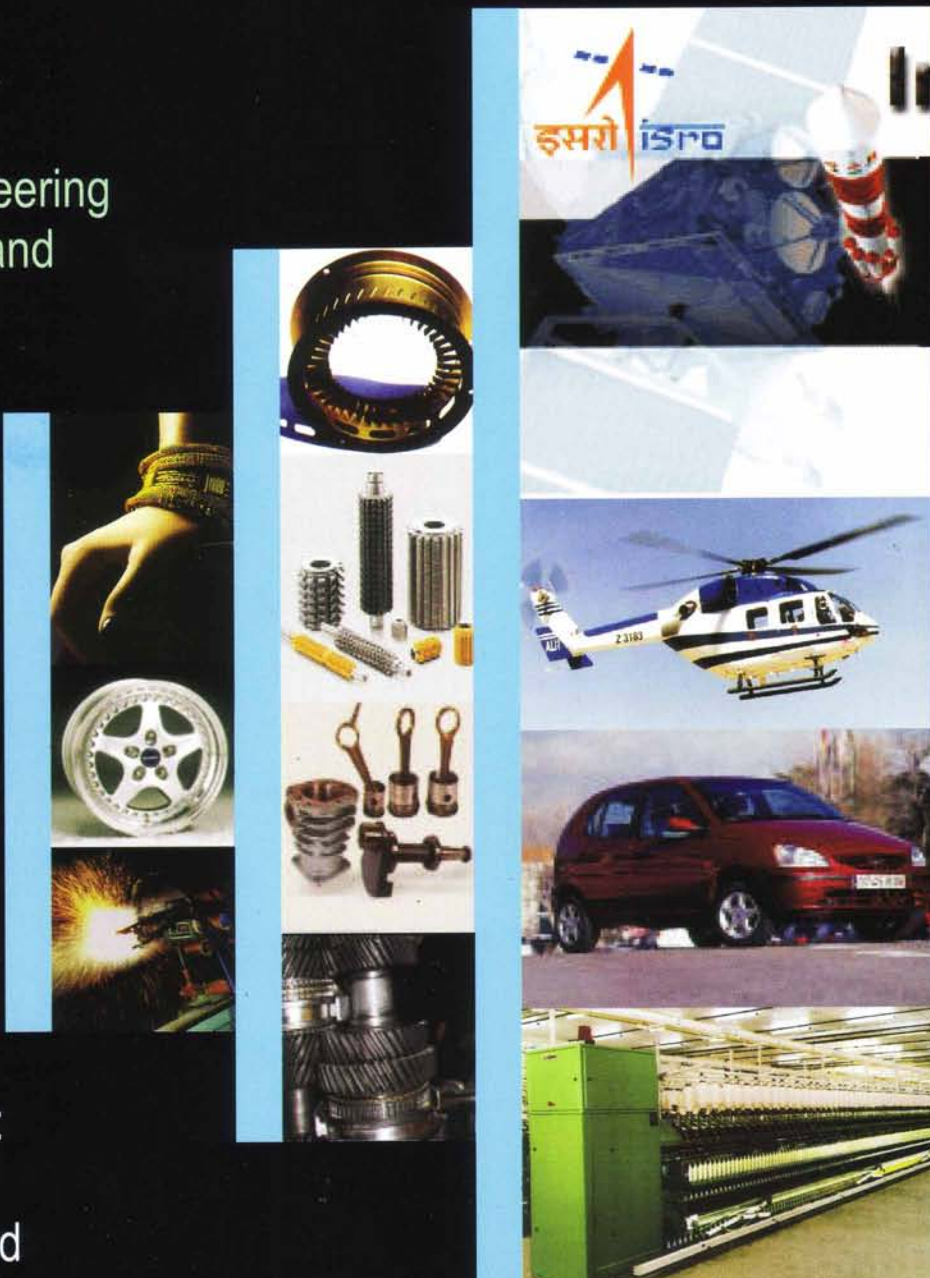
INCOSURF 2004

Bangalore, India

August 25-27, 2004

INCOSURF 2004

Emerging Surface Engineering Technologies and Applications



Special Focus:
Aerospace
Automotive and
Textile Industries

www.incosurf2004.com

Organized by

The Electrochemical Society of India, Bangalore

Indian Space Research Organization, Bangalore

IA-15: VIBRATION ISOLATION SYSTEMS FOR OPTICAL AND LASER INSTRUMENTS AND EXPERIMENTS RELATED TO SURFACE ENGINEERING AND METROLOGY

S. N. Bagchi and Ratish Jain

Vibration Engineering Design Section, Resistoflex Pvt. Ltd, B-103, Sector-5, Noida-201 301, India
Email: Resistoflex@vsnl.com

ABSTRACT
Application of vibration isolation techniques focusing optical and laser based interferometric set ups related to surface measurements and fabricating machineries are discussed. Surface finishing by Diamond Tooling Machines (DTM), Micro/nano Electro-Mechanical Systems (MEMS/NEMS) and microelectronic component fabrications etc., require micro and nano level dimensional accuracy. Isolation of floor and building vibrations of micro seismic nature is essential requirements for these applications.

An overview of mechanical and structural vibration affecting the resolution and accuracy of results presented. The design and installation of vibration and shock isolators between the supporting structure and the instrument, effectively reduces the relative movement and disturbances, which improves the image quality and resolution.

Introduction to the topic is drawn from the analogy of Molecular Vibration in infrared spectroscopy to Machine Vibrations. The application focusing the laboratory and workshop environment is highlighted. The laboratory equipments and experiments include microscopes, interferometers, spectrographs, surface topography using speckle and moiré fringe patterns, holography etc. An overview of mathematical models and computerized design methods including fuzzy logic and generic logic based optimization techniques and selection methods are presented. Different types of isolators are categorized under elastomeric type, metallic spring–damper systems and air springs. A comparison of isolation efficiency achievable with different isolators is explained. Glimpses of isolation requirement in other areas and the futuristic scenario are also outlined.

INTRODUCTION
Vibrations and oscillations are inherent in nature. Starting from atoms and molecules to a gigantic planet everything vibrates or oscillates when acted upon by a compatible force of alternating nature. In its simplest form the second order differential equation $m\, d^2x/dt^2 + c\, dx/dt + kx = F(t)$ provides the solution in 3D space using Newtonian or classical mechanics (Fig. 2 and 3). However, statistical mechanics is applicable in case of random or stochastic vibrations. The four fundamental forces of nature classified as gravitational, electro-magnetic, strong nuclear forces and weak interaction provide the field of force for interaction with particle or bodies and dynamic forces [1-8].

The vibrations and oscillations are repetitive whereas shock is mathematically defined as an event in space and so a fourth dimension of time is required to define the shock in the 3D space. Computerized time–history programs are used for shock simulation studies. Shock response is expressed in terms of velocity, acceleration or displacement.

The frequency of vibration depends on the mass and the spring force involved and extends from very low frequency (VLF) to optical frequencies (order of 10^{14} Hz.) and further to X-rays and gamma rays. Molecular vibrations involving covalent bonds are in the infrared frequency range. It is interesting to note that the systems involving very large bodies oscillate with very low frequency. The time period involved is very large. For example earthquake is of 0.5 Hz. order and 10 storied building f_n is of the order of 1 Hz. For machine vibrations the fundamental frequency involved is from a few Hz. extended to around 150 Hz. for high speed machines.

Mathematical Formulations and Response Studies
Basic approach to isolation system design calculations are based on
1. Newtonian Mechanics-Particle and lumped masses –Mechanical Systems
2. Statistical Mechanics- Energy based SEA, PSD methods-Aerospace

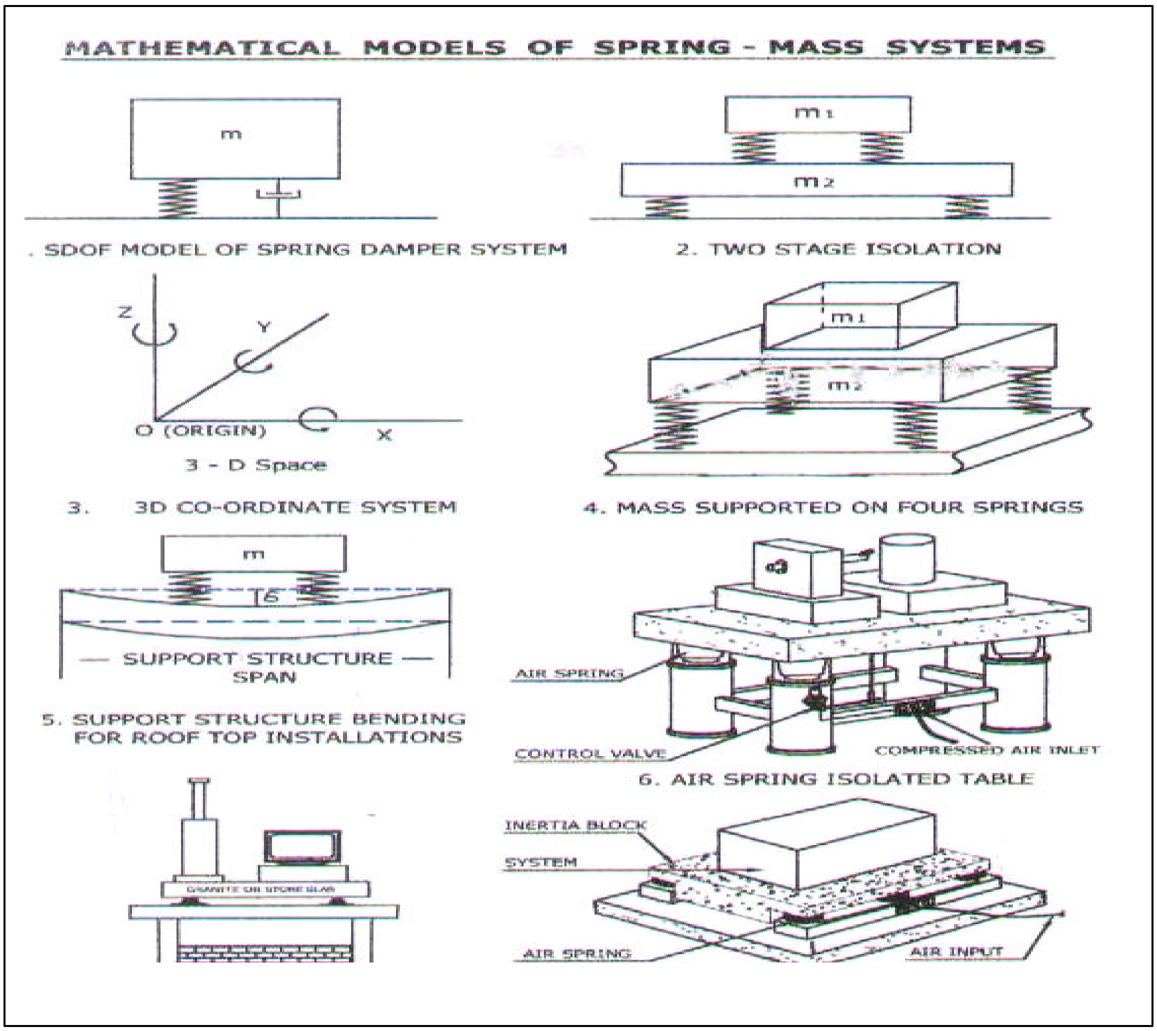
3. Wave Mechanics-Acoustics
4. Quantum mechanics-Atoms and Electro Magnetic Waves
5. Elasto dynamics-Stress wave propagation – Seismic
6. Thermodynamics-Thermal shocks

Design and Selection

The design of the vibration isolation system is machine specific. The following input data is required for the calculation and optimization of the isolators.

Input Data: Requirement for design (i). Mass of the machine, (ii). System center of gravity, (iii). Slowest operating speed, (iv). GA drawing showing the center of gravity position and (v). Input spectra of disturbances in time or frequency domain (FFT) etc.

Calculation: Initial calculations are based on SDOF (Single Degree of Freedom) spring mass model (Fig.1). The optimized selection of isolator is based on previous validated experience, stiffness of the supporting structure, location of the machine (ground floor, basement or roof top installations). Roof top installations are critical in nature and depend on the stiffness and span of the roof top structure. For the installation on elevated structures the structure resonance also has to be configured (Fig. 5). The sample calculation and selection for the fan motor system presented.



For slowest Operating speed = 500 rpm
Vertical isolation efficiency > 98% System natural frequency = 1.8 Hz.
Applications are in laboratories and ground transportations only. Example-Vibration Isolated Table.

Comparison of Various Mountings

Description	Rubber	Steel spring	Air spring
Load-deflection Characteristic	Axially nonlinear Shear linear	Linear	Nonlinear and variable
Load capacity	Max. 200 kN	Max. 360 kN	Max. 240 kN
Natural frequency	3 to 20 Hz.	1.5 to 6 Hz.	1 to 3 Hz
Damping	Average	Low	Low orifice damping
Height adjustment	Using shims / screw		Air pressure
Height regulation	None	None	With height regulating valves
Installation	Simple	Critical design & location	Simple
Maintenance	None	None	Air Supply
Cost	Low	Medium	High
Bulk material properties	Long chain folded polymer	Steel, Helical, spiral form	Air Thermo elasticity

Wire Rope and Cable Isolators

Metal and multidirectional configurations of mounts are suitable for shock and vibration isolation. The load deflection has non-linear characteristics and is widely used for aerospace and mobile applications. Being all metal construction it can be used over a wide range of temperature from -180 + 300 ^{0}C. The damping provided is high in the range of 15 to 20%. In addition wire mesh type of isolators are also used for shock isolation.

CONCLUSION

The application of vibration isolation systems are widespread in almost all facets of our industrial and transportation activities from automobile to space vehicles. The design input spectra of dynamic forces covers from vibrations and shock due to machines and mechanisms, ground vibrations of seismic or micro-seismic nature and speeds in supersonic and hypersonic velocity range. The optimized solutions are system specific and unique. Application range covers from coal crusher and heavy machineries for power generation to latest nano-technology of atomic and molecular dimensions.

1. Nano satellites <10 kg using MEMS technology, (Aerospace applications).
2. Storage memories to quantum dots (QD), (micro electronics and nano-technology). Isolation of such micro level vibration is the futuristic technology scenario.

REFERNCES

1. S. N. Bagchi, Design of Moire Fringe Refractometer-M.Tech. Dissertation submitted, Instrument Design and Development Centre, IIT, Delhi, 1971.
2. Ratish Jain and S. N. Bagchi, J. Metrol. Soc. India, 13 No4 (1998) 43.
3. Ratish Jain and S.N. Bagchi, Proc. Workshop on recent earthquakes, Univ. of Roorkee, May 2001,pp 247–249.
4. Ratish Jain and S. N. Bagchi, Proc. Int. Conf. Fibre Optics Photonics. Vol. II, pp 795-797, Calcutta Dec. 2000
5. S. N. Bagchi, J. Acoustic Soc. India, 28 No.1-4 (2000) 87.
6. Ratish Jain and S. N. Bagchi, Proc. Nat. Conf. Machines Mechanism (NaCoMM), IIT, Kharagpur, Dec. 2001, pp 481-488.
7. Ratish Jain and S. N. Bagchi, Proc. of 12th Sym. Earthquake Eng., IIT Roorkee Vol. 2,Dec. 2002, pp 1543–1549.
8. Ratish Jain and S. N. Bagchi, J. Metrol. Soc. India, 18 No.2 (2003) 211.