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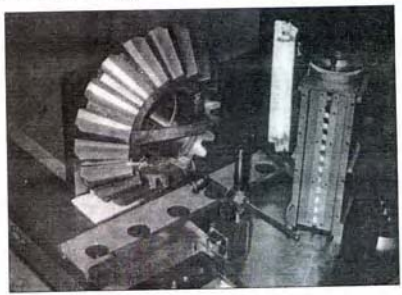

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APPLICATION OF VIBRATION ISOLATION TECHNIQUES FOR HI-TECH METROLOGY LABORATORIES

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ABSTRACT

This is an industrial application oriented presentation of review nature focussing vibration and shock isolation techniques and concept used for isolating even the micro-seismic vibrations in a modern metrology laboratory. The stringent specifications on dimensional tolerances and advances in machining capabilities had to be backed up by a comparable metrological capability. For MEMS (Micro Electro Mechanical Systems), space quality optical devices, Diamond Tooling Machines (DTM) etc involves metrological back up for accuracies of the order of wave length of light "Lambda" using Laser or Optical interferometer methods.

So the structural vibrations of passive nature must be isolated for high-resolution instrumentation. The disturbances are due to running of DG sets, compressors, AC machines, blowers, Lift movement, and heavy vehicle movement on roads or train movement on a nearby railway track. Even the foot traffic movement in the vicinity of the laboratory may cause fringe shift in interfrometric measurements.

An introduction to the various types of Vibrations and shock input forces and the design methodology followed for selection and installation of isolators are described in industrial context. The mathematical calculations for spring stiffness; load optimisation, isolation efficiency and 3D computerized CRMS (Compound Resilient Mounting Systems) program highlighted.

The different types of isolators used in industries are presented. The Air spring systems for low frequency isolation with fn < 2 Hz for sensitive set up and high isolation efficiency focused.

Glimpses of applications in other areas like automobile, aerospace, machines and mechanisms, power plants and Hi-Tech frontier technology areas presented

INTRODUCTION –

With the rapid development and progress in micro machining capabalities, the facilities in dimensional metrology field also developed significantly from micron to nanometer level of molecular dimension order. Optical interferometer, Laser holography and surface topography test set ups are now used in wide range of industries from automobile to aerospace and micro-electronics to micro-optics related fabrication workshops.

Earlier times the precession measurement and quality control laboratories used to be located at a distant area where the ground and acoustic noise disturbances were minimum. But now a day due to fast feedback and interaction requirement for production, the high precession measurement laboratories are situated near workshop activity centre. Also due to logistic requirement and limited space availability, many times the metrological labs are situated in the same building. So the building vibration causes disturbances during experimentation.

In many new Frontier hi-tech areas like MEMS (Micro Electro Mechanical Systems) and Nanotechnology, the requirement for precession and accurate measurement facilities also touched a new dimension. For such accurate measurements, the micro vibrations and micro seismic shocks even create disturbances and inaccuracies in results. The vibration isolation techniques related to metrology laboratories will be highlighted.

FORCES INDUCING SHOCK & VIBRATION –

The interaction of forces of dynamic nature with a particle, or lumped masses induces response as vibration or shock effect. The forces may be broadly catagorised as Fundamental forces of Nature, mechanical forces and biological or biodynamic forces. The magnitude of force has to be of compatible to induce a detectable response. As per unified theory of forces the four fundamental forces of nature are classified as

1. Gravitational
2. Electromagnetic
3. Strong Nuclear Forces
4. Weak interaction.

The opposing forces are damping or drag forces.

SHOCK-

Shock forces are due to explosion, collision or stress wave propagation of mechanical or thermal nature. Starting from big bang to collision of planets, falling of asteroids & meteoroids and hitting the planet surface are some of the examples from cosmology and astrophysics. Earthquake due to seismic forces are also one of the devastating and damaging shock forces of nature. Globally active work is being done to reduce the disastrous effect by isolation techniques focusing hospitals, schools and multistoried buildings in the initial phase.

VIBRATION -

The dynamic force of repetitive nature induces steady state vibration. The forces may be periodic or stochastic in nature or a complex combination of both.

RESPONSE OF DYNAMIC FORCES

Shock excitation is due to sudden pulses of high amplitude and short duration. The input force is defined as half sine, square wave or triangular pulse with time duration.

The response is expressed in terms of

(1) Velocity

(2) Acceleration

(3) Displacement for mechanical systems.

Some of the related examples are as follows: -

1. Atomic & Molecular vibrations -

Related to optical and infrared frequency band of Electro-magnetic spectrum. Subject- Atomic, Diatomic and Polyatomic spectroscopy, photo-acoustic spectroscopy and Electrodynamics and Nuclear Magnetic Resonance (NMR) and Electron Spin Resonance (ESR)

2. Machine vibrations -

IC engines, Jet engines, Turbomachines, DGsets etc. In a laboratory environment the structural vibrations are induced the infrastructure facilities like HVAC machines, compressors, fans & blowers, chillers, refrigeration units and lifts.

3. Aircraft & Aerospace -

Superimposition of aero-engine & acoustic spectrum. at subsonic, supersonic and hypersonic speeds. Vibration isolation required during flight. Shock loading during aircraft landing or turbulent condition flying. Spacecraft and satellite equipment shock isolation protection is required for lift off and stage separation phases. Subject details- Aerodynamics, Acoustic loading, and Avionics, Aero-engines vibration.

4. Fluid flow in pipelines - acoustic noise related to fluid velocity, viscosity and physical dimensional parameters of pipeline. Major subject related to Fluid dynamics.

5. Bio-Dynamics & Human body related effect -

Some of the general effects of exposure to vibrations are: -

(a) Fatigue after long travel by train or bus. (b) Visual acuity of eye and resolution (c) headache and loss of hearing sensitivity leading to deafness (noise) (d) aircraft or jet travel snag. (e) Sea sickness. Since our body organs are flexibly connected different organs have different natural frequency (fn). For example stomach, spine, head knee joints etc.are in lower frequency range and gets excited during long distance traveling road or rail, which in turn causes fatigue. Using Air Spring suspension system (fn < 2Hz.), which isolates even the lower frequencies as compared to metallic spring suspension. This effectively means more comfort and less fatigue.

MATHEMATICAL CONCTEPT AND SOLUTIONS

The basic concept may be visualized easily by using the spring mass model (fig.1a). However in its simplest form it may be represented by a single spring with damper system supporting a consolidated mass M. The representative spring isolator is defined by the spring constant. Spring mass model is initially used to calculate the natural frequency (fn) of the system in SDOF mode for the selection of isolator. Standard Load deflection charts are used for reference in industrial context. The input machine data along with GA drawing is required for the selection of isolators. The overall visualizations and initial parametric selections are based on concepts of (a) FUZZY logic (b) GENERIC logic (c) NUMERICAL ANALAYSIS (d) OPTIMISATION techniques. The mathematical solutions and validation results after installations are in agreement within tolerance (+/-) 10%

TYPES OF ISOLATORS -

1. Viscoelastic material based neoprene/silicon rubber isolators.
2. Metallic spring based -Spring damper systems
3. Wire rope/cable isolators and non-linear systems
4. Air Springs for low natural frequency < 2 Hz

The mathematical formulations and calculations provide guidelines for the basic data related to spring stiffness and damping parameters. The isolators for industrial application are manufactured in different load and deflection ranges. In general isolators are selected from the standard modules to match the requirement.

The isolation systems of visco-elastic material, spring-fluid dampers, helical wire rope systems and air springs are briefed. Air spring systems due to its low Eigen frequency of the order of 2 Hz.are used for designing isolated worktable for sensitive experiments.

METROLOGY LABORATORY -

The objective of isolation in any sensitive Metrology, spectroscopy or microscope laboratory is to improve the resolution at the final recording stage. The relative movement between object plane and image plane cause blurring, diffusion smearing of image or resolution. This is of specific significance when the final detector is human eye or a photographic plate, subjected to a long time exposure.

The isolation systems are in stages

(a) Isolators below sensitive instrument.

(b) Isolation of laboratory floor - Floating floor

(c) Isolation of heavy machines like compressors, DG sets, AC machines and AC ducts and pipelines etc near the laboratory area.

APPLICATION IN OTHER AREAS -

(a) Transportation of Turbo-machines, aircraft jet engines or space vehicles and satellites on trailers.

(b) For heavy machines like DG sets, coal crushers, FD fans, Turbo- generators, centrifuges, forging hammer, presses etc.

(c) For acoustic chambers, anechoic and reverberation chambers, recording studios and Buildings.

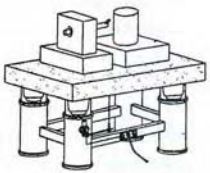
(d) Aerospace and naval ship related applications

(e) Air springs for better comfort in deluxe buses and trains.

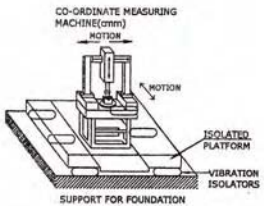
CONCLUSION -

System design and application installation involves a wide-ranging multidisciplinary field combining mathematics, material science, and physical science and manufacturing technology. Since the vibration affects structures, buildings, instruments and human performance as well as comfort level, so it has become necessary to reduce the vibration and shock effects in buildings, railways, automobiles, aircrafts and ships during traveling where the human body response is important. Any modern NVH (Noise Vibration and Harshness) laboratory, metrology laboratory, Micromachining and Microelectronic workshop invariably require a high degree of overall isolation at various stages as described earlier. Hence the infusion of isolation concepts in foundation layout planning in the building to machine installation stage is required to achieve vibration and shock isolation of micro level order.

Vibration Isolation of Sensitive Instruments

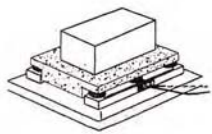


Vibration isolated table for sensitive instruments



Base isolation for C M M

Simple & Economical solution for Microscopes in Schools & College Laboratories

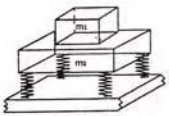


Airspring supported platform for low frequency isolation

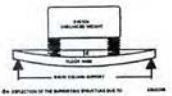
VIBRATION ENGG. APPLICATION DRAWING
DRG. NO. APP-0104002 (NOT TO SCALE)
DRN.VIKASH,CHKD.SNB, DESIGN & DRG. SEC. RPL

ISOLATION OF SOURCES OF VIBRATION IN LABORATORIES & BUILDINGS

(1) Machines on Rooftop or Elevated Structures

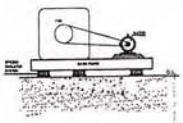


(a) MASS SUPPORTED ON FOUR SPRINGS

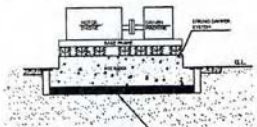


(b) EFFECT OF SUPPORTING STRUCTURE BENDING

(2) Isolation Of Mechanical Systems

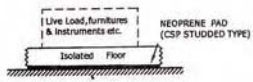


(c) Fan - Motor System

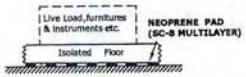


(d) D G Set

(3) Isolation of Floor Vibration



(e) FULL AREA COVERED



(f) PARTIAL AREA COVERED

VIBRATION ENGG. APPLICATION DRAWING
DRG. NO. APP-0104002 (NOT TO SCALE)
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