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INNOVATIVE VIBRATION CONTROL DEVICES USED IN BUILDINGS

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ABSTRACT

Vibration of structure due to earthquake, wind or rotating machines are very common and they are getting complicated nowadays. The impact of these vibrations accounts for loss of live and/or property. The aim of this paper is to study the different innovative devices such as semi active variable stiffness (SAVS), passive piezoelectric vibration shunt control technique, Shape memory alloy, Euler Spring isolator, Gospodnetic-Frisch-Fay beam and roll and cage(RNC) isolator developed recently to control the vibration of buildings. The paper illustrate with the applications, advantages, disadvantages and mechanical properties of these devices. SAVS is a beamlike device which alters its stiffness by using the variations of moment of inertia of an area as it rotates around a normal axis passing through its centroid. The Euler spring isolator is based on the post-buckling dynamic characteristics of the column. The Gospodnetic–Frisch-Fay beam, which is free to slide on two supports has restoring mechanism. Shape Memory alloy reduced the vibration based on the shape memory effect (SME) and pseudo elasticity associated with the thermal-induced or stress-induced reversible hysteretic phase. The roll-n-cage (RNC) isolator in corporate isolation, energy dissipation, buffer and inherent gravity-based restoring force mechanisms in a single unit.

KEYWORDS: Vibration Control, Semi Active Variable Stiffness (SAVS), Roll And Cage(RNC) Isolator, Shape Memory Alloy, Passive Piezoelectric Vibration Shunt Control Technique

INTRODUCTION

The structures made with better techniques and machines in the recent past have fallen prey to earthquakes leading to huge loss of life and property and untold sufferings to the survivors of the earthquake hit area, which has obliged the engineers and scientists to think of improved techniques and methods to save the constructions and structures from the destructive forces of earthquake. In the recent past have provided more evidence of different type of structures under different earthquakes and at different foundation conditions as a food for thought to the engineers and scientists. It gives a birth to different types of techniques to save the structures from the earthquakes.[1**].** Seismic isolation of a structure reduces the transfer to the structure of ground motion produced by an earthquake. Seismic isolation is typically obtained by a damping system acting as base isolation between the structure and the ground. Such damping systems are designed to protect structural integrity and prevent damages and injuries to the occupants by reducing seismic forces and deformations in the structure. Several types of base isolation systems have been proposed and investigated.[2] Friction dampers are often an essential component of these base isolation. Several friction devices have been tested experimentally. Also viscous elastic dampers are often used in base isolation systems. Base isolation concept was coined by engineers and scientists as early as in the year 1923 and thereafter different methods of isolating the buildings and structures from earthquake forces have been developed over the world. Researchers are also working on techniques like SAVS device, dampers using shape memory alloys, roll and cage (RNC) isolator, Euler Spring isolator, Gospodnetic-Frisch-Fay beam, Passive piezoelectric vibration shunt control technique etc. SAVS dampers are additional mass on the structure provided in such way that the oscillations of the structure are reduced to the considerable extent. The mass may be a mass of a solid or a mass of a liquid. Dampers using shape memory alloys are being tried as remedy to earthquake forces. In this system, super elastic properties of the alloy is utilized and there by consuming the energy in deformation at the same time the structure is put back to its original shape after the earthquake. The roll-n-cage isolator is mainly along with a stiff rolling body which is placed in between two stiff circular plates fixed to the isolated objects and the base floor, respectively. Stiffeners used to enhance the behaviour of the metallic yield of the dampers. From its name, it adopts the rolling mechanism to reduce the load path between the isolated object and base.

Due to the advantages of light weight, low-cost and solid-state actuation, piezoelectric materials as actuators and sensors are successfully applied to the vibration control of different kinds of structures. Piezoceramic patches can be easily surface-bonded on a structure without major modification of the original structure or they can be embedded into the certain structures, such as the composites.

Piezoelectric-based vibration control can be classified as active vibration control, passive vibration control and hybrid active-passive vibration control. The deflection curve of a elastic beam forced to deform by three numbers of frictionless symmetrical knife edged supports, was analyzed by Gospodnetic[3] and documented by Frisch-Fay [4].The vibratory behaviour of a Gospodnetic–Frisch flexible beam without any axial constraint, and therefore free to slide on its supports, has been studied analytically and numerically. An Euler spring is column of a spring steel which is squeezed elastically beyond its buckling load. The analysis of deflections of elastic columns after buckling was developed by Euler by using elliptic integrals.

The present paper concerns these six innovative devices (e.g. SAVS, dampers using shape memory alloys, roll and cage(RNC) isolator, Euler Spring isolator, Gospodnetic-Frisch-Fay beam, Passive piezoelectric vibration shunt control technique) and illustrate with force equations, diagrams, methodology, applications, and advantages or disadvantages.

INNOVATIVE SEISMIC ISOLATION DEVICES

Semi Active Variable Stiffness Device (SAVS)

Control of vibrations is a challenging task in various branches of engineering and technology. In recent years, considerable research efforts have been devoted to the development and utilization of semi active structural control systems for vibration reduction applications[5].

A semi active control system generally originates from a passive control system. The attention received in recent years can be attributed to the fact, semi active vibration control systems offer most of the performance characteristics of active systems without requiring large power sources.[6]

An innovative design for a (SAVS) device is presented in this paper. This beamlike device is capable of altering its stiffness in a smooth manner between minimum and maximum levels by using the variations of moment of inertia of an area as it rotates around a normal axis passing through its centroid.[7]

The innovative variable stiffness device proposed in this paper considers the variation of moment of inertia as an area rotates around a normal axis passing through its centroid. The formulations are developed by using the well-known theory of skew bending or unsymmetrical bending of beams. The details are discussed in the following subsections. [8,9] SAVS dampers are additional mass on the structure provided in such way that the oscillations of the structure are reduced to the considerable extent. The mass may be a mass of a solid or a mass of a liquid. In present study, a rectangular cross section is assumed for the beamlike SAVS device. Other cross sections may be used except those sections whose moment of inertia does not change by rotation, e.g., circular, pipe, square, and square-box sections.

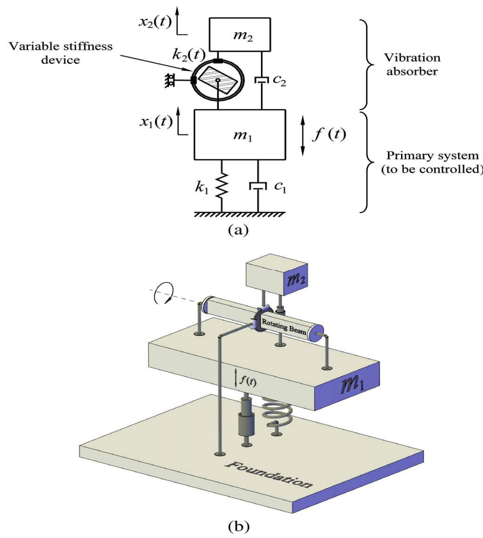


Figure 1: (a) Symmetric Diagram of SAVS; (b) 3D View of the Connectivity of SAVS to Primary and Secondary Masses [10, 11]

The proposed variable stiffness device is established on the issues addressed in the preceding subsection. This device is a fixed-end elastic beam with a rectangular cross section whose rotational degrees of

Freedom around a neutral axis at the supports are released. As a case study, the efficacy of the proposed SATVA for suppression of undesirable transient vibrations during the start-up of a rotating machine is investigated. Consider a vibratory machine equipped with a SATVA. This integrated system can be modeled as a SDOF system, as schematically shown in Figure 1

Applications

In an effort to overcome the disadvantages of the variable stiffness devices, an innovative semi active variable stiffness (SAVS) device is proposed. This beamlike device is capable of altering its stiffness in a smooth manner between minimum and maximum levels by using the variations of moment of inertia of an area as it rotates around a normal axis passing through its centroid. Theoretical expressions for the change of device stiffness as a function of rotation angle are developed underlying the concept of unsymmetrical bending of beams. A SATVA is developed based on the proposed SAVS device. This adaptive vibration absorber is capable of real-time retuning and operates effectively in broadband frequency excitations. A control strategy is used as the tuning algorithm. The effectiveness of the proposed SATVA is demonstrated through a numerical example employing a SDOF model equipped with the SATVA. The results are reported and compared with those of the system fitted with a passive vibration absorber.

Advantages and Some Conceptual Study about SAVS Devices

The primary advantages of this device are the simple structure, low power requirement, ease of design and manufacturing, quick adjustment of stiffness from minimum to maximum, and few moving parts.

A new SATVA is developed based on the SAVS device, which is capable of adjusting its frequency in real time.

The effectiveness of the SATVA for suppression of undesirable transient vibrations during the start-up of a rotating machine with a constant angular acceleration is investigated. It was shown that the SATVA reduces the maximum and RMS displacement response of the primary system by approximately 74 and 67%, respectively. Many other fields of application can be imagined for the presented SAVS device in engineering.

Disadvantages

Smart materials offer an alternative adaptive mechanism that is very suitable for creating variable stiffness devices and have been the subject of recent trends. Although smart materials provide a simple mechanism for altering the stiffness of the spring without many moving parts, they are not capable of producing a sufficient combination of required force and stroke for the application.

Gospodnetic Frisch Fay Beam

The static deflection curve of a thin elastic beam forced to deform by three symmetrical frictionless knife edged supports, was analyzed by Gospodnetic and documented by Frisch-Fay. Since the beam is inextensible, there is no limitation on its deflection, and a closed form solution for the deflection curve was given in terms of elliptic functions. The beam is rigid, there is no limitation on its deflection, and a closed form solution for the deflection curve was given in terms of elliptic functions. Figure 2

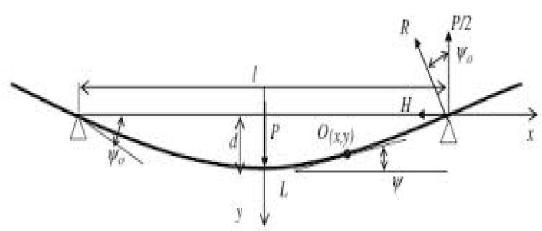


Figure 2: Schematic Diagram of Deflected Under Static Load of a Flexible Beam and Free to Slide at Two Knife Edge Supports

Shows a schematic diagram of a beam similar to the Gospodnetic Frisch flexible beam which is free to slide at two knife edge supports.[12]

Shows a schematic diagram of a beam similar to the Gospodnetic Frisch flexible beam which is free to slide on two knife-edged supports under the action of the load P. It can be used as a resilient isolator between the machinery. The beam can also model a load carrying bearing for pressure pipelines against earthquake ground motion [13].

As the load, P, increases both the beam length, L, and the end slope angle,Ψ_0, increases respectively denotes the displacement at the mid-span, X=l/2. The two supports A and B are knife edged supports are separated by distance l. Note that L and l are only equal when the beam is horizontal without any sag. [14]

The load$\frac{Pl^2}{EI}$, and deflection,$\frac{d}{l}$, are plotted in terms of slope angle $\Psi_0$in Figure 3

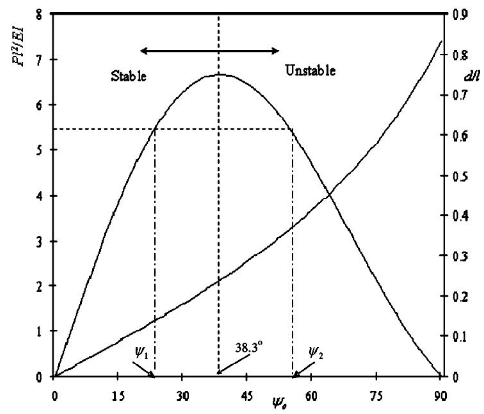


Figure 3: Dependence of Load and Deflection on the End Slope Angle Based on the Exact Solution Showing the Critical Angle $\Psi_0 = 38.3^o$at which the Beam becomes Unstable

It is seen that the maximum load $\left(\frac{Pl^2}{EI}\right)max = 6.672$is at the end slope angle $\Psi_0 = 38.3^o$For every load there are two different values of the slope angle,$\Psi_{01} < 38.3^o$and$\Psi_{02} > 38.3^o$. For all values of the slope angle,$\Psi_{01} < 38.3^o$ the beam strain energy is larger than the work done by the static load, and thus the beam is stable. On the other hand, for all values of$\Psi_{02} > 38.3^o$ the work done of the static load exceeds the corresponding elastic restoring energy and thus the beam enters into the unstable state. For any load greater than the maximum value$\frac{Pl^2}{EI} > \left(\frac{Pl^2}{EI}\right)max$the beam becomes unstable.

Dynamic Behaviour of the Beam

The vibratory behaviour of a flexible beam without any axial constraint, and therefore free to slide on its supports, has been studied analytically and numerically. A polynomial of the eleventh-order to accommodate the entire range of beam deflection (until it loses its resilient capacity) is developed. The dynamic behaviour of the beam in the absence and the presence of external excitation is studied for the stability of fixed points and response characteristics. For an unperturbed beam, we find that the beam exhibits periodic orbits for all initial condition that result in an initial energy smaller than the maximum restoring elastic energy.

Applications

The beam Possess a homo-clinic orbit for the critical initial energy, equivalent to the maximum restoring elastic energy. Above this energy level the beam slides without return.

Under external sinusoidal excitation, safe basins of attractions have been numerically estimated for different values of excitation level.

Currently, the random response characteristics of the beam under random excitation is being studied for the response probability density function and other statistical functions. Equally important is the effectiveness of the beam as a nonlinear vibration isolator under deterministic and stochastic excitations, which is also being studied.

Euler Spring Column Isolators

An Euler spring is a column made of spring steel material that is compelled elastically beyond its buckling load. The research of finite deflections of prismatic elastic columns after

Buckling was developed by Euler using elliptic integrals. It was demonstrated that the neighbourhood of an equilibrium state could be explored analytically by means of a perturbation approach. The most important problems include the post-critical behaviour, which involves stability analysis in the vicinity of bifurcation points. Schmidt and Da Deppo presented an assessment of the classical work on large deflection of non-shallow arches.

Traditionally, buckling is regarded as a failure criterion of structures. However, the post-buckling behaviour of flexible rods is of practical interest if one considers the resulting axial displacement. Buckling loads and post-buckling behaviour are very important to structural design.

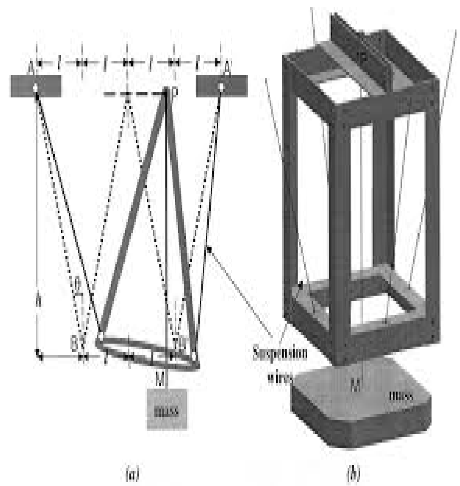


Figure 4: Schematic Diagram of the Roberts Linkage Isolator with a Suspended Load from the Wire PM [15]

The size and shape of the elastic curve in the post-buckling state is referred as elastic. The stability theory of buckled and post-buckled elastic structural elements under static load is given well in many Refs. [16]. It was determined that the part of an equilibrium state given analytically. The buckling is a failure criterion of the structures, the post-buckling characteristics of flexible rods is of basic interest if one consider that the resulting axial displacement. Buckling loads and post-buckling characteristics are very important to structural design. [17]

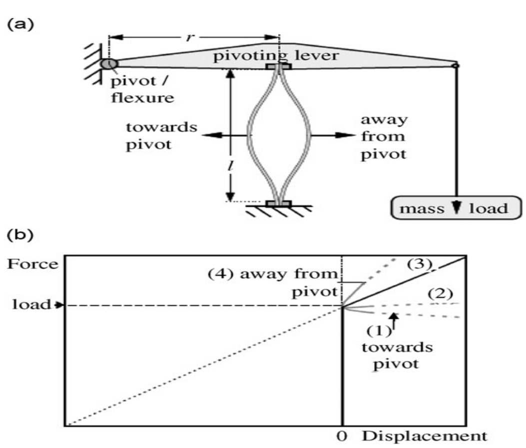


Figure 5: Post-Buckling Euler Beam Vertical Isolator: (a) Euler Column Isolator Showing its Mount and its Buckling Columns is Away from Each other, (b) force–Displacement Relationship: 1—low or Negative Spring Stiffness, 2—Reduced Spring Stiffness, 3—Linear Spring Stiffness and 4—High Spring Stiffness

Applications

One of the recent applications of the Euler spring is its utilization as a vertical isolator. A major advantage of the Euler spring is that it stores negligible static energy below its working range thereby minimizing both the stored elastic energy density and the spring mass required to support the suspended test mass. This feature makes Euler springs an excellent candidate as a vertical isolator.

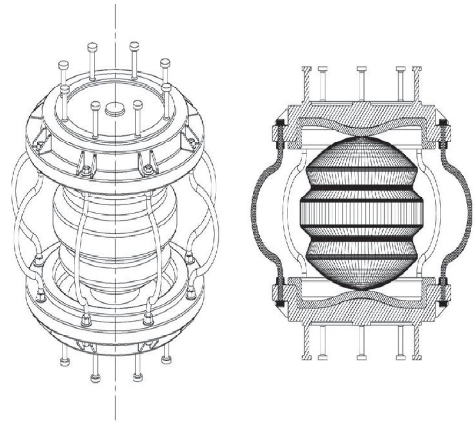
A schematic diagram of the Euler spring isolator is shown in Figure 5(a). As the flat spring blade starts to buckle, the bulk of the blade can be offset in either one of two directions. If it is mounted in the pivoted support structure shown in Figure 5(a) then the effect of offset in one direction is markedly different from the effect of offset in the other direction. If the offset occurs towards the pivot then very low (and even negative or unstable) spring stiffness is obtained as indicated by curve 1 shown in Figure 5(b).

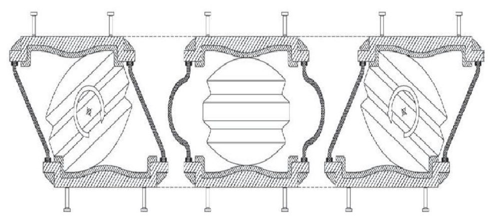
On the other hand, if the offset occurs away from the pivot then much higher spring stiffness is achieved as indicated by curve 4 in Figure 5(b). If a pair of matched spring blades is employed with one going in each direction, then the spring stiffness shown by curve 3 is graphically indistinguishable from what it would have been if it had been constrained to move linearly rather than in the rotating support structure actually employed.

It follows that by choosing an appropriate ratio between the bending stiffness of the blade(s) moving towards the pivot to those moving away, a suitable mix of curves 1 and 4 can be reached yielding a much reduced spring stiffness as given by curve 2. The next sub-section describes the elastica and axial stiffness of the Euler column.

Roll n Cage Isolator

The RNC (see Figure 6) is mainly constructed by a stiff rolling body (1) placed between two stiff circular plates (2,3)which fixed to the isolated object and the base floor. The connection between these three parts takes place through less stiff plates (4,5). Metallic yield dampers (6) are outlined and represented around the rolling body to provide stiffness and damping. Stiffeners (7,8) are used to increase the characteristics of the metallic yield dampers. The concept and the operation principles are stated in a copyright. The roll-n-cage isolation bearing adopts the rolling mechanism to reduce the load path between the isolated object and its base. Such rolling mechanism gives minimum degree of object-base coupling as it requires lower force. To avoid the side effects in the RNC isolator is provided with a number of metallic yield dampers. They are sized and arranged as shown in Figure 6 to provide enough addition during deformation and to show the same shear strain in any horizontal direction. The geometry is designed to prevent vertical displacements of the superstructure as shown in Figure 6(c–e), what prevents vertical accelerations. This is get by means of the actually designed curvatures of the inner face of the stiff upper and lower plates (2,3) and has the constant thickness of the less stiff neoprene plates (4,5) shown in Figure 6(b). Such design shows exactly the vertical elevation of the isolated superstructure for rolling of the elliptical structure (1)





Rolling + Damping + Zero uplift +Buffer +Gravity Based Re-Centering Mechanism

Figure 6: (a) 3D view of the Proposed RNC Isolator, (b) Partial Sectional Elevation of the RNC Isolator, (c) Extremely Deformed Position to the Left of the RNC Isolator, (d) Neutral Position of the RNC Isolator, and (e) Extremely Deformed Position to the Right of the RNC Isolator

keeping the same vertical offset between the upper and lower plates (2,3) as elaborated in Figure 6(c–e) by dashed horizontal lines. This guarantees that the RNC isolator does not improve the vertical component of the acceleration referred by international codes.

Mechanical Characteristics

The general-purpose finite element code ANSYS Multi physics has been applied to enable computer-aided design and testing of the RNC. For configuration of the RNC system, the following characteristics are followed:

- Design and modeling of the individual components of the RNC isolation system: rolling body (1), upper and lower stiff bearing plates (2,3) and less stiff plates(4,5), metallic yield dampers(6) and bearing plates stiffeners(7,8).
- The individual components to set up the whole isolator and identification of all contact conditions among them.
- Definition of the materials for each component.
- Selection of finite element type and mesh size according to behaviour of the component materials.
- Assignment of the boundary conditions and through the nodal constraints and nodal restraints.

Working Principle & Applications

The RNC is an anti-vibration device is designed to insert between the building & the ground to reduce the earthquake. Rather than increasing the seismic resistance capacity of structures, the device is based on the concept of decreasing seismic demand. At the end it incorporates isolation, energy dissipation, buffer and restoring force mechanisms in a single unit. It helps multi-directional isolation by dissipating energy and restraining uplift and maximum horizontal displacements. It improves vibration isolation and other systems. It also used to protect motion-sensitive equipment, including measuring devices, precision machines and equipments of the type found in laboratories and operating rooms, as well as museum pieces, antiquities stored in buildings.

Advantages

It provides multi-directional isolation by dissipating energy and restraining uplift and maximum horizontal displacements.

It improves vibration isolation, which up until now has been achieved by using different types of elastomeric bearings, including high-damping neoprene bearings and lead-plug rubber bearings, and by means of friction pendulum and other systems.

Aside from reducing motion induced in buildings and bridges by earthquakes and other vibration sources the team says the device can also be used on a small scale. It can be used to protect motion-sensitive equipment, including measuring devices, precision machines and instruments of the type found in laboratories, research canters and operating rooms, as well as museum pieces, antiquities, and other valuable objects stored in buildings.

Shape Memory Alloy (SMA)

A shape-memory alloy is an alloy that signify its original size and shape and returns to its pre-deformed shape when heated. It has a lightweight, solid-state alternation to conventional actuators systems. Shape-memory alloys used in industries including automotive, biomedical etc.

The main 2 types of shape-memory alloys are copper-aluminium-nickel, and nickel-titanium (NiTi) alloys but SMAs can also be created by zinc copper, gold and iron. Though iron-based and copper-based SMAs, such as Fe-Mn-Si, Cu-Zn-Al and Cu-Al-Ni, are available and cheaper than NiTi, NiTi based SMAs are preferable for most applications due to their stability and superior thermo-mechanic behaviour. SMAs exist in two different phases, like three different crystal structures (i.e. twinned martensite, detwinned martensite and austenite) and six possible transformations. NiTi alloys change from austenite to martensite upon cooling; M_f is the temperature at transition to martensite completes upon cooling. Same as during heating A_s and A_f are the temperatures at which the transformation from martensite to austenite starts and finishes. Several use of the SME may lead to a shift of the characteristic transformation temperatures. The maximum temperature at which SMAs can no longer be stress induced is called M_d. The change from the martensite phase to the austenite phase is only dependent on temperature and stress. While martensite can be formed from austenite by rapidly cooling carbon-steel, this process is not reversible, so steel does not have shape-memory properties. SMA is typically asymmetric, with a relatively fast actuation time and a slow de--actuation time. A number of procedures have been proposed to reduce SMA deactivation time.

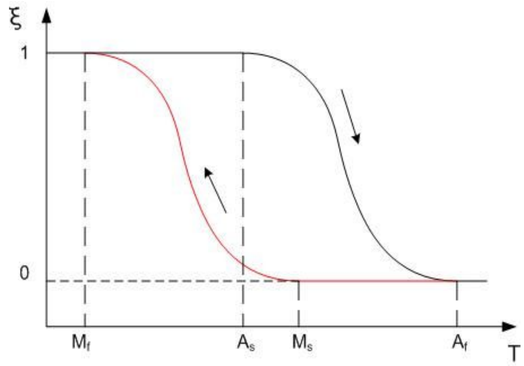


Figure 7: In this Figure, ξ(T) Represents the Marten Site Fraction

Applications

- SMAs find a various uses in civil works such as bridges and buildings. Such a application is Intelligent Reinforced Concrete (IRC), which integrates SMA wires installed within the concrete. These wires can raise cracks and contract to heal macro-sized cracks. Another use is active tuning of structural natural frequency using SMA wires to damp vibration.
- Boeing, Aircraft engines are developed the Variable Geometry Chevron using a NiTi SMA. Such a variable area fan nozzle (VAFN) draw would allow for such and more effective jet engines in the future. SMAs are being transverse as vibration dampers for launch vehicles and jet engines.
- The large amount of hysteresis observed during the super elastic effect allow SMAs to dissipate energy and damp vibration. SMAs also propose potential for other high shock uses such as ball bearings and landing gear. There is also strong interest in using SMAs for various actuator applications in jet engines, which reduce their weight and boost efficiency.

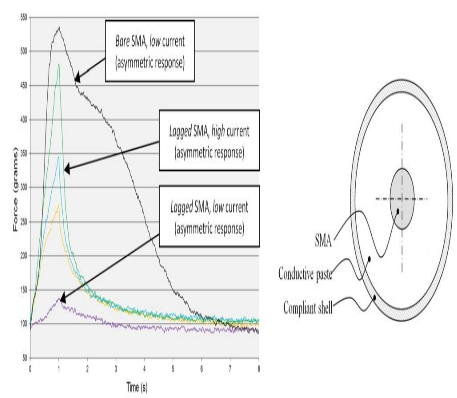


Figure 8: Comparative Force-Time Response of Bare and Lagged Ni-Ti Shape Memory Alloy

The piezoelectric Shunt Damping Technique

The piezoelectric shunt damping technique based on the direct piezoelectric effect has been known as a simple, low-lost, lightweight, and easy to implement method for passive damping control of structural vibration. In this technique, a piezoelectric material is used to transform mechanical energy to electrical energy. The term “piezo” is equated from the Greek word for pressure. Piezoelectricity is a technique presented by non-Centro symmetric crystals whereby an electric charge is induced in the material on the application of a stress., Contrarily it is the growth of an induced strain which is directly proportional to a electric field. The piezoelectric effect was discovered by Jacques and Pierre Curie in 1880.[18] They found that if certain crystals were subjected to mechanical strain, they became electrically polarized and the degree of polarization was proportional to the applied strain. The Curies also discovered that these same materials deformed when they were exposed to an electric field. This has become known as the inverse piezoelectric effect. For the Piezoelectric effect to occur, the absence of a centre of symmetry is necessary. In addition to the piezoelectric effect, piezoelectric materials exhibit a pyro-electric effect, according to which electric charges are generated when the material is subjected to changing temperature.

Properties of Piezoelectric Materials

In piezoelectric materials integrate the elastic and electrical behaviours; mechanical and electrical parameters be involved in component relations. The electrical relation for an unstressed non-piezoelectric medium under the influence of an electric field can be expressed as

$$D = \epsilon E \tag{1}$$

where ***D*** is the electric displacement, ***ϵ*** is the permittivity of the medium and ***E*** is the electric field strength.

The mechanical relation for the same medium at zero electric strength under the action of an applied stress will be

$$S = sT \tag{2}$$

Where ***S*** is strain, ***s*** is the compliance of the medium and ***T*** is stress.

For a piezoelectric medium, the interaction between electrical and mechanical variables can be described by following constitutive equations:

$$S = S^E T + dE \ldots\ldots (3) D = dT + \epsilon^T E \tag{3}$$

where ***d*** represents the piezoelectric constants, the superscript ***E*** indicates a zero, or constant, electric field; the superscript ***T*** indicates a zero, or constant, stress field.

The direction of positive polarization is usually chosen to coincide with the Z-axis of a rectangular system of crystallographic axes X, Y and Z. The direction of X, Y and Z are represented by 1,2 and 3 respectively. The shear forces about these axes are represented by 4, 5 and 6 respectively. After the poling process, the piezoelectric material is transversely isotropic in the plane normal to the poling direction.

In the converse piezoelectric effect, the piezoelectric material will generate a mechanical Strain in response to an applied electric field, as described in equation (1).

The Piezoelectric material function as an actuator due to the converse piezoelectric Effect, as shown in Figure 9.

In the piezoelectric effect, the piezoelectric material Will initiate an electric charge when it subjected to mechanical stress, as described in Equation (2). The piezoelectric material can behave as a sensor due to the direct Piezoelectric effect, as shown in Figure 9.[19]

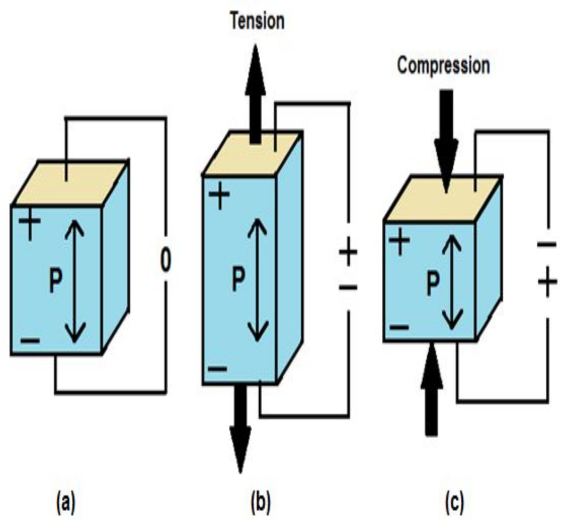


Figure 9: Piezoelectric Material as an Actuator

Advantages

At present, the most effective piezoceramic material is Lead Zirconate Titanate (PZT). The lionization of PZT is due to its strong Piezoelectric effect and high Curie point, as well as the maximum range of properties. PZT has the following advantages:

- Repeatable nano-meter and sub- nano-meter sized steps at high frequency can be achieved with PZT because they derive their motion through solid state crystal effects. There are no moving parts.
- PZT can be designed to move heavy loads (several tons) or can be made to move lighter loads at high frequencies.
- PZT acts as a capacitive load and requires very little power in static operation, Simplifying power supply needs.
- PZT requires no maintenance because they are solid state and their motion is based on Molecular effects within the ferroelectric crystals.
- Vibration is of important concern of many engineering systems, from machine tools to flexible structures in aircraft. In most cases, vibration is undesirable and requires attenuation or vibration suppression. Due to the advantages of light weight, low-cost and solid-state actuation, piezoelectric materials as actuators and sensors are successfully applied to the vibration control of different kinds of structures.

CONCLUSIONS

Based on the understanding of innovative base isolation devices discussed above, the following conclusions can be made.

- The study and conceptions of a SAVS device is presented. The primary advantages of the device are the simple & easy structure, low power requirement, in case of design and fabricating, quick salvation of stiffness from minimum to maximum, and few moving parts. A SATVA is proposed based on the SAVS device, which is capable of maintaining its frequency in actual time.
- Shape memory alloys exhibiting super-elastic effect possess characteristics that make them ideal for applications in passive control of seismic response of buildings. Innovative steel connections with SMA copper-based rods were evaluated. In order to verify the super-elastic effect, isolated rods were subjected to static monotonic and dynamic cyclic tests. The shape memory effect (SME) enables martensite Nitino materials to be used as actuators and also enables their applications in active and semi-active controls of civil structures.
- A seismic isolation bearing proposed an concept the ideal isolation. It is referred to as RNC isolator and named after its operation principle. The RNC integrates several passive techniques to allow disassociating between the isolated object and its base during earthquakes. Then, it turns back to its neutral position before excitation without crossing a predetermined maximum displacement. The RNC is elaborated, modelled, characterized and subjected to extensive numerical assessment to check its efficiency.
- Due to their advantages of low cost, quick response, light weight, and solid-state actuation, piezoceramic materials are used as actuators and sensors in wide range of fields. Active vibration control and structural health monitoring using piezoceramic materials are investigated in this dissertation.
- The active behaviour of the beam in the absence and the presence of external excitation is studied for stability of fixed points and response behaviours. For a fixed beam, we find that beam exhibits cyclic orbits for all initial conditions that results in an initial energy smaller than the restoring elastic energy. The beam goes through a homo clinic path for the critical initial energy, equivalent to the maximum restoring elastic energy. Above this energy level the beam slides but not return. Recently, the random response behaviours of the beam under random excitation is being studied for the response probability function.
- Euler springs isolator designed at low frequency level to isolate excitation signals such as gravitational waves. Extra-low-frequency isolators include the folded pendulum isolator, the X-pendulum isolator table, and the conical pendulum. Efforts for cutting of the resonant frequency such as magnetic anti-spring, torsion crank linkage, and geometric anti-spring have been drawn. The analyses of isolators were based on elastic and axial stiffness of the Euler column. So it needs to introduce the exact analysis of the elastica and stiffness & has been also used for vertical vibration isolation at low frequency.

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NOTATIONS

- beam length, L
- end slope angle, Ψ_0
- The critical (Euler) buckling load, P_E
- M_f = temperature at which the transition to marten site completes upon cooling
- A_s, A_f = temperatures at which the transformation from marten site to austenite starts and finishes
- ***D*** **=**electric displacement
- ***€*** **=**permittivity of the medium
- ***E*** = electric field strength.
- ***S*****=** strain
- ***s*** = compliance of the medium
- ***T*** = stress
- ***d*** = piezoelectric constants
- Lead Zirconate Titanate (PZT)

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