Review: Reducing Vibration Amplitude with Parametric Optimization and an Efficient Dynamic Vibration Absorber for a Supported Beam

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ABSTRACT

The primary vibrating system of the supported beam type, employed in numerous places such as bridges and double-beam constructions, has its theoretical natural frequencies and Mode shape specified. It is possible to lessen beam vibration and assess the efficiency of tuned vibration absorbers on a beam structure by determining the location and quantity of dynamic vibration absorbers (DVA) on a supported beam. When DVAs are present, the vibration amplitude lowers; the reduction amount depends on the number and location of DVAs. Additionally, the Vibration of the structural beam can be affected by the connected DVAs. Connecting the DVA at the optimal location of the vibrational peak is crucial, and it depends on the vibration modes. Harmonic analysis determines the harmonic response for external excitation. Finally, the operating conditions of the primary structure or equipment can affect the performance of the DVA. For instance, if the immediate structure experiences varying loads or forces, the DVA must be designed to accommodate these changes.

Keywords: Dynamic Vibration Absorber, Finite element Method, Single DVA, Multi-DVA, Mass, stiffness, damping ratio, amplitude.

INTRODUCTION

Resonance, wear, and excessive Vibration of one component have caused several system failures and performance shortfalls [1]. Most vibrating structures have specific frequencies at which they oscillate with greater intensity. These frequencies are referred to as the structure's inherent or resonance frequencies. Even a minimal periodic driving force can result in high-amplitude vibrations at these particular resonance frequencies. The building will start shaking a lot when resonance occurs. The DVA, a passive vibration control device, is frequently used to dampen Vibration. The idea of DVA is to eliminate Vibration using counter-back movements. A structure's DVA will react by creating some force when some force is applied to it.

Dynamic vibration absorbers (DVAs) have recently been extensively studied as a highly effective solution for controlling vibrations in various engineering applications. DVAs are passive devices attached to a vibrating structure to reduce amplitude and improve stability. Dynamic vibration absorbers (DVA) have continuously increased usage in primary and secondary applications for vibration attenuation of real-life applications owing to their superior functions, ease of installation, and low unit cost, as mentioned previously.

Based on this, numerous studies have investigated the effectiveness and performance of DVAs in various applications, including mechanical and civil engineering, aerospace, and automotive industries. Based on this, DVA has attracted many research workers and has been considerably improved to achieve realistic results.

Despite the significant progress made in DVA research, some challenges still need to be addressed. For instance, the optimal design of DVAs is still an active area of research, with many studies focusing on finding the optimal mass and stiffness of the device [2]. In real-world applications, various factors affect the effectiveness of DVAs, such as damping level, excitation type, and DVA mounting location [3]. The study of literature on DVA is essential for engineers and researchers who want to design and implement effective vibration control systems. It helps them to understand the concept, optimize the design, evaluate the performance, and choose the best parameters for a given application. It also allows them to stay up-to-date with the latest advancements in the field and consider their designs' environmental and safety impacts.

Operational and modal testing were used to evaluate the excessive vibration levels. Next, using the innovative modal superposition approach, a model of the vehicle body with several DVAs is constructed. It is found that a strong peak at the low frequency is dominated by a single mode, which can be attenuated with under-frame equipment as a single DVA. Several local modes contribute in the frequency range of 30 to 35 Hz and are controlled by multiple DVAs. The best parameters for these DVAs are investigated, including mass, location, and natural frequency [4]. Transient and free vibration investigations were presented using the advanced finite element method for a functionally graded Timoshenko beam (FGM). The governing equilibrium equations and boundary conditions (B-Cs) were established using the Hamiltonian principle.

Furthermore, the impacts of the mass distribution and continuous stiffness of the (FGM) beam were thoroughly investigated [5]. The dynamic studies of a functionally graded beam were given. The beam's governing equations are found using the displacement field established by Timoshenko beam theory, and they are subsequently solved using the advanced finite element method based on Hamilton's principle. The beam is considered to be a boundary condition to be free-climbed (F-C) [6]. The dynamic analysis of a fluid in a pipe that is stiffened by a linear spring was studied using the advanced finite element method. The effects of spring location and stiffness increase (linear spring) were thoroughly investigated.

Additionally, consideration was given to how flow velocity affects the dynamic stability of the system [7]. To lessen the responses of vibration systems, inserter-based dynamic vibration absorbers, or IDVAs, have been widely deployed. It investigates understudied applications to the nonlinear system. A generalized harmonic transformation is used to the nonlinear system's random response to examine it and determine the relationships between the nonlinear main system's and the IDVA secondary system's responses. It also reveals that the IDVA's effectiveness in reducing responses is resilient to both the random excitation's strength and the primary system's nonlinearity [8].

2. REVIEW OF LITERATURE

2.1 BEAM WITH SINGLE DVA:

A precise and effective method for identifying the nodes and antinodes of a complex structure has been developed [9]. The technique involves adding a virtual component, such as a grounded spring or a lumped mass from mythology. Doing so lets us observe how the virtual component's location or coordinate affects the constructed system's free Vibration. Four simple systems with precisely determinable node and antinode locations are first analyzed to validate the proposed identification method. The systems under investigation were based on a uniformly cantilevered Euler-Bernoulli beam with a single lumped attachment at its free end, a lumped mass, and a grounded torsional and translational spring.

It provided a broad evaluation of the effectiveness of linear and nonlinear dynamic vibration absorbers (DVAs) in addressing moving loads or vehicles. A moving load or vehicle was used to excite a supported linear Euler-Bernoulli beam and a DVA linked to the beam to reduce vibrations. The results showed that DVAs with nonlinear stiffness and greater power were more successful than linear ones in lowering the maximum beam deflection for the test situations considered. However, those with incrementally linear stiffness were the best DVAs for moving loads and vehicles [10]. Lattice system simulation shows elastic metamaterial with a low-frequency passband, where wave propagation is limited to the passband [11]. Two kinds of double passband elastic metamaterials have been designed. The locally resonant-type metamaterials exhibit outstanding wave attenuation performance in the frequency range between the two passbands. In contrast, the diatomic-type metamaterials perform well at low and high frequencies. When designing band-pass filters for this model, it is recommended to use a structure with the same mass at both ends. [12] innovative inverter-based dynamic vibration absorbers (IDVAs) were presented to improve the passive DVA's performance. Firstly, by comparing the inserter with DVA at different sites, several distinct IDVAs are shown. Next, the closed-form optimal parameters of six specific types of IDVAs were found, utilizing the conventional fixed-point theory as a foundation. The inserter in the grounded DVA (IR2) linked to the earth has the best vibration absorption capability, according to the comparisons between the IDVAs.

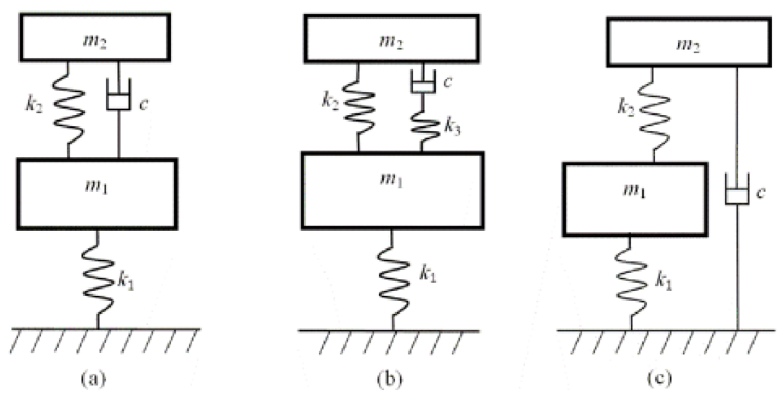

Fig.(1): models of DVAs; a)The type by Den Hartog;(b) Asami; (c) Ren. [12].

Presented the development of a nonlinear dynamic vibration absorber (NDVA) with negative stiffness to broaden the bandwidth and suppress resonance in vibration absorption [13]. A magnetic negative stiffness spring (MNSS), made up of three magnet rings connected in parallel with a mechanical spring and arranged in an attractive pattern, was installed on the NDVA. The NDVA was attached to the primary mass to construct the coupled system's dynamic equations following an analysis of the magnetic force and MNSS. The averaging method was used to analyze the emotional responses. An iterative algorithm was proposed for parameter optimization to achieve optimal vibration absorption performance of the NDVA and reduce time consumption.

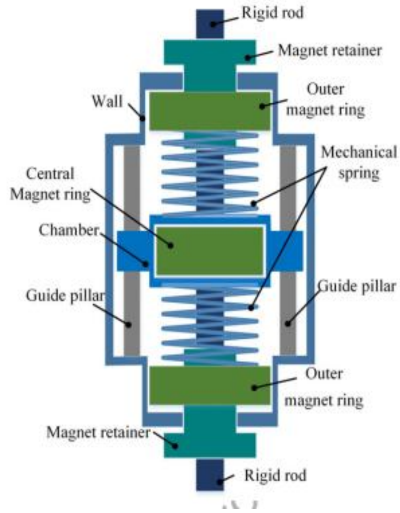

Fig.(2). NDVA model [13].

The presented function for the DVA design is built using Den Hartog's equal-peak approach, and the design is expressed as an optimization problem [14]. The DVA settings are chosen to reduce the primary system's reaction to base motion or harmonic force. Provide a frequency response curve (FRC)--based computational approach that updates the absorber's settings by minimizing the goal function.

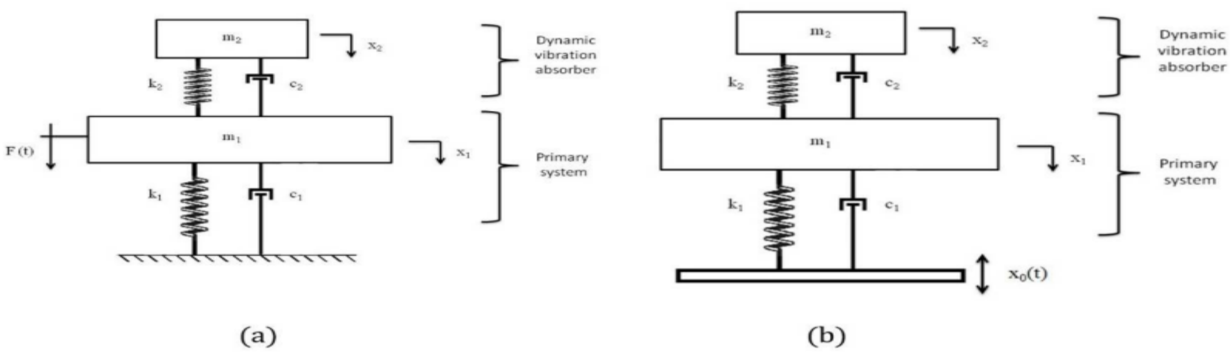

Fig.(3): (a) system of force excitation and (b) motion excitation [14].

The spring and un-spring masses were examined to see how they affected the passengers' root-mean-square vertical acceleration to determine the ideal value for the damping coefficient. The NDVA was attached to the primary mass to create the coupled system's dynamic equations after the magnetic force and stiffness of the MNSS were examined. Increasing the sprung mass in proportion to the unsprung mass raises the optimal damping coefficient value by 131.5 Ns/m but does not change the root-mean-square value per the acquired data. On the other hand, for each increase in the sprung mass, the root-mean-square value increases by 0.005 m/s^2[15].

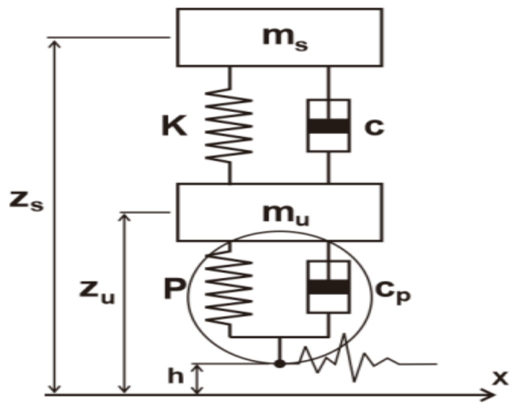

Fig.(4): Model of a quarter automobile with two degrees of freedom[15].

They investigate two configurations of negative stiffness dynamic vibration absorbers (NS DVA). There are two techniques for optimizing the parameters of absorbers - fixed points theory and stability maximization criteria. By calculating the mechanical stiffness ratio to the N.S. of the central system, analytical solutions to the ideal parameters of NS DVAs can be obtained. If NS DVAs are modified using fixed points theory, the optimal negative stiffness ratio within the stable zone can be found. Both harmonic and free vibration situations are simulated numerically. According to simulation results, the linked system's vibration control effectiveness may be significantly enhanced by adding negative stiffness by extending the frequency span of vibration suppression and lowering the peak [16].

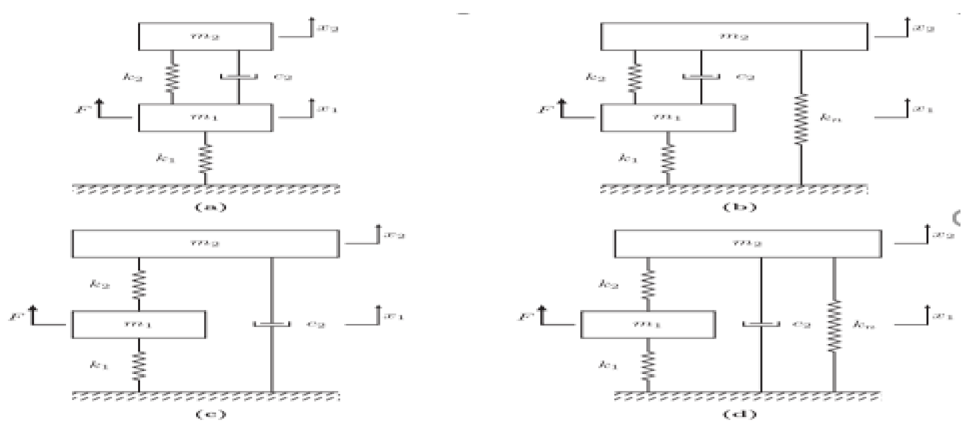

Fig. 5. Four types of absorbers under direct force excitation: (a) DVA-I; (b) NSDVA-I; (c) DVA-II;

Determined the best course of action for this hysteretic ally-damped DVA. It is presumed that structural damping, which is amenable to hysteretic damping, also exists in the primary system. The DVA was optimized using three criteria: stability maximization, H2

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optimization, and H∞ optimization. The researchers have successfully discovered exact algebraic solutions for the stability maximization criterion and the H∞ optimization. Simultaneous equations involving six unknowns were used to meet the H2 requirement and find their numerical solutions [17].

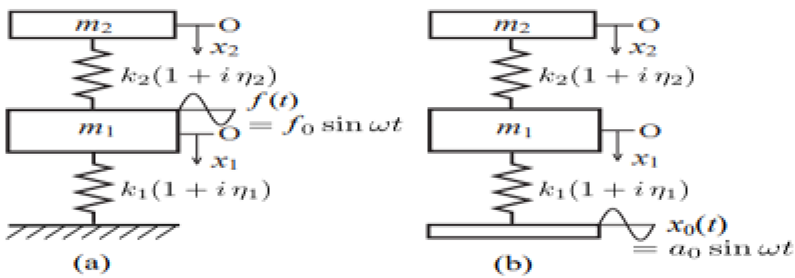

Fig. 6: Systems with hysteretic damping that are subjected to an analytical mode (a) force and (b) motion excitation [17].

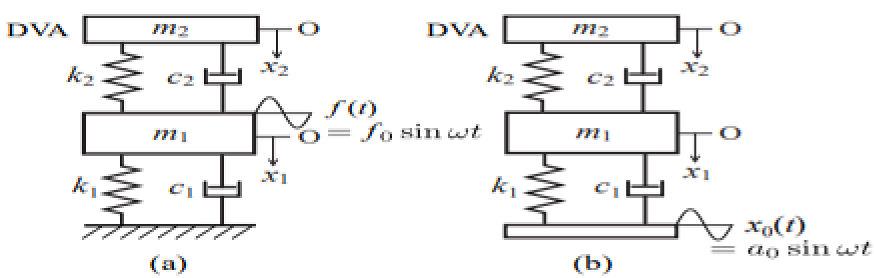

Fig. 7: Systems with hysteretic damping that are subjected to an analytical mode (a) force and (b) motion excitation [17].

They investigated using a DVA to reduce the overall vibrations of a fixed-fixed Euler-Bernoulli beam subjected to forced excitation. The theoretical solution is used to determine the optimal resonance frequency of the DVA to minimize Vibration to a large extent. An experimental test confirmed the academic results, which revealed that a single DVA may theoretically lower amplitude by 80–85% and practically by 75–80%. It was noted that the DVA locations are a critical factor in the vibration response of the beam. In addition, vibration reduction was at its maximum when the DVA was close to the maximum displacement point [18].

2.2 BEAM WITH MULTI- DVA:

Longitudinal metamaterial bars were investigated as elastic wave absorbers for controlling vibration wave frequencies [19]. A cantilever bar of length l m with different boundary conditions was studied. Several unit cells with springs and masses attached to keep the bar in place served as a model for the elastic bar. The time response due to the external excitation was determined theoretically. Based on integration and finite difference, the results demonstrate that discrete unit cell models are effective only for elastic waves with wavelengths much longer than the unit cell length. Additionally, it was found that the concept of conventional mechanical vibration absorbers served as the basis for developing a metamaterial-based adjusted absorber. Negative effective mass and opposing practical stiffness principles were discussed as well.

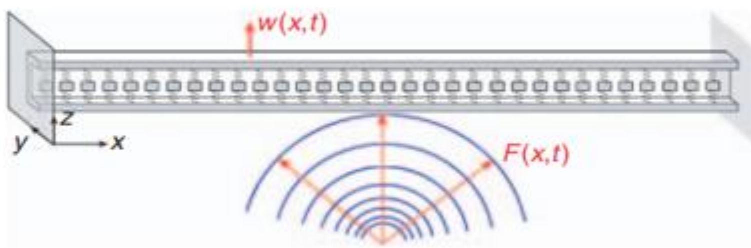

Fig.(8): An isolated/absorbed vibration metamaterial beam [19].

They analyzed the dispersion curves of a mass-in-mass lattice system with multiple resonators. The results showed that adjusting the spring constant and internal masses' size could vary the frequency and dynamic responses [20]. Using empirical measurement, they looked into the transverse Vibration of an F-F end beam connected to DVAs. It comprises a flexible beam with two symmetrical masses on either side. An accelerometer is used to measure the amplitudes and natural frequencies of the beam's vibration response through experimental investigation to determine the transverse Vibration of an F-F end beam connected to the DVA. An electric shaker transversely excites the harmonic excitation of one side of the beam. The absorbers are then attached, and the beam amplitudes are compared and discussed before and after the connection. The experiment's results demonstrated that by absorbing the beam vibration, the DVA significantly decreased the amplitude of Vibration of the beam structure [21]. This work examined the transverse Vibration of an F-F end beam using experimental measurement [22]. The dynamic vibration absorber (DVA), comprising a flexible beam with two masses positioned symmetrically on either side, is analyzed and designed.

Additionally, the classical theory formula is covered. The DVA has dramatically decreased the primary mass's amplitude response at the desired frequency and investigated analytically the response of a one-dimensional metamaterial for vibration dissipation that

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utilized local resonances to filter the excitation of the low frequency. An experimental investigation was also illustrated to check the validity of the analytical modeling. An extra nonlinear spring was used to study the nonlinear behavior of resonance. By applying a constant factor, the theoretical findings have been adjusted to match the driving amplitude of the experimental system. [23].

They introduced the dynamic vibration absorber (DVA) theory, which controls car body vibration in high-speed electric multiple units (EMU). The equipment installed on the chassis was viewed as a DVA, and the automobile body was modeled as an Euler-Bernoulli beam [24]. Theoretical research is done on the impact of equipment suspension characteristics, such as mass, mounting location, damping ratio, and suspension frequency, on the flexible vibration reduction of the automobile body. The equipment and body of the car were modeled to respond to the observed track excitation condition using a three-dimensional coupled rigid-flexible vehicle system dynamics model. It highlights how adopting suitable suspension settings for the equipment may successfully apply the DVA theory to the flexible vibration reduction of the car body while improving the riding comfort of EMU. Acoustic metamaterial plate design principles, modeling techniques, and working mechanisms for elastic wave absorption and structural vibration damping were revealed [25]. The operational principle behind acoustic metamaterial plates is based on traditional vibration absorbers. The absorbers' local resonant frequency establishes the stopband's location. According to numerical results, the ratio of absorber mass to unit cell mass increases the stopband width. Increasing the absorbers' damping results in a significant reduction in the amplitudes of low-frequency vibrations. However, excessive damping can neutralize the stopband effect. Absorbers are more effective at suppressing low-frequency vibrations than the material damping found on plates.

Acoustic multi-stopband metamaterial plates were designed to suppress vibrations and absorb elastic waves in a wide frequency range. The metamaterial plate is an isotropic vibration-absorbing plate combined with 2-DOF mass-spring subsystems [26]. The extended Hamilton's principle was used to simulate a working unit of an infinite metamaterial plate without damping. Two stopbands were verified to be present using the averaged 3-DOF model's dispersion analysis. Frequency response analysis and transient analysis were carried out to study these stopbands. The results show that each working unit's bandwidth could be improved by raising the absorber mass and decreasing the isotropic plate's average mass. Examined metamaterials and their potential uses in theoretical vibration absorption. Because of the analogy with these materials, the acoustic metamaterials must have negative effective (dynamic) mass to allow vibration removal at a particular frequency [27]. How the units were fastened to the beam determined Beams formed of acoustic metamaterial to be vibration absorber units. Depending on how the units were fastened to the beam, the structure could absorb waves in one direction, like longitudinal waves, or in two directions, like transversal and longitudinal waves.

Furthermore, the acoustic metamaterial can produce one, two, or more frequency gap beams.

The problem was studied analytically, and the free and forced vibration analyses were considered. The fixed plate was fixed on all sides [28]. The results showed that the metamaterial plate could produce multiple resonant-type band gaps, where the lower-bound frequency of each gap coincides with the resonance frequencies of the resonators. Classical modal analysis of the one-dimensional mass-in-mass lattice was analyzed, and corresponding dispersion relations were derived. The initial findings demonstrated notable benefits over the traditional mass-in-mass lattice, including more significant band gaps and higher damping ratios [29]. The presented concept showed considerable potential in seismic meta-structures and low-frequency acoustic isolation damping. They thoroughly analyzed a mass-in-mass lattice model-based two-dimensional acoustic metamaterial with single and multiple resonators. An analytical demonstration illustrated the dynamic properties and multiple stop bands of mass-in-mass lattice systems with resonators in a two-dimensional lattice system [30].

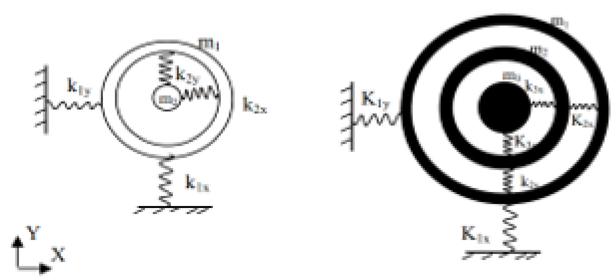


Fig.(9): 2D lattice unit for single mass-in-mass with (a)one resonator and (b)two resonators [30].

They investigated a nonlinear metamaterial beam's ability to absorb Vibration in several modes. The metamaterial beam's frequency response was measured using a series of embedded nonlinear local resonators to investigate a multifrequency stop band system [31]. By utilizing a differential evolutionary optimization method along with a route-following approach, the optimal frequency-response curves of the metamaterial beam in the nonlinear zone were obtained. [32] Focused on a single-phase elastic metamaterial featuring vibration and elastic wave suppression. The resonator consisted of a square lattice-shaped matrix in a cylinder-shaped central core encircled by uniformly spaced ligaments. The study achieved both theoretically and experimentally. The results demonstrated that the unit cell's rotational resonance generated a negative effective modulus and its translational resonance a negative effective mass. The elastic metamaterial's negative effective mass resulted in wave attenuation as well. The results provided a theoretical framework for creating elastic metamaterials in a single phase. DVA with N.S. is a possible solution to reduce longitudinal vibration transfer along a marine shafting system. Vibrations in the low-frequency band are managed using an analytical model of the shafting system based on a propeller equivalent mode, both with and without the suggested DVA [33]. A design approach that accounts for variations in the oil stiffness of the thrust bearing and propeller static thrust is provided to determine Belleville springs' static and dynamic stiffness under various operating situations.

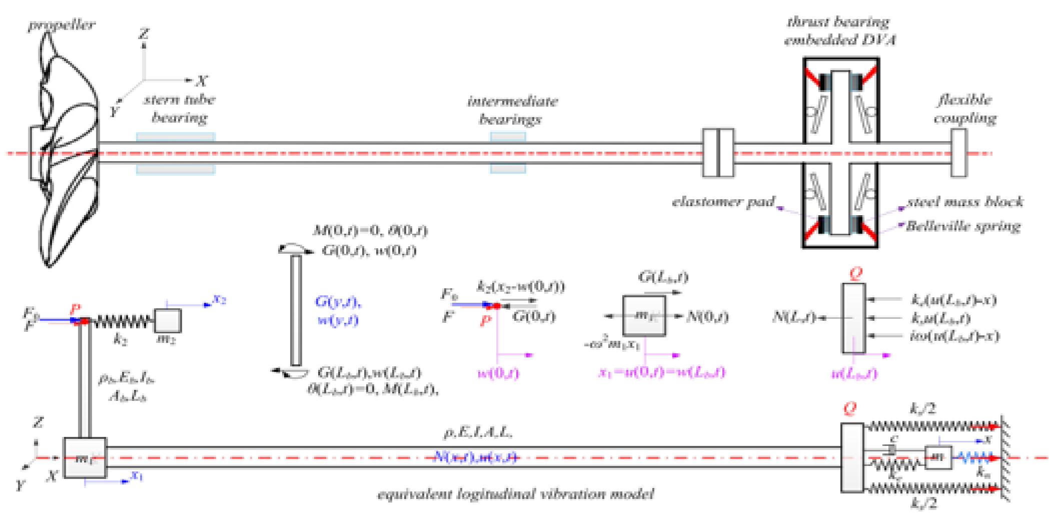


Fig.(10): Model for controlling the transmission of dynamic longitudinal Vibration in a shafting system featuring a thrust bearing with negative stiffness (N.S.) and a combined DVA [33].

An improved beam-based DVA (beam DVA) is suggested to reduce a general structure's resonant Vibration. The compound system comprises the connected beam-based DVA, and the host beam is modeled using the reacceptance theory. Comparisons between Abaqus's findings and the Transfer Matrix method (TMM) approach are used to validate the model [34]. Investigated to determine the best possible design for different kinds of DVAs (dynamic vibration absorbers) in response to random loads. Design options being considered are 2-DOF traditional dynamic vibration absorbers (TDVA) with both translational and rotational motion, DVAs linked in series or parallel, and inverter-based DVAs (the IDVA-C6, C4, and C3 models). The variance of the squared modulus of the frequency response for the undamped main structure is analytically calculated under both random excitation scenarios using the H2 optimization criteria [35].

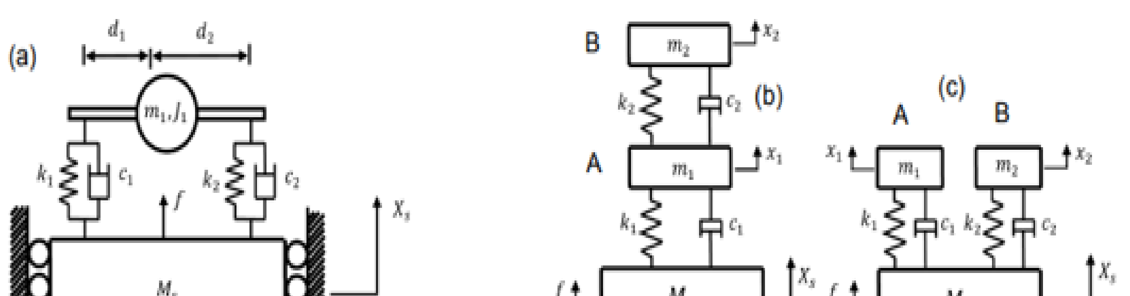


Fig.(11): models (DVAs);(a) 2-DOF with translational and rotational motion (2dof TVA); (b) DVAs arranged in series; (c) DVAs set in parallel [35].

Investigated given mass ratio, the optimal values of the DVA stiffness, N.S., and damping ratio are found using the fixed-point theory. Using the smaller fixed point approach technique leads to a solution that approaches zero, resulting in an ideal N.S. ratio. When exposed to harmonic and random excitations, the DVA with N.S. controls both force transmission and mass response better than the typical DVA, as demonstrated by comparing the three-parameter isolator. It is important to note that the ideal values for the DVA with N.S. differ when comparing the control of force transmission and the mass response of the central system [36].

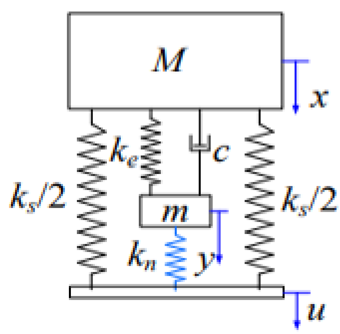


Fig.(12): The DVA isolation system under base displacement excitation with negative stiffness[36].

The parameters that have been investigated have been optimized for a precision platform that has been proposed. This platform has an advanced vibration isolation and mitigation (VIM) system that incorporates viscoelastic (VE), magnetorheological (M.R.), and VIM devices to control vibration responses. Using the Non-Dominated Sorting Genetic Algorithm (NSGA-II) optimization approach, the system selects the maximum damping forces of the M.R. dampers and the dynamic responses as objective functions. Once several Pareto solutions were attained, one was chosen to compare with the initially well-designed VIM system. According to numerical data, the optimization technique would concurrently lower the maximum control forces of the M.R. dampers and effectively attenuate the precision platform's vibration [37].

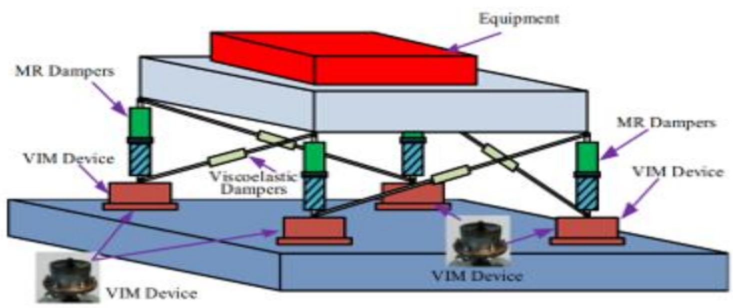


Fig.(13): The VIM system's configuration on particular platforms [37].

A magneto-mechanical metamaterial construction capable of vibration attenuation and energy harvesting was presented. The metamaterial dual-function structure prototype was built. The proposed structure consisted of local resonators (DVAs) arranged periodically, combining cantilever beams and permanent magnet coil systems. The results revealed that the model simulation and the experiment agreed. The metamaterial structure's vibration attenuation and energy harvesting properties were linked, according to the findings. In addition, the metamaterial structure shown here improved electric power generation significantly through vibration energy harvesting [38]. Analyzed the sandwich panel's Vibration and acoustic characteristics using metamaterial. Both panels were considered, both with and without damping. The panels consisted of resonant components that were periodically connected to a host sandwich panel. Through a numerical comparison between metamaterial and bare panels, the effects of the periodic design on the properties of Vibration, sound radiation, and sound transmission were examined. The investigation results demonstrated that, compared to the decrease achieved by increasing the mass, the occasional design dramatically reduces Vibration and sound throughout a wide frequency range. After testing and designing experimental specimens of sandwich panels made of both bare and metamaterials, a decrease was seen across a broad frequency range [39].

The experimental results confirmed the numerical findings, and the impacts of different structural parameters on Vibration and sound reduction were examined in detail [40]. It is suggested to enhance the grounded type DVA with a lever component in order to decrease unnecessary bulk and boost effective mass, hence enhancing the DVA's control performance. They find and solve the differential equations of motion for the DVA. The optimal parameters are found using the H∞ and H2 optimization criteria. The DVA's control performance was compared with the other three popular DVAs under the H∞ and H2 criteria. By modifying the amplification ratio, the DVA may achieve high performance at tiny mass ratios, offering a theoretical foundation for constructing new types of DVAs: mitigation, stroke limitation, and reduction of static stretching.

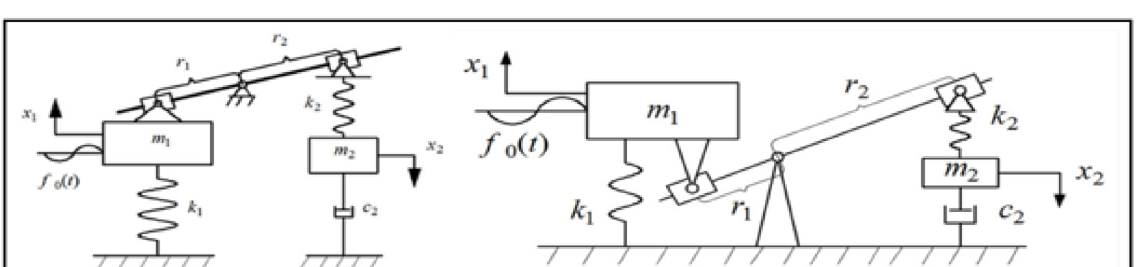


Fig. 14 : (a) lever component of grounded type DVA with another inertial reference frame serving as the lever fulcrum and (b) ground type DVA lever component with the lever fulcrum located at the ground [40].

A mathematical model of a quarter car with an active suspension and a DVA is created. Next, a two-stage particle swarm optimization-based optimization control strategy is suggested to improve the linear quadratic regulator controller's linked dynamic vibration absorber-suspension performance. This method uses a DVA to lessen Vibration in the wheel and motor. The particle swarm optimization approach best fits the DVA settings and weighting factors for the linear quadratic regulator controller. In the second step, a finite-frequency H∞ controller is designed for the active suspension to enhance the car's ride comfort using linear matrix inequality optimization. The vehicle's in-wheel motor vibration is decreased in addition to strengthening ride comfort [41].

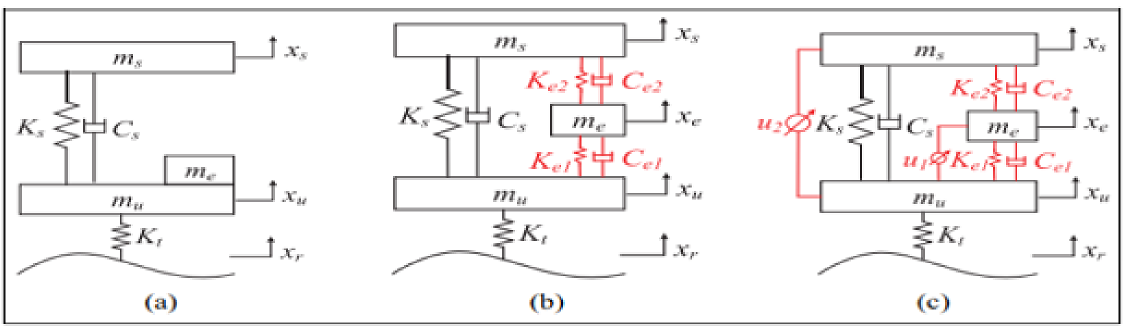


Fig.15: Quarter-vehicle models that include an electric wheel: (a) Con-EW, (b) generalized DVA-EW, and (c) active DVA-EW. Con-EW: [41].

It explored using metamaterials to mitigate structural vibrations that negatively impact a structure's performance and safety. This work proposed an enhanced dual-resonator metamaterial beam (DRMB), which utilized a series of dual-resonators with a spring-connected rigid body at the free end [42]. The DRMB's mass and frequency response were determined, and a transfer matrix approach was used to calculate the theoretical dispersion relation analytically. The number of cells mass, stiffness, and spring ratio of the DRMB were investigated for their effects on bandgap and transmissibility performance. The actual results confirmed the theoretical model and showed that the DRMB's bandgap and low-frequency vibration suppression capacity improved significantly with increases in mass ratio, number of cells, spring, and stiffness ratio. The triple-spring dual-resonator effectively suppressed beam vibration.

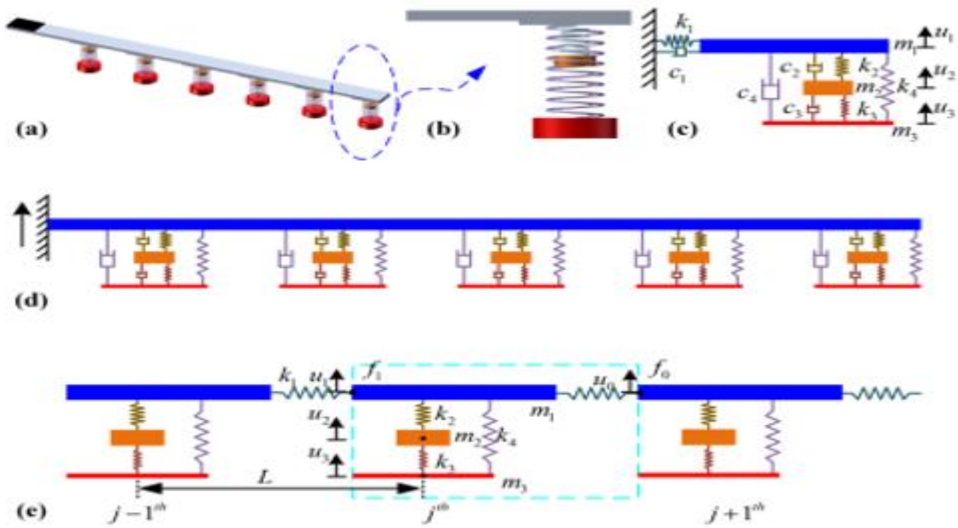


FIG. 16. The new metamaterial beam being set up: (a) the DRMB's tangible model. (b) the DRMB's single unit cell. (c) Model for computing the single unit cell of the DRMB. (d) A model for computing the DRMB in finite units. (e) A model for computing the infinite DRMB [42].

Presented the ideal mass-damper-inverter (M-TMDI) design that minimizes vortex-induced Vibration (VIV) in bridge construction [43]. Analytical parameters were provided based on a 2-DOF system for the specific M-TMDI model, where the inverter's end was connected to the fixed ground. The M-TMDI inserter location on the bridge deck was built in closed form using multiple-DOF technology. Numerical analysis was conducted on a continuous steel box-girder bridge that was subjected to the VIV to verify the superiority and optimal design of the M-TMDI control. The results show that the optimally designed M-TMDI performs better than the TMD and three-element TMD in terms of immediate amplitude mitigation, steady-state amplitude mitigation, stroke limitation, and static stretching reduction.

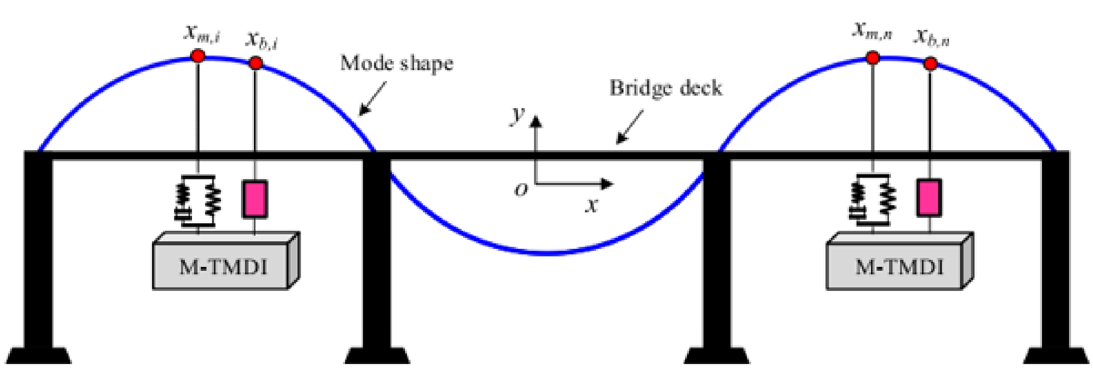


Fig. 17. The M-TMDI-equipped flexible bridge [43].

A vibration absorber that is dynamic and has negative stiffness has been developed. Absorber components were optimized with the two-fixed point technique and the H ∞ maximization criteria [44]. In an undamped system under harmonic excitation, the ideal values of the tuned mass damper and grounded stiffness components are determined to minimize the resonance amplitude. The damping ratio, tuning frequency, and negative stiffness parameter are all minimized by using the two-fixed point approach. In the resonant vibration region, it is demonstrated that the pre-tensioned stiffness offers sound attenuation. Additionally, this gadget may expand the effective frequency range of Vibration.

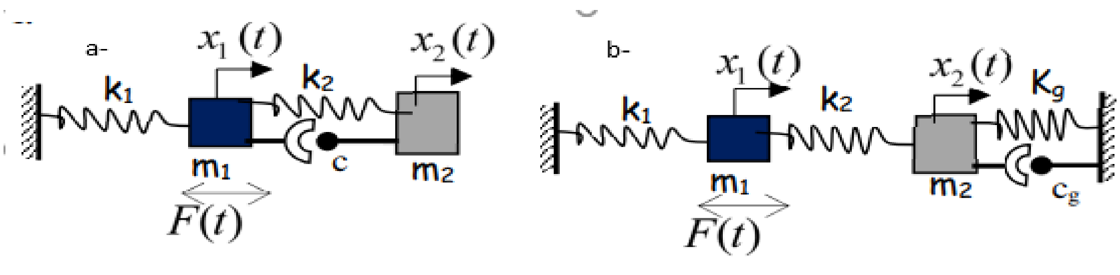
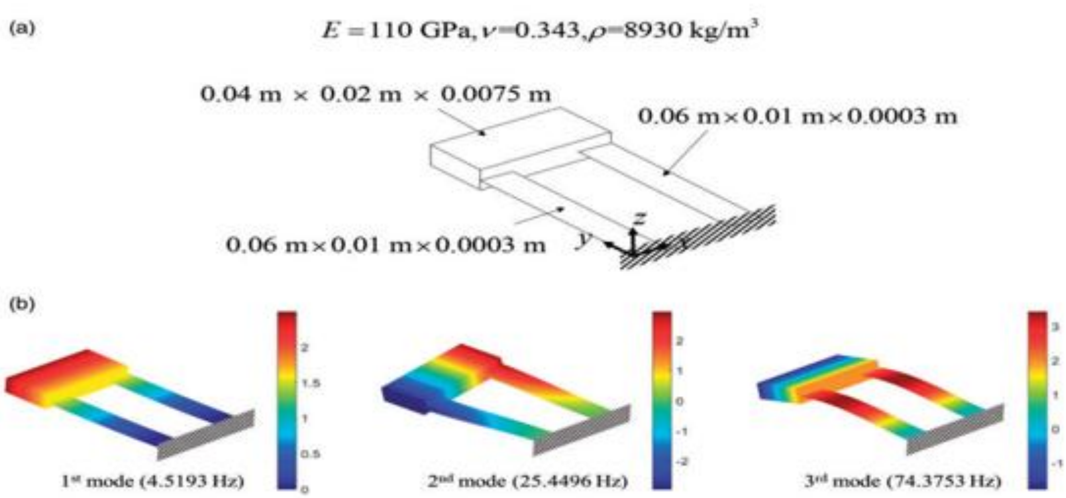


Fig. 18. (a) Traditional model, (b)DVA with negative stiffness [44].

A new dynamic absorber was presented that concurrently attenuates vibrations at three resonance frequencies [45]. A novel DVA without a damper tuned of several frequencies was developed to get around the restriction and reduce vibrations across a broad frequency range. The current dynamic absorber's mass and two arm beams are attached to a hosting structure. The eigenfrequencies of the dynamic absorbers may be accurately tuned to those of the hosting structure by varying the geometric dimensions, providing a procedure for optimizing the geometric parameters using a numerical optimization approach.



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4th Teeb Basim Abbas

Fig. 19.: (a) a design of multifrequency vibration absorber and (b) the mode shapes [45].

The Maxwell model with multiple N.S. springs and viscoelastic material is added to the DVA system, changing every system parameter [46]. The established differential equation of motion is utilized to demonstrate the analytical solution of the central system. The H1 optimization concept and fixed-point theory determine the dimensionless system features, such as the optimal damping ratio, initial optimal negative stiffness ratio of the dynamic vibration absorber, and ideal natural frequency ratio. It has been demonstrated that the dynamic vibration absorber has a more notable vibration reduction effect in the case of both harmonic and random excitations when compared to other conventional dynamic vibration absorbers.

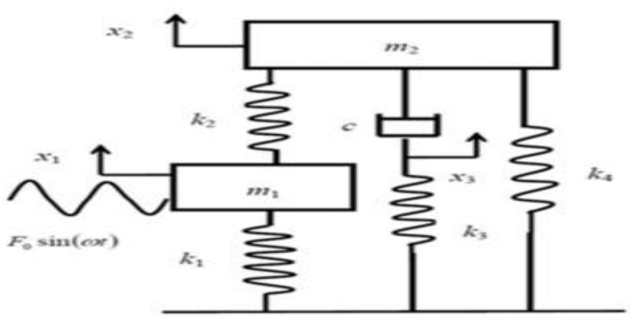

Fig. 20. Maxwell DVA including several N.S. springs [46].

Joist floor constructions experience less low-frequency Vibration when the design parameters of numerous DVAs are optimized [47]. First, an analytical model that integrates the motion of beams and a plate was used to calculate the Vibration of the joist floor structure. Subsequently, the absorbers were shown as SDOF mass-spring-damper assemblies attached to the floor structure. A comparative analysis was conducted between the optimal DVA solution and conventional improvement measures. Consequently, floor vibration in the target low-frequency bands could be reduced by DVAs more effectively than traditional improvement techniques, even with an equivalent increase in floor weight. Developed a rigid-flexible three-dimensional rail car model to assess the effects of various apparatus hanging beneath the chassis in light of the C.B. mode's mass, position, and frequency [48]. Research from experiments validated the rigid-flexible rail vehicle concept. To reduce flexible Vibration, the car body is modeled as an Euler-Bernoulli beam. The calculations suggest that heavy equipment should be suspended towards the center of the C.B. to optimize the high-frequency bending frequency. Through DVA optimization, notable resonance improvements of 9.71% for the first mode, 17.30% for the second mode, and 13.65% for the first vertical mode were achieved.

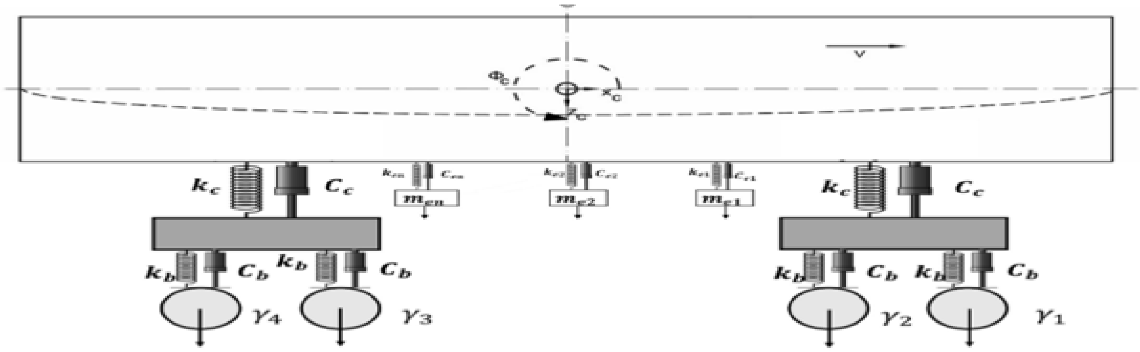

Fig. 21. Diagrammatic representation of the ICF coach passenger rail vehicle[48].

They have presented a trustworthy and practical method for simulating and computing the DVA-beam system. Examine the computational precision of the DVA-beam element under various boundary conditions, including the cantilever beam in four positions, the clamped-clamped beam in the center, and the cantilever beam with multiple DVAs connected. A numerical comparison between the beam tip responses and those predicted by the ADAMS software verified the DVA-beam element's reliability in handling various boundary conditions [49].

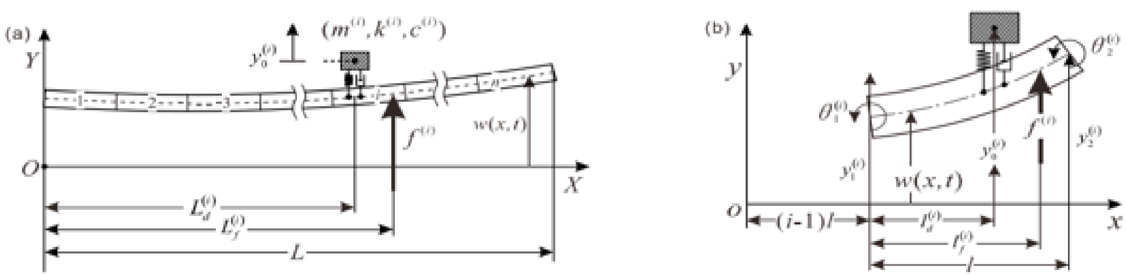

Fig. (22): Beam construction connected to DVA : (a) Physical model ; (b) DVA-beam element [49].

A 12-DOF model with the central vibration system and an MDOF DVA were presented. A genetic algorithm combines the design approach of a single DVA with the analysis of the Multi-DOF dynamic vibration absorption concept [50]. This study uses the under-car body MDOF DVA in a high-speed train dynamics model to investigate the influence of vibration control on each DOF of the MDOF DVA using a virtual excitation approach. It was advised to install the MDOF DVA using a high static and low dynamic stiffness (HSLDS) mount that was based on a cam-roller-spring mechanism.

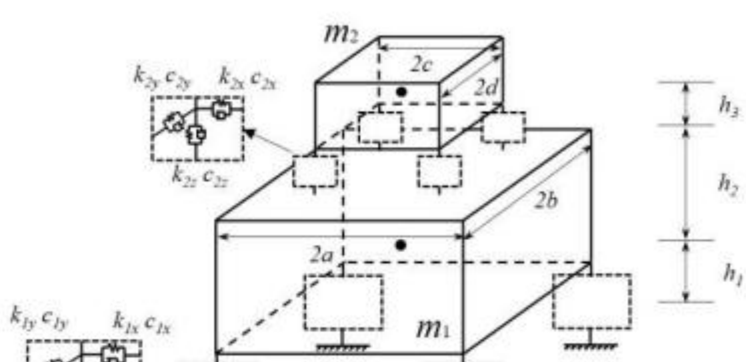

Fig. 23: Diagrammatic schematic of an MDOF DVA [50].

2.3 FINITE ELEMENT METHOD:

In a commercial FEA program like ANSYS, the free and forced vibrations of a fixed-fixed ends plate were simulated in this work to examine the natural frequencies, mode form, and response of the plate. The initial findings suggest that the addition of a single absorber significantly reduced the Vibration of the plate. As varied dynamic characteristics of the plate were measured, it was discovered that the addition of the passive vibration absorber significantly impacted the structure [51]. For a flexible cantilevered structure with an unbalanced rotor, the effectiveness of a beam-type twin DVA was demonstrated through computational and experimental FEA. Experimental measurements and numerical calculations show that Vibration can be significantly reduced by using the proposed dual-mass, cantilevered DVA on a flexible cantilevered platform supporting an unstable rotor system at its tip [52] **and p**resented modeling and analysis strategies for designing metamaterial beams as elastic wave absorbers. Tiny subsystems are attached to an isotropic beam at different spots to create an acoustic metamaterial beam. Dispersion analysis and frequency response analysis were used to determine the stopband of a metamaterial beam. The results showed that choosing the correct values for the beam as a dynamic vibration absorber substantially impacted the beam's amplitude response [53]. The idea of tuned vibration absorbers applied to a beam structure was examined theoretically using finite element analysis. Depending on where they were attached, the tuned vibration absorbers had four conditions for connecting to the fixed-fixed end beam. The impact of tuned absorber positions on beam vibration characteristics was investigated using harmonic analysis [54]. Examined how well a lightweight dynamic vibration absorber (LDVA) works to lessen Vibration in buildings with thin walls. The finite element approach was used to analyze both forced and free vibration responses during the investigation. The outcomes demonstrated that Vibration throughout a frequency range of 0-600 Hz could be effectively reduced by a single LDVA installed at the plate's center [55].

Twin LDVAs did not suppress the third and fifth modes of the thin-walled structure; instead, they only lessened the resonance of the first, second, and fourth modes. Based on the data, the study found that single LDVAs were superior to dual LDVAs in minimizing Vibration in thin-walled constructions throughout the whole frequency range. [56] A dynamic vibration absorber was created at the resonance frequency of one of the leading vibrating systems. The basic vibrating system's natural frequencies and mode shapes were determined theoretically and through FEA analysis. The device, essentially a modified version of the conventional damped vibration absorber, simultaneously adds an extra undamped absorber mass to the damped mass. Finds the ideal parameter to reduce the amplitude of the Vibration using MATLAB.

Demonstrated an experimental study for the design of mechanical metamaterials for simultaneous automatic vibration attenuation and energy harvesting using finite element analysis and 3D printing [57]. The mechanical metamaterials comprised a primary vibrating frame attached to a square array of free-standing piezoelectric cantilevers. According to experimental measurements and numerical calculations, the suggested dual-mass, cantilevered DVA can significantly reduce Vibration when used on a flexible cantilevered platform supporting an unstable rotor system at its tip. The mechanical metamaterials that were constructed accomplished the dual goals of energy harvesting and vibration isolation at the same time. [58] analyzed several resonance-based metamaterial concepts using analytical models and finite element analysis as potential retrofits or replacements for elastic supports in heavy machinery, specifically large generators. One such concept involved using grounded resonators to create a mechanical high-pass filter that reduces Vibration at the frequency of interest. The resonators consisted of mass and spring systems that work like DVAs. These concepts successfully reduced off-resonance operating frequencies of the generator at the low-frequency range of heavy machinery. [59] presented an ANSYS APDL simulation to analyze the vibration properties of a fixed-ended beam after it is provided with a dynamic vibration absorber in the vibrating node and antinode. This study aimed to determine the ideal placement and quantity of DVA on the F-F beam to lessen beam vibration. According to the simulation results, the vibration amplitude of the beam was reduced, especially when the DVA was connected near the vibrating antinode.

3. CONCLUDING REMARKS:

Based on the deep study of the literature above, essential conclusions can be drawn when studying dynamic vibration absorbers (DVA). Some of these conclusions must be taken into consideration, including:

- Characteristics of the main structure: The characteristics of the primary structure, such as its mass, stiffness, and damping, can affect the design and performance of the DVA. Therefore, it is essential to consider the primary structure's characteristics when designing and optimizing the DVA.

- Frequency range of Vibration: The frequency ranges of Vibration that the DVA is designed to reduce are critical considerations. To guarantee that the DVA successfully decreases vibrations in the intended frequency range, selecting the appropriate design parameters, such as the mass, frequency, and damping ratio, is crucial.

- Performance evaluation: It is essential to evaluate the performance of the DVA to ensure that it effectively reduces vibrations in the desired frequency range. Performance evaluation can be done through analytical, numerical, or experimental methods.

- The lowest three vibration modes can significantly reduce the metamaterial beam oscillations by utilizing local absorbers and properly regulating their constitutive characteristics.

- The analysis of the nonlinear frequency response of the beam with nonlinear absorbers surrounding the lowest three modes demonstrates that intentionally introducing cubic nonlinearity into local resonators can result in better vibration suppression performance for the nonlinear resonators than linear resonators.

- Operating conditions: The operating conditions of the primary structure or equipment can affect the performance of the DVA. For instance, if the immediate structure experiences varying loads or forces, the DVA must be designed to accommodate these changes.

- System complexity: The complexity of the DVA system can affect its performance and cost. A more complex DVA system may be more effective in reducing vibrations, but it may also be costlier to design and implement.

Overall, the design and implementation of a DVA system require careful consideration of the primary structure's characteristics, the frequency range of Vibration, environmental factors, cost, performance evaluation, and safety. By considering these factors; engineers can design and implement an effective and efficient DVA system.

Recommendations: for future work, many aspects may be concerned with the objectives of the current work in addition to other features that are not considered in the current job. Experimental work and Validate the theory by using the finite element method.

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