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Experimental and numerical Comparison of traditional spring DVA and shape memory alloy actuated DVA for fixed beam vibration control

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ABSTRACT

A desirable smart material that might be employed in dynamic vibration absorbers (DVA) as a stiffness adjustment element is shape memory alloy (SMA). This paper offers a numerical and experimental platform that examines the vibration of a stationary beam that has been operated by a SMA. In this study, a DVA is created using springs made of shape-memory alloy to eliminate vibration in a fixed beam. The system has a fixed beam secured by a C clamp. Real-time vibration was provided by the shaker with the help of a function generator. Results for the vibration's amplitude were recorded after the conventional spring with mass was mounted at a distance of 305.1 mm from the left end of the fixed beam. The SMA spring with mass was used in place of the conventional spring, and experiments were run at various frequencies. To record the results, the FFT and accelerometer were interfaced using Pulse software. The fixed beam with spring mass system is modelled in ANSYS Workbench R15.0 in accordance with the experimental setup. Over a range of frequencies, the results of a harmonic response analysis were compared. The experimental & analytical results are in good agreement when one SMA spring or two SMA springs connected in parallel or series are used to dampen the system effectively. The outcomes of this work can be utilised as a reference for designing DVA with a Nitinol spring as a stiffness tuning component in circumstances where smooth and continuous tuning of the absorber is required.

Selection and peer-review under responsibility of the scientific committee of the International Conference on Aspects of Materials and Mechanical Engineering.

1. Introduction

The shape memory effect refers to the ability of metal alloys to recover from severe damage without permanently changing their shape when heated. [1]. Due to their various properties, including the shape-memory effect (SME), pseudo-elasticity or large recoverable stroke (strain), high damping capacity, and adaptive properties that are caused by the materials' (reversible) phase transitions, shape-memory materials (SMMs) are one of the most crucial components of intelligent/smart composites [2]. Shape memory alloys (SMAs) have two remarkable properties that are temperature-dependent: the shape memory effect and the super elastic effect. SMAs' hyperelastic nature has a stronger recentering effect. Civil engineers have paid close attention to this behaviour in order to build structures that are earthquake-resistant [3].

Shape memory alloys (SMA), which have an incredibly broad range of applications, are employed in a variety of technological disciplines, such as the aerospace, automotive, and biomedical sectors. What makes these alloys so desirable is their remarkable deformation recoverability, which is easily regulated by varying applied thermomechanical or magnetic stimuli. Today, the need for even better SMAs is increasing swiftly, along with the quest for them. These efforts have benefited from the predictions made by theoretical research in the areas of (a) component actuation performance (as characterised by pre-defined constitutive laws); (b) microscopic deformation mechanics and processes; and (c) discrete lattice physics (resulting from subtle quantum effects). For each particular pathway, a detailed mathematical study and simulations at multiple length scales, from continuum to subatomistics, are necessary. There is currently no single prediction framework that can reliably account for the multiscale physical processes associated with SMA deformations due to their extreme complexity; instead, they are managed using different modelling methodologies [6].

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A fixed beam is employed as the fundamental representative model of an advanced flexible engineering structure to examine the role that shape memory alloy plays in managing structural vibrations. This chapter uses experimentation to establish the forced excitation frequency of a fixed beam. The Fixed Beam is made of aluminum with dimensions of 915 mm in length, 30 mm in width, and 3 mm in thickness. The forced excitation frequency of the beam is used to determine a frequency range for the experiment. Dyna Alloy, USA, is used to generate closed coil helical tension springs to evaluate the efficiency of SMA in reducing vibration. Smart materials, or SMAs, have physical characteristics that change with temperature. To measure the deflection of the SMA spring for applied current, a typical setup is created. Deflection and load experimental measurements are used to calculate the stiffness.

1.1. Dynamic vibration absorber

Unwanted vibrations caused by an externally aroused structure must be removed by attaching a vibration absorber system to it. The vibrating apparatus is often referred to as a dynamic vibration absorber or vibration absorber. In these situations, the stimulation frequency is almost the same as the inherent frequency of the machine or structure. The spring mass system (absorber), which is coupled to the mass (machine or structure), can vibrate freely while the stimulated mass (machine or structure) can have zero vibrational amplitude.

1.2. SMA (Shape memory Alloy) comes in two varieties:

- One way shape memory

When a metal is in a cold state, below Tc, it can be bent or stretched in one direction using shape memory. Until the heating level reaches Tc, the metal will maintain the same shape (above Th). When this type of material is cold, it can change its qualities, but when heated, it can hold its previous position, where Tc is purported to range from −150 to 200 degrees Celsius and Th is purported to range from 2 to 20 degrees Celsius [1].

- Symmetrical shape memory

When heated, the material of this kind reflects a different attribute from the one it reflects when it is cold.

Smart materials like SMAs have physical characteristics that change with temperature. By altering the electrical current passed through the SMA spring, stiffness may be managed. As a result, a tremendous amount of potential can be created, which could be used to control vibration.

1.3. Use of Nitinol SMA springs

Nickel-titanium (Niti) alloy coil springs with shape memory (SMAs), which have a long stroke and significant recovery force, are used in the majority of products. Another advantage of using SMA springs is that they may function as both sensors and actuators [7].

1.4. Applications of shape memory alloy (SMA)

Based on the main function of the memory element, shape memory applications are classified into four categories.While the SE can be utilised to store deformation energy, the SME can produce motion and/or force. Because of their particular behaviour, NiTi SMAs have been applied in novel and creative ways in the sectors of electronics (MEMS devices), aviation and automobiles. For instance, the same NiTi thermos variable rate (TVR) springs used in self-cleaning ovens are also used in industrial safety valves, Memrysafe® antiscald valves from Memry Corporation, domestic safety devices to regulate hot water flow, and Mercedes-Benz automatic transmissions to provide smooth gear shifting. Some of these applications employ analogous procedures, ideas, or methodologies that also apply in other contexts. What makes these actuators even more intriguing is that they can serve in various applications as both sensors and actuators [9].

1.5. Application of shape memory alloy in fixed beams

Due to structural deterioration and/or increased external loads, RC beams used in construction projects like buildings and bridges may experience considerable deflections. By causing the concrete to crack and spall, such deflections raise questions about the durability and applicability of RC beams now in use. Pre-stressing the beams with SMAs can successfully decrease excessive deflections, and employing longitudinal and transverse SMA rebars, respectively, for flexural and shear strengthening, can improve structural capacity. It is interesting that RC beams have been the subject of almost half of the studies conducted to date on the application of SMA reinforcement for civil engineering buildings. This is mainly because adding SMAs to horizontal structural components is so straightforward. The studies that are now accessible have been grouped according to the super-elasticity and SME properties of SMA, two SMA qualities that are mainly exploited for strengthening. On the tension side of RC beams, SMAs are widely used as internal, NSM, embedded, or external reinforcement [10].

1.6. Past approach of SMA

In 1938, Greninger and Mooradian recorded the first SME measurements for copper-zinc (Cu-Zn) alloys and copper-tin (Cu-Sn) alloys. Kurdjumov, Khandros, Chang, and Read both published in-depth studies on the underlying features of the memory effect that are governed by the thermoelastic behavior of the martensite phase a decade later. These discoveries piqued the curiosity of numerous academics and inventors, but they were unable to find practical or industrial uses due to the pricey materials, challenging manufacturing procedures, and undesirable mechanical properties. Although William Buehler created the NiTi alloy in 1959, commercial SMA applications couldn't be realized until William Buehler and Frederick Wang published their study on the SME in the NiTi alloy in 1962.

1.7. Recent developments

In the 1990 s, the SMM community initially applied shape memory technology (SMT). Since then, SMA application design has undergone substantial changes and is now widely employed across a variety of industries, including those in the automotive, aerospace, robotics, and biomedical sectors. Applications for low-frequency vibration and actuation now successfully use SMA actuators. Recently, many researchers have employed an experimental approach to improve the properties of SMAs. To attain a larger operating temperature range and higher material stability, they have changed the compositions of the materials (quantifying the SMA phase transition temperature), and they have improved the mechanical design (or approach), controller systems, and fabrication techniques. With a CAGR of 12.8 % between 2011 and 2016, BCC Research predicted that the global market for smart materials would be worth roughly USD 19.6 billion in 2010, close to USD 22 billion in 2011, and perhaps surpass USD 40 billion by 2016. [9].

1.8. Futuristic approach of SMA

The three primary levels at which future improvements in SMAs might be envisaged are the development of new or improved SMAs, the merging of the functional qualities of SMAs with the structural properties of other materials (for example, hybrid or composite SMAs), and the search for new markets.The NCATB alloy, a different newly created ferrous-based SMA, has shown a maximum super- elastic strain of roughly 13.5 % and a very high tensile strength of 1200 MPa. Shape memory composites (SMCs), which are recently made by combining SMAs with other materials, enhance the performance and utility of SMAs (SMCs). The material's performance has been improved by the use of various SMA and other material combinations, it has improved self-healing ability, triple-state switching, active stiffening, toughness, and damping capacity. [9].

1.9 Research Survey: Numerous researchers have worked hard to improve the pseudo elastic response of SMA springs.Li **Tian, et.al** [11]**,**have investigated the three-dimensional ABAQUS model of a genuine power transmission tower (Dassasult Simulia Company, Providence, RI, USA). The TMD (tuned mass damper) and PTMD are simulated using the finite element method. The effects of the mass ratio, ground motion intensity, gap, and incident angle of seismic ground motion are all looked at in order to get the optimal design, analysed as well is the transmission tower's response to TMD and PTMD. The findings demonstrate that the PTMD is highly successful in minimising the longitudinal and transverse vibration of the transmission tower. As the mass ratio rises, the reduction ratio rises as well**. Li Pengyun, et.al** [12], An example linked system with two power transmission towers and three lines is used to assess the viability and dependability of the suggested approach. The efficiency of the suggested energy criteria in evaluating the performance of structural dynamic reactions.**E. Świtońsk, et.al** [13], have provided two vibration control strategies. In the first technique, a shape memory alloy absorber is used, and in the second, a magneto rheological bearing is used in the revolute joint of the manipulator mechanism. Shape-memory alloys and magneto rheological fluids provided a wide range of options for vibration control systems. Absolute frequency changes in the case of the SMA absorber are sufficient to alter the dynamic properties of main systems. **S Saadat, et.al** [14], A comparison of the behaviours, models, applications, and limits of NiTi for seismic isolation and structural vibration control was made. It is concluded that a great deal of analytical and experimental research has been done on the viability of NiTi-based seismic isolation devices, fabrication, constitutive modelling, temperature and loading frequency sensitivity dependence and so on. New hybrid designs should be the focus of future study. It is not feasible to build a seismic mitigation system with its primary components entirely made of NiTi-based energy absorption and vibration isolation devices. The viability of NiTi-based seismic isolation devices, fabrication, constitutive modelling, temperature and loading frequency sensitivity dependence, and so on. New hybrid designs should be the focus of future study. It is not feasible to build a seismic mitigation system with its primary components entirely made of NiTi-based energy absorption and vibration isolation devices. **Shengchun Liu, et.al** [15], have suggested that based on the Qixia Wendeng (Kunyu) 500 kV transmission line project, separate 3-D finite element models of a single tower, one tower and two spans of conductor wires, three towers and four spans of conductor wires, five towers and six spans of conductor wires, and six towers and five spans of conductor wires were created and compared. Even more than a transmission tower under wind stress, the effect of wind load distribution on conductor wires is astounding. Design cannot overlook the impact of conductor wires on towers. On the transmission tower-line system, the effect distributed by fluctuating wind load is greater than that distributed by static wind. Design must take changing wind impacts into account**. Qin Li, et.al** [16], describe using the ANSYS programme, distinct three-dimensional finite element models of a single tower, a tower and two conductor wire spans, a tower and three conductor wire spans, and a tower and five conductor wire spans were created and compared. The Qixia Wendeng (Kunyu) 500 kV transmission line project served as the basis for these models. It is amazing how the wind load affects conductor wires; it has an impact even bigger than the wind load on the transmission tower itself. In design, conductor wires' impact on towers cannot be disregarded. On a transmission tower-line system, a fluctuating wind load has a bigger impact than a static wind load. Effects of changing wind must be taken into account when designing. Finally, several suggestions are provided for enhancing SMA springs' capabilities as dampers and energy absorbers.

2. Experimental set up

The basic representative model of an advanced flexible engineering structure is a fixed aluminum beam. The fixed beam is 915 mm in length, 30 mm in width and 3 mm in thickness. The experimental setup is ready to calculate the forced excitation frequency of the stationary beam. Utilizing a fixture, nut and bolt system, the beam is fastened at both ends. The function generator and shaker are employed to speed the beam. The structural dynamics USA company is the shaker. The shaker is accelerated at the necessary frequency using the APLAB function generator. To measure the amplitude of vibrations, an accelerometer with a sensitivity of 100 mV/g is installed 250 mm from the right fixed end of the beam. The FFT is coupled with the accelerometer. Pulse software and the FFT are connected to the computer. For the measurement, analysis, and assessment of sound and vibration data, Pulse software offers a comprehensive solution.

The frequency generator is finely tuned starting at 1 Hz to determine the force excitation frequency of the fixed beam following the proper installation and connection of all equipment. Through the use of a frequency generator, the frequency is fine-tuned up to 51 Hz, although no peak was noticed. Tuning continues indefinitely until the first peak is noticed. Data of acceleration and amplitude were recorded for each corresponding frequency using the Pulse programme software. The initial peak, measuring 0.939 mm in amplitude, was seen at 51 Hz. Since the fixed beam's forced excitation frequency was 51 Hz, a frequency range of 48 Hz to 54 Hz was chosen for the entire experiment. So, using a function generator, a beam is excited at regular intervals between 48 and 51 Hz, and with the use of FFT, corresponding graphs of acceleration and amplitude vs frequency are created.

3. Amplitude and acceleration measurement with conventional and SMA springs

The dimensions of a SMA spring and a conventional spring are the same. Frequency vs amplitude and frequency vs acceleration are obtained for the beam after being aroused throughout a 48 to 54 Hz frequency range. The following graphs show the results for Fixed Beams with and without Dynamic Vibration Absorbers (DVAs), Fixed Beams with a Single Conventional Spring DVA, and Fixed Beams with a Single SMA Spring DVA.

The analytical and experimental values of frequency shift and displacement transmissibility are shown in Tables 1, 2, and 3. Primary system's experimental time response relates to maximum and minimum. The figure's shown below illustrates how secondary stiffness at a constant excitation frequency of 51 Hz can be tuned to reduce vibration level.

Table 1
Comparison of Fixed Beam Vibration Amplitude across Frequency Range.

Sr.No.	Frequency in Hz	Amplitude in mm	
		Experimental	Numerical
1	48	0.486	0.455
2	49	0.551	0.512
3	50	0.81	0.7468
4	51	0.939	0.8586
5	52	0.369	0.3338
6	53	0.147	0.1329
7	54	0.065	0.0587

Table 2
Comparison for Amplitude of Fixed Beam with Conventional Spring Mass System at 305.1 mm from left fixed end.

Sr. No.	Frequency in Hz	Amplitude in mm	
		Experimental	Numerical
1	48	0.477	0.448
2	49	0.531	0.495
3	50	0.705	0.653
4	51	1.08	0.995
5	52	1.14	1.036
6	53	0.507	0.4606
7	54	0.264	0.2389

Table 3
Comparison for Amplitude of Fixed Beam with 1 SMA Spring at 305.1 mm from left fixed end.

Sr.No.	Frequency in Hz	Amplitude in mm	
		Experimental	Numerical
1	48	0.444	0.41768
2	49	0.504	0.46946
3	50	0.684	0.63653
4	51	0.885	0.813
5	52	0.46	0.42037
6	53	0.192	0.17419
7	54	0.101	0.0919

Fig. 2. Photograph showing Beam with 4 hooks for suspending Spring DVA.

According to Fig. 3**(a,c)**, the vibration's amplitude was 0.4587 mm at 48 Hz and 0.939 mm at 51 Hz. The acceleration at 48 Hz and 51 Hz, respectively, is shown in Fig. 3**.(b,d)**. 32104 mm/sec^2 at 48 Hz and 1 mm/sec^2 at 51 Hz were used to accelerate the beam. The vibrational amplitude at 48 Hz and 52 Hz, respectively, is shown in Fig. 4**(a,c)**. At 48 Hz, the vibration's amplitude was 0.4765 mm, and at 52 Hz, it was 1.136 mm. The acceleration at 48 Hz and 52 Hz, respectively, is shown in Fig. 4**.(b,d)**. 33863 mm/sec^2 at 48 Hz and 121263 mm/sec^2 at 52 Hz were used to accelerate the beam. Fig. 5**.(a,c)** shows the vibration's amplitude at 48 Hz and 51 Hz, respectively. At 48 Hz, the vibration's amplitude was 0.4442 mm, and at 51 Hz, it was 0.8853 mm. The acceleration at 48 Hz and 51 Hz is depicted in Fig. 5**.(b,d)**, respectively. 58255 mm/sec2 at 48 Hz and 90913 mm/sec2 at 51 Hz were used to accelerate the beam.

4. Results and discussions

This work shows that experimentation has been carried out by employing a single conventional spring DVA and then switching it out for a single SMA spring DVA. It can be seen that there is a decrease in the primary system's vibration amplitude. Using a single SMA spring, the effectiveness of the vibration dampening is increased. In Fig. 1, the experimental setup is described in detail. The main component of the system is a 3 × 30 × 915 mm beam that is fixed at both ends. It has four hooks that are spaced 152.7 mm and 305.1 mm from the left and right ends, respectively. According to Fig. 1, the secondary spring-mass system is clamped to the primary system. The beam has four hooks to suspend Spring DVA, and they are identical and are depicted in Fig. 2. Conventional springs have a stiffness of 0.704 N/mm and are used as a DVA in conjunction with mass without actuating the system. Utilizing an accelerometer 250 mm from the right fixed end, the vibrations of the beam were measured. A SMA spring was used in place of the conventional DVA spring to effectively control vibration. The SMA Spring DVA was activated by applying a 3A current through a dual mode power supply, causing the spring to heat up to 219 degreesC and reach a stiffness of 4.932 N/mm. At a frequency of 50 Hz, where the vibration's amplitude was 0.81 mm without

Fig. 1. Photograph showing position of accelerometer and Exciter.1. Aluminum Fixed Beam 2. Stylus of Exciter 3. Accelerometer 4. SMA Spring DVA 5. Dual Mode Power supply 6. Function Generator 7. Fixture for mounting the Beam.

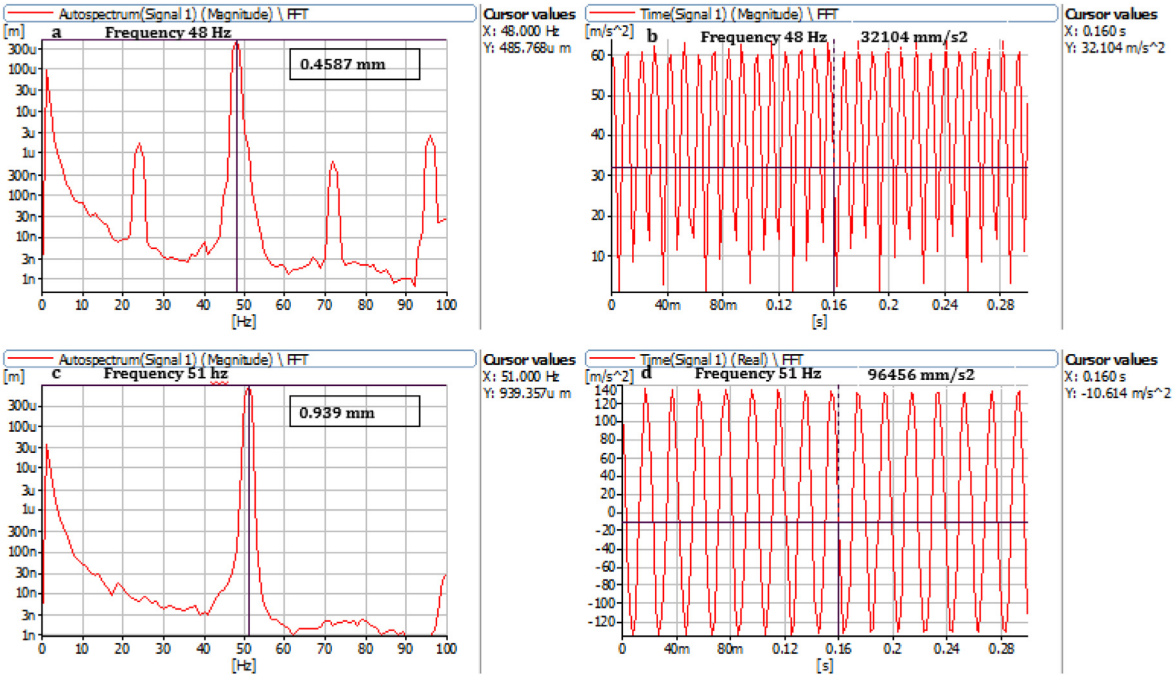


Fig. 3. Graphs Frequency vs Amplitude (a,c) and Frequency vs Acceleration(b,d) for Fixed Beam without Dynamic Vibration Absorber.

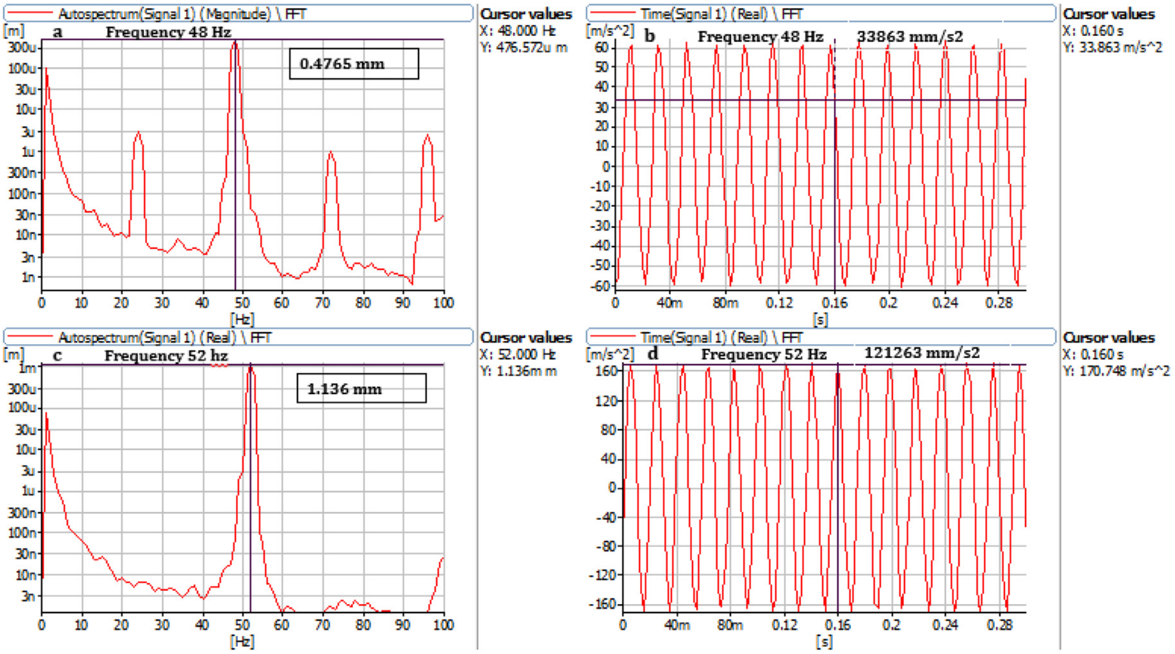


Fig. 4. Graphs Frequency vs Amplitude(a,c) and Frequency vs Acceleration(b,d) for Fixed Beam with One Conventional Spring Dynamic Vibration Absorber at 305.1 mm from left fixed end.

DVA, it has been decreased to 0.684 mm by utilizing a single SMA spring's DVA due to the SMA spring's increased stiffness. For a single SMA spring, readings were taken for a frequency range of 48 Hz to 54 Hz. For each frequency, current was fed through the SMA spring DVA to make the spring stiffer. Repeated frequency sweeps were done, and responses for frequency vs amplitude and frequency vs acceleration were recorded.

A comparison of experimental and analytical displacement values is shown in Figs. 6 and 13. The graphs show that SMA spring DVA is useful for controlling vibrations both theoretically and empirically. The experimental amplitude of 0.939 mm without DVA was reduced to 0.885 mm by using one SMA spring DVA. The analytical value of amplitude of 0.8586 mm without DVA was reduced to 0.813 mm by using one SMA spring DVA. Nitinol is used in the form of a closed-coil helical spring when it is combined with mass. By making sure that the system is underdampened, it is active throughout the soft martensitic phase of SMA and contributes to better DVA performance. Additionally,

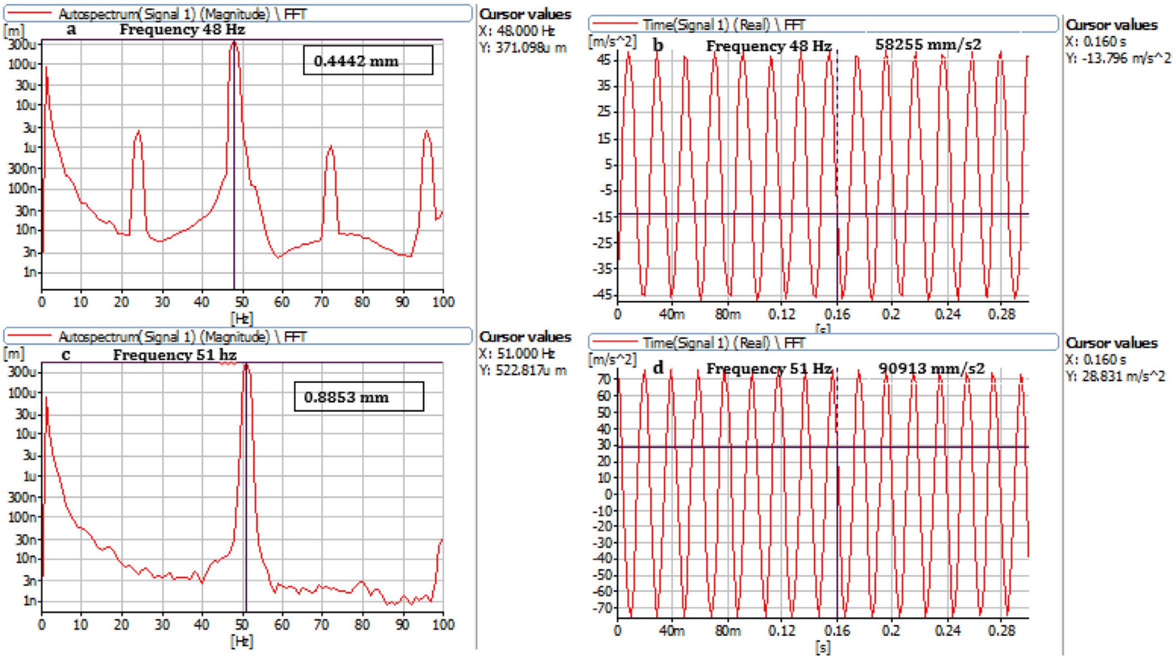


Fig. 5. Graphs Frequency vs Amplitude(a,c) and Frequency vs Acceleration (b,d) for Fixed Beam with One SMA Spring Dynamic Vibration Absorber at 305.1 mm from left fixed end.

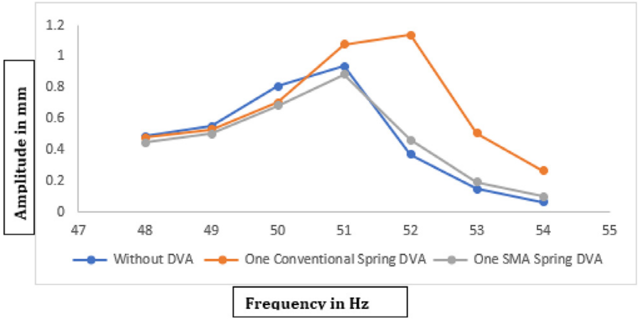


Fig. 6. Experimental Analysis of Vibration Amplitude for Without absorber, one Conventional & one SMA for Fixed beam.

due to the spring's lower stiffness, it enables the DVA to operate at a frequency range that would be impossible for a traditional spring DVA. Experimental values for SMA spring DVA are found in the temperature range of 219 degreesC, and these values are superior to those found when utilising traditional spring DVA. Since the SMA spring's stiffness at 219 degreesC is 4.932 N/mm, it is more rigid than a conventional spring, whose stiffness is 0.704 N/mm. Since the stiffness of SMA in this region can be enhanced by changing the temperature by varying the current from 0 to 3 A, this justifies the use of SMA springs instead of conventional springs. The experimental and analytical results of the SMA Spring DVA are in good accord. Table 2 and Fig. 4 display the reduction in vibration level based on experimental findings for Conventional Spring DVA. As illustrated in Fig. 4d, acceleration is found to be 121263 mm/sec^2 whenever the main system's vibration frequency is 52 Hz. This is due to the fact that the system is vibrating in its second primary mode, when stiffness is at its highest level of 0.704 N/mm. By switching from conventional spring DVA to a SMA spring DVA, whose stiffness is increased to its maximum value (4.932 N/mm), it is discovered that the acceleration level is reduced to 90913 mm/sec^2 by the natural frequency shift of the

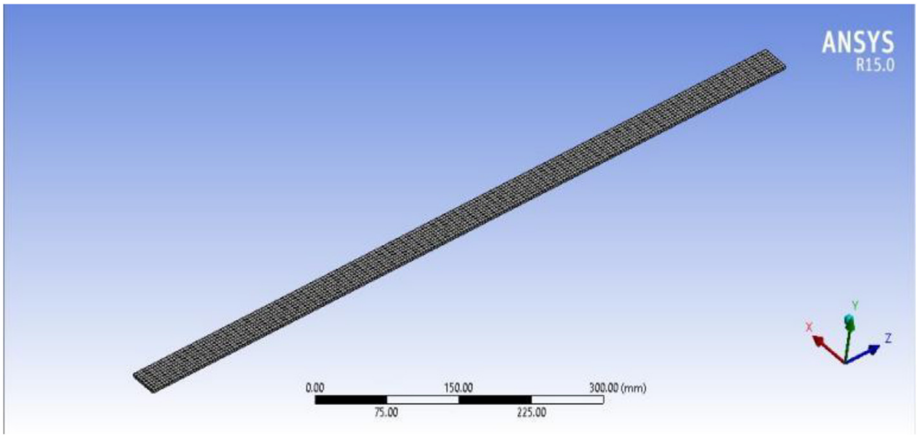
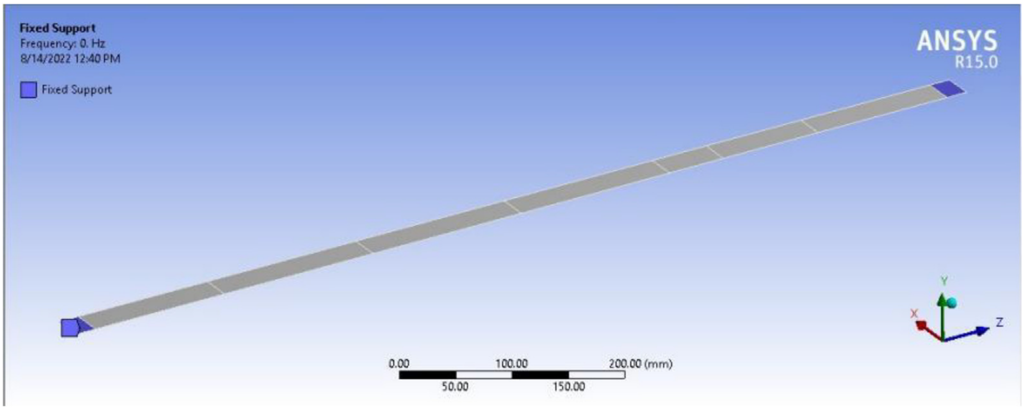


Fig. 7. Meshing of Fixed Beam.

system. So, by adjusting stiffness, the acceleration level is reduced by 33.383 %.

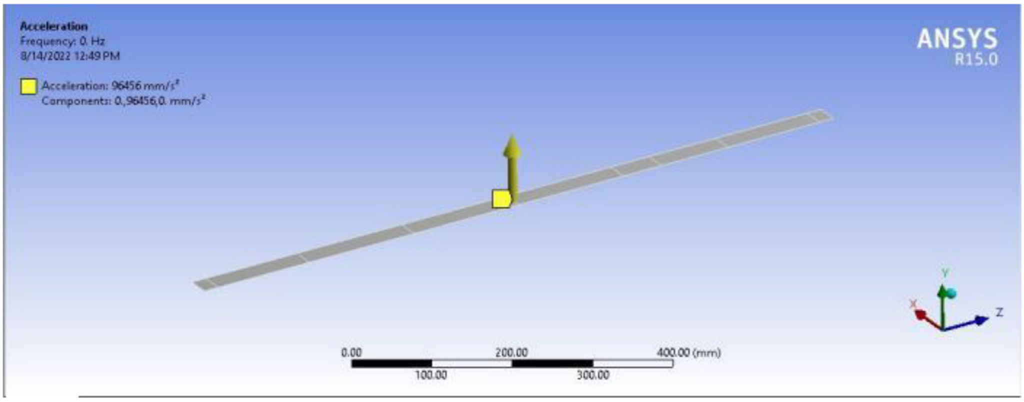
5. Numerical analysis

According to the experimental arrangement, the fixed beam with spring mass system is modeled in ANSYS Workbench R15.0. The specification of material characteristics and fine meshing were completed. Harmonic response analysis was carried out under various settings after the boundary conditions were determined. The results for vibration amplitude were calculated. The fine meshing of the beam model is depicted in Fig. 7. The beam has boundary conditions applied to it by being fixed at both ends, as seen in Fig. 8; therefore, as illustrated in Fig. 9, force was applied at the center of the beam in terms of acceleration. The acceleration vs frequency graph, which has been described as the RMS value in m/sec^2, was used to determine the force exerted by the exciter during experimentation for a specific frequency. This RMS value was translated to mm/s^2 and used as the same force on the stationary



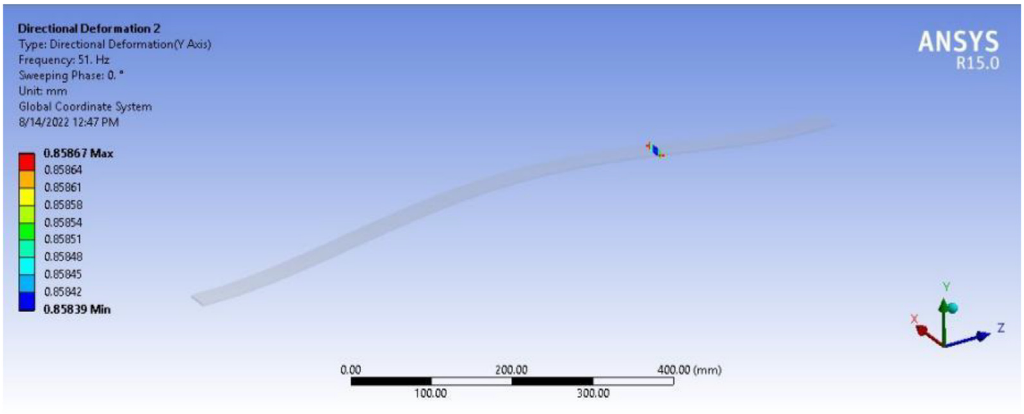
Fixed Support
Frequency: 0. Hz
8/14/2022 12:40 PM

Fig. 8. Boundary Condition applied to Fixed Beam.



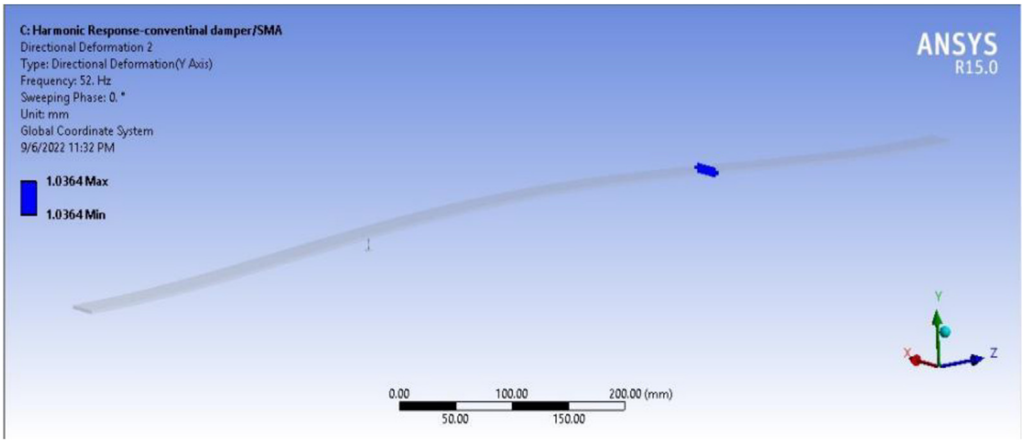
Acceleration
Frequency: 0. Hz
8/14/2022 12:49 PM
Acceleration: 96456 mm/s^2
Components: 0.,96456,0. mm/s^2

Fig. 9. Force applied at center of Fixed Beam.



Directional Deformation 2
Type: Directional Deformation(Y Axis)
Frequency: 51. Hz
Sweeping Phase: 0. °
Unit: mm
Global Coordinate System
8/14/2022 12:47 PM

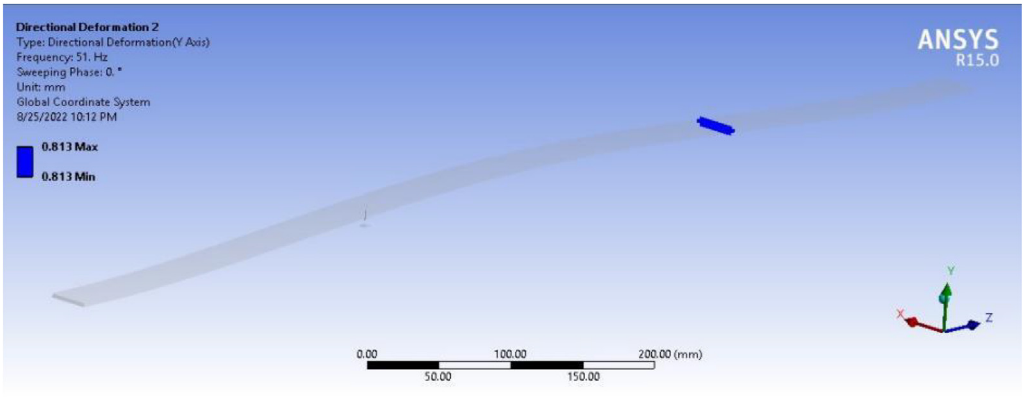
Fig. 10. Amplitude of vibration for 51 Hz using FEA without Dynamic Vibration absorber.



C: Harmonic Response-conventinal damper/SMA
Directional Deformation 2
Type: Directional Deformation(Y Axis)
Frequency: 52. Hz
Sweeping Phase: 0. °
Unit: mm
Global Coordinate System
9/6/2022 11:32 PM

1.0364 Max
1.0364 Min

Fig. 11. Amplitude of vibration for 52 Hz using FEA with one conventional Spring Dynamic Vibration Absorber.



Directional Deformation 2
Type: Directional Deformation(Y Axis)
Frequency: 51. Hz
Sweeping Phase: 0. °
Unit: mm
Global Coordinate System
8/25/2022 10:12 PM

0.813 Max
0.813 Min

Fig. 12. Amplitude of vibration for 51 Hz using FEA with one SMA Spring Dynamic Vibration Absorber.

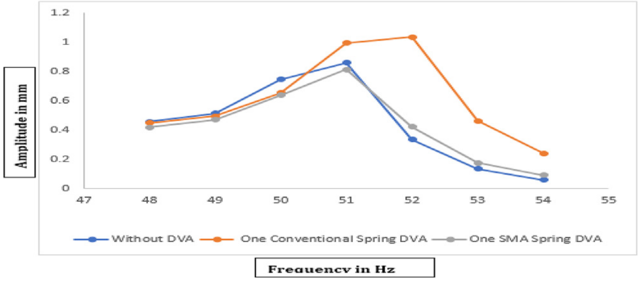


Fig. 13. Comparison of Vibration Amplitudes Using FEA for Without absorber, one Conventional & one SMA spring for Fixed beam.

beam during the experiment in the numerical analysis. The harmonic response analysis was performed for a frequency range between 48 Hz and 55 Hz, and results were derived for vibration amplitude. The peak values of amplitude for each set—without DVA, with one conventional spring DVA, and with one SMA spring DVA—are depicted in Figs. 10, 11, and 12 below. The model's and FEA's outputs are shown:

6. Conclusion

This work provided an up-to-date review of the usage of shape memory alloys in vibration control systems. This novel material's many unique properties open up new possibilities for the design and use of dynamic vibration absorbers for buildings and infrastructure systems. Significant progress has been made in the numerical modeling and real implementation of SMAs for vibration response control of civil engineering structures. The findings of this research and the limitations placed on the use of SMAs for structural vibration control can be summed up as follows:

- In this study, two analyses were performed numerically and experimentally to analyse fixed beams without DVA, with standard spring DVA, and with springs made up of a shape-memory alloy. The outcomes show how well SMA spring-based DVA works to control vibration, both experimentally and numerically.
- Without a dynamic vibration absorber, the values of amplitude and acceleration were 0.939 mm and 96456 mm/sec^2 respectively at a frequency of 51 Hz, and by using a single conventional spring dynamic vibration absorber, the values of amplitude and acceleration were 1.34 mm and 121263 mm/sec^2 respectively at a frequency of 51 Hz.
- One SMA Spring Dynamic Vibration Absorber was shown to be the most effective in damping vibrations through comparative analysis. Vibration can be reduced up to 18.421 percent by utilising a single SMA. The proportion of error is less than 8 %, and the numerical findings closely matched the experimental data.
- The outcomes show that the SMA spring reduces vibration more successfully. Analytical and experimental conclusions are contrasted with the outcomes of an experimental test on a Nitinol spring.
- In order to effectively regulate vibration, this paper demonstrates how to replace conventional spring DVA with SMA spring DVA while reducing its drawbacks. A 3A current is

passed through a Nitinol spring to raise its stiffness from 0.098 N/mm at ambient temperature to 4.932 N/mm at a temperature of 219 degree C. By adjusting the stiffness of the SMA, nitinol offers another method of stiffness tuning, allowing the dynamic vibration absorber to be adjusted smoothly.

- The analytical and experimental results for SMA spring DVA demonstrate that the combination of Nitinol springs and mass attached to them allows for the smooth and continuous tuning of SMA spring DVA.
- Tuning the absorber system significantly lowers the primary system's vibration level. As a result, smart materials reduce or completely eliminate the downsides of conventional materials, making it easier to regulate major system vibrations. The initial stiffness of SMA and the degree of stiffness shift can be controlled by varying the temperature between 0 and 3 A and selecting the right material properties.

CRediT authorship contribution statement

Shivam Shukla: Conceptualization, Methodology, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing. **Rahul Barjibhe:** Visualization, Supervision, Project administration.

Data availability

The data that has been used is confidential.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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