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Control of vibrations in smart intelligent structures for a multivariable case using fast sampling method

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Abstract - *Vibration control plays a very important role in the modern day world especially in control of earthquakes & in aerospace engineering. With reference to this, research is being carried out in this exciting field. Control of vibrations in smart intelligent structures for a multivariable case using fast output sampling method is presented in this paper. Simulation is carried out in Matlab & the results show the effectiveness of the method presented in this paper.*

Key Words: Smart structures, Fast output sampling, Vibration control, Beams, Sensors, Actuators.

1. Introduction

Smart materials such as sensors & actuators together integrated or embedded into the structure are what is called a "Smart Structure" and are often called as the intelligent structures, which are used for control of vibrations in structures & earthquakes. Smart materials are a subset of the smart structure [1]. Thus, a smart structure is a distributed parameter system that employs sensors & actuators at different finite element locations on the beam and makes use of sophisticated feedback controllers that analyze the responses obtained from the sensors and use different control logics to command the actuators to apply localized strains to the plant to respond in a desired fashion. Smart structures have also got the capability to respond to the changes in the environment on the plant, whether internal or external such as load changes or temperature changes [2]. A smart structure system comprises of 4 important sub-parts such as sensors, controller, actuators and the plant (flexible beam), whose condition is to be controlled [53]. Each component of this smart structure system has a certain functionality and the entire sub-systems are integrated to perform a self-controlled smart action, similar to a living creature who can "think", make judgment and take actions on own at the appropriate time, thus inducing the smart & intelligentness [3].

Smart materials and smart structures, often called as the intelligent structures form a new rapidly growing interdisciplinary technology in the modern day world, especially after the world trade centre disaster [4]. This smart structure technology enhances the structural properties by integrating sensors, actuators, signal-processing, electronics and control technologies into it, thus resulting in an improved overall dynamic performance [5]. These intelligent structures form the basis for the nanotechnology concepts. Numerous applications of this technology can be found in aerospace, civil, transportation, defense, flexible manipulators, MEMS, NEMS, bio-technology, automobiles, communications, antennas and in earthquakes [55] - [60]. One exciting and interesting example of its applications is the active vibration control (AVC) in structures such as in beams, plates, structures and in shells, which is our topic of research [6].

In recent years, this active vibration control of structural characteristics using smart materials such as piezoelectrics, SMA, ER-Fluids, MR-Fluids, PVDF and optic fibers, carbon nano-tubes, pyroelectrics, graphite, etc has received considerable attention and has become an important problem in structures [7]. One of the ways to tackle this vibration problem is to make the structure smart, intelligent, adaptive and self-controlling by making use of smart intelligent materials; else they may affect its stability, longevity and its performance [54]. These smart materials can be used to generate a secondary vibrational response in a mechanical system which has the potential to reduce the overall response of the system by the destructive interference with the original response of the system, caused by the primary source of vibration [8].

The paper is organized as follows. A brief review about the smart structures is presented in the introductory section. The control law used in the research work is presented in section 2 followed by the control simulations in section 3. Justifications of the simulation results are presented in section 4. The section 5 presents the conclusions of the work done. This is followed by the references & the author biographies.

2 Fast output sampling control law

The concept of how the control law is developed using the fast output sampling feedback control technique is shown in the Fig. 1 as [9]

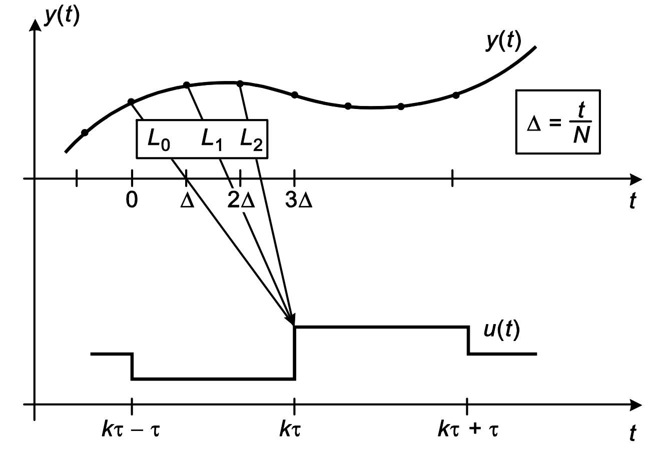

Fig. 1 : FOS method (graphical illustration)

The block diagram shown below in Fig. 2 gives overall information about the control strategy development as a dual feedback loop is incorporated [10].

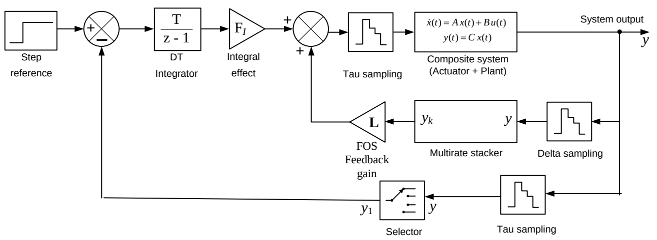

Fig. 2: FOS f/b method applied to the smart beam – Block diagram

In this section, we develop the control strategy for the MIMO representation of the developed smart structure model using the fast output sampling feedback control law developed by Werner and Furuta [55] [56] [57] with 2 actuator inputs u_1, u_2 and 2 sensor outputs y_1 , y_2 for the developed multivariable smart structure as shown in Fig. 3 as [11]

Physical Parameters	Aluminum Beam	Piezoelectric sensor / actuator
Length	L_b = 0.3 m	L_p = 0.075 m
Width	b = 0.025 m	b = 0.025 m
Thickness	t_b = 1.2 m	t_p = 1.2 m
Young's Modulus	E_b = 193 GPa	E_p = 68 GPa

Table 1 : Dimensions-Properties of Al Beam & PZT Sensor & Actuator

with the dimensions of the plant as shown in Table 1 [12].

Usually, as the complete state vector is not available for feedback, the design of a state observer is not a straightforward solution for multivariable and multimodel problems either [13].

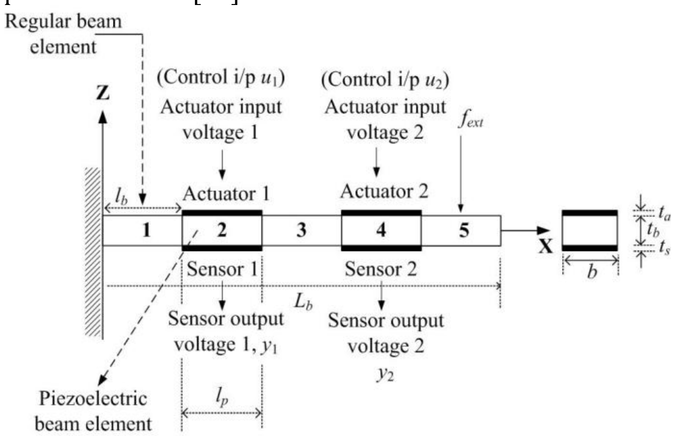

Fig. 3 : A MIMO smart beam (2 i/p & 2 o/p)

If the controller is to be implemented digitally on a computer, then a sampled data controller has to be designed anyway, and in this section it is shown how a robust sampled-data state feedback gain with zero-order hold can be realized by a fast output-sampling controller [55] [56] [57]. In this type of control law as shown in Fig. 1, the value of the input at a particular moment depends on the output value at a time prior to this moment (namely at the beginning of the period) [50]. Werner and Furuta [55] [56] [57] have shown that the poles of the discrete time control system could be assigned arbitrarily (within the natural restriction that they should be located symmetrically with respect to the real axis) using the fast output sampling technique [51]. Since the feedback gains are piecewise constants, their method could easily be implemented, guarantees the closed loop stability and indicated a new possibility [14]. Such a control law can stabilize a much larger class of systems [49]. The control objective is to sample the output $y(t)$ at a faster rate, i.e., at Δ intervals and applied to the controller at τ interval which is more advantageous [52]. At the same time, the states are not needed for feedback in the FOS case and here, we realize the state feedback using the output feedback [15].

2. Control simulations of the smart beam

The FEM and the state space model of the smart cantilever beam is developed in MATLAB using Timoshenko beam theory. The cantilever beam is divided into 4 finite elements and the sensor, actuator is placed as collocated pairs at finite element positions 2 and 4 respectively, thus giving rise to a MIMO beam. A fourth order state space model of the system is obtained on retaining the first two dominant modes of vibration of the system. The FOS control technique discussed in the previous section is used to design a controller to suppress the first 2 dominant vibration modes of a cantilever beam through smart structure concept for the multivariable model of the smart structure system using the developed state space model and its performance is evaluated for vibration control after carrying out the simulations in Matlab® [16]

The first task in designing the FOS controller is the selection of the sampling interval τ [18]. The maximum bandwidth for all the sensor / actuator locations on the beam are calculated (here, the 2nd vibratory mode of the plant) and then by using existing empirical rules for selecting the sampling interval based on bandwidth, approximately 10 times of the maximum 2nd vibration mode frequency of the system has been selected [45]. The second mode natural frequency was 34.36 Hz., thereby the sampling interval selected is $\frac{1}{10\times\omega_2}=\frac{1}{10\times 34.3655}\approx$ 0.003 secs [17]. The sampling interval is selected on the basis of the mode frequencies which in turn are a function of the system parameters of the **A, B, C, D** matrices which is turn is a function of the beam parameters [19].

Let $(\Phi_\tau, \Gamma_\tau, C)$ be the discrete time system (tau system) of the system be sampled at a rate of $1/\tau$ seconds respectively. It is found that the tau system is controllable and observable [20]. The ranks of the matrices are 4 [47]. The stabilizing state feedback gains are obtained for the tau system such that the eigenvalues of $(\Phi_\tau + \Gamma_\tau F)$ lie inside the unit circle and the response of the system has a good settling time. The impulse response of the system with the state feedback gain F is observed. Let (Φ, Γ, C) be the discrete time system (delta system) of the system be sampled at the rate of $1/\Delta$ secs respectively, where $\Delta = \tau / N$ [48]. The number of sub-intervals N is chosen to be 4. An external force $\mathbf{f}_{ext}$ (impulse disturbance) of 1 Newton is applied for duration of 50 ms at the free end of the beam shown in Fig. 4 and the open loop responses of the system are observed [21].

The fast output sampling feedback gain $\mathbf{L}$ for the system is obtained by solving $\mathbf{LC} \cong F$ using the LMI optimization method [5] which reduces the amplitude of the control signal u. When the controller is put in the loop, the closed loop impulse responses (sensor outputs y) with fast output sampling feedback gain $\mathbf{L}$ of the system is observed [22].

3 Simulation Results

The variation of the control signal with time for the MIMO model shown in the Fig. 3 are also observed. The tip displacements are also observed with and without the controller [23]. Simulations are also performed for the SISO based smart structure with one input and one output (Timoshenko beam divided into 4 finite elements with sensor & actuator at position numbering 2) and the open loop response, closed loop response with, the control input and the tip displacements are observed. The results are compared and the conclusions are drawn [24]. The FOS gain matrix for the MIMO model of the smart beam is given by

$$\mathbf{L} = 10^2 * \begin{bmatrix} -0.4868 & 0.4763 & -0.4683 & 0.4562 \\ -0.3456 & 0.3325 & -0.3235 & 0.3122 \end{bmatrix}$$

Research was carried out for the vibration suppression of cantilever beams. The beam was modeled using Timoshenko beam theory. MIMO concept (multiple input multiple output sensors) with 2 sensors & 2 actuators was used in the research work [25]. Controller was designed & when the designed controller was put in the loop, the vibrations died out very quickly. Coding was done in Matlab®10. The code was run, simulations were performed & the results were observed [26]. The open loop response (without the FOS feedback controller), the closed loop response (with the FOS feedback controller) with the FOS feedback gain $\mathbf{L}_1$, $\mathbf{L}_2$, the control input u_1, u_2 of the MIMO system to the actuator pair placed at finite element position 2 & 4 are shown from Fig. 4 to 9 respectively [27]. The tip displacements for the MIMO system without and with the FOS controller are also shown in Figs. 10 & 11 respectively [46]. Lengthy discussions were made on the observed simulated results, compared & finally commented for their effectiveness & justification. The quantitative & qualitative results shown in this section depicts the effectiveness of the proposed methodology developed [28].

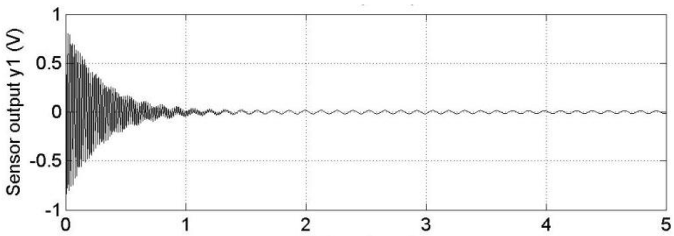

Fig. 4 : OL response of sensor-1 (y_1)

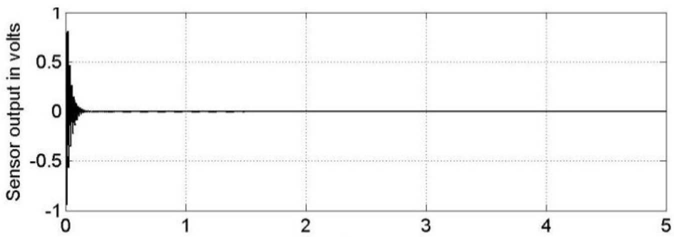

Fig. 5 : CL response of sensor-1 (y_1)

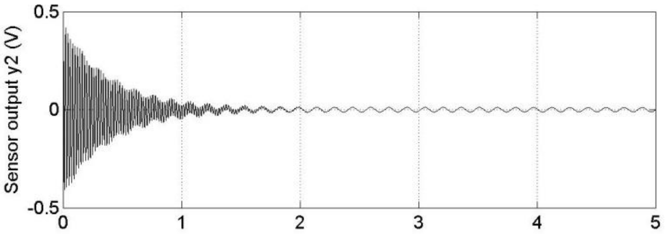

Fig. 6 : OL response of sensor-2 (y_2)

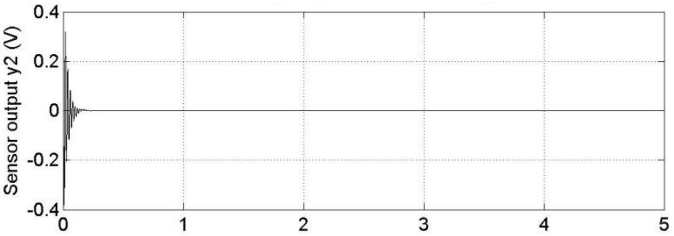

Fig. 7 : CL response of sensor-2 (y_2)

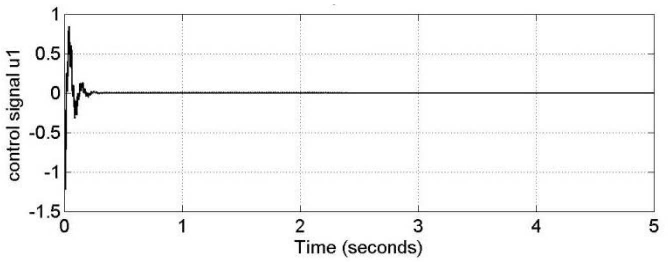

Fig. 8 : Control i/p to actuator-1 (u_1)

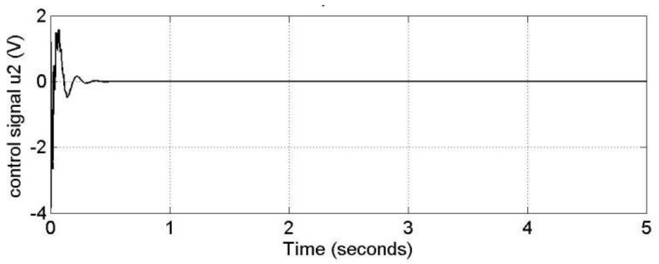

Fig. 9 : Control i/p to actuator-2 (u_2)

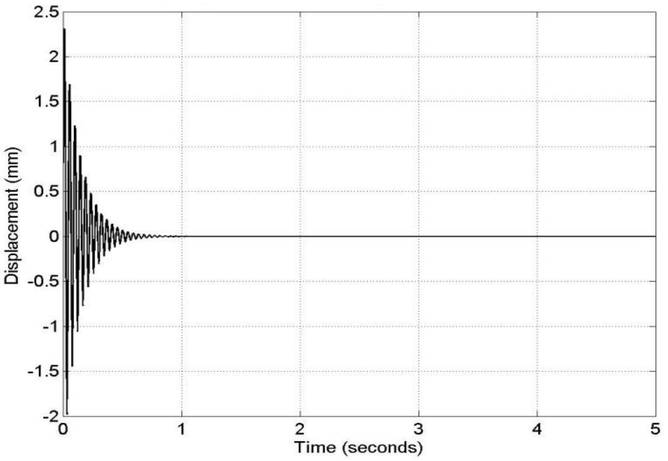

Fig. 10 : MIMO beam – Tip displacement w/o FOS controller

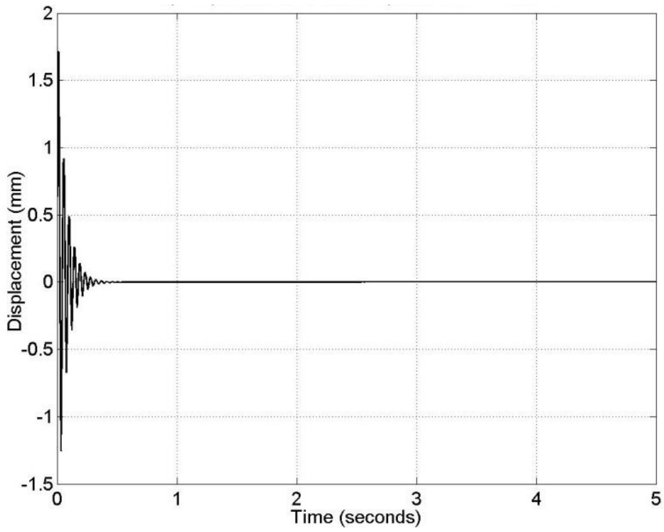

Fig. 11 : MIMO beam – Tip displacement with FOS controller

As shown from the bode plot in the Fig. 12, the 2 modes are well controlled [44]. The 1st mode is controlled from 20.4 dB to –87.7 dB, whereas the 2nd mode is controlled from 5.69 db to –85 dB which can be seen from the quantitative results depicted in the Tables 2 to 4 respectively [29].

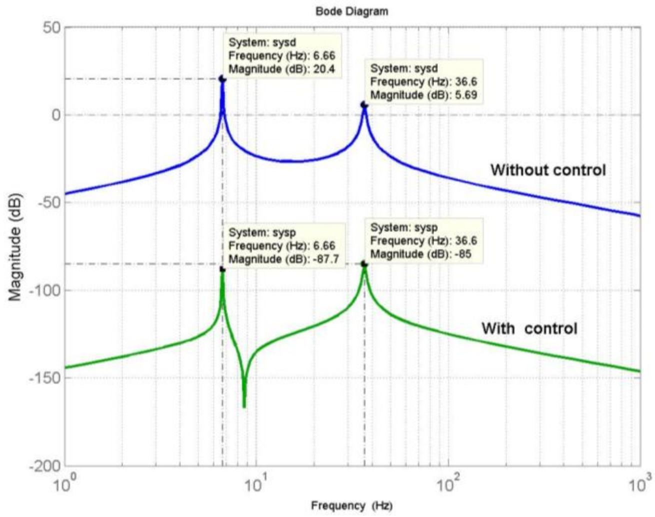

Fig. 12 : MIMO control of the 2 modes ω_1 & ω_2 and (magnitude)

Model	Sensor / Actuator pair	Bode plot Magnitude (without control)		Bode plot Magnitude (with control)		Modal frequencies	
		1st mode	2nd mode	1st mode	2nd mode	1st mode	2nd mode
Timoshenko MIMO	Finite Element Positions 2 , 4	20.4 dB	5.69 dB	– 87.7 dB	– 85 dB	6.66 Hz.	36.6 Hz.

Table 2 : The first 2 modes of vibration statistics

Model	Sensor / Actuator pair	Open loop response Sensor o/p y_1, y_2 (Settling time : secs)	Closed loop response Sensor o/p y_1, y_2 with SFB (Settling time : secs)	Closed loop response Sensor o/p y_1, y_2 with FOS f / b gain L (Settling time : secs)	Magnitude of control input u_1, u_2 (Settling time : secs)
Timoshenko MIMO	Finite Element Positions 2 , 4	0.96 V (6 secs), 0.78 V (8 secs)	0.92 V, (0.5 secs) 0.71 V (0.8 secs)	0.85 V, (0.2 secs) 0.65 V (0.35 secs)	0.84 V, (0.3 secs) 1.82 V (0.5 secs)
Euler-Bernoulli MIMO	Finite Element Positions 2 , 4	2.81 V, (7 secs) 1.98 V (9 secs)	2.72 V, (0.6 secs) 1.88 V (1 secs)	2.7 V, (0.4 secs) 1.84 V (0.6 secs)	1.6 V, (0.5 secs) 2.3 V (0.8 secs)

Table 3 : Results of the Matlab Simulation results (different responses) using FOS method

Model	Sensor / Actuator pair	Tip displacement magnitude, without control (settling time in secs)	Tip displacement magnitude, with control (settling time in secs)	% reduction in settling time of the tip displacement curve
Timoshenko MIMO	Finite Element Positions 2 , 4	2.4 mm, (1.5 secs)	1.8 mm, (0.5 secs)	66.66 %
Euler-Bernoulli MIMO	Finite Element Positions 2 , 4	3 mm, (2.5 secs)	2.5 mm, (1 secs)	60 %

Table 4 : Matlab Simulation results of the MIMO system's tip displacement

4 Justification of multivariable method for vibration control

Timoshenko beam theory has been used to model the beam and the piezoelectric patches, thereby, obtaining an accurate state space model starting from the finite element model incorporating the shear and the axial displacements [30]. Then, the fast output sampling feedback controller has been designed for the MIMO smart structure state space model by retaining the first 2 vibratory modes. The beam was divided into 4 finite elements with sensor / actuator pair placed at finite element positions 2 and 4. The various responses are obtained for the designed model [31]. Through the simulation results, it is shown that when the plant is placed with this controller, the plant performs well. It is also observed that modeling a smart structure by including the sensor / actuator mass and stiffness and by placing the sensor / actuator at 2 different positions introduces a considerable change in the structural vibration characteristics than placing at only one location, i.e., for a SISO case [32].

The results obtained using the Timoshenko beam theory was also far better than the results obtained for the same beam modeled using Euler-Bernoulli beam theory approach. The simulation results is presented and compared on a table using the numerical results [43]. The designed FOS feedback controller thus requires constant gains and hence is easier to implement in real time. In this work executed, for the multivariable case, it is observed that when the pair is kept at 2 different locations, the open and closed loop responses of the MIMO system is less oscillatory compared to the single input single output case [33].

The responses for the MIMO case takes lesser time to settle than the beam modeled using Timoshenko theory for SISO case because of the multiple interactions of the inputs and the control effort u required is also less. The state feedback gain for the multivariable plant is obtained so that its poles are not placed at the origin and has a good settling time. The pair kept at position 2 controls the two vibratory modes at that finite element position 2, while the pair kept at position 4 also controls the two vibratory modes, but placed at that finite element position 4. Overall performance of the system is better than the SISO case and for the MIMO Euler-Bernoulli beam as the Timoshenko model is an accurate model. Hence, it can be concluded that [34]

- Multivariable control of a smart structure is better compared to the single input single output control as the two vibratory modes can be suppressed to a larger extent at two different finite element positions and
- The response characteristics with f and with also are improved
- The tip displacements are improved and the vibrations dampen out quickly in this case compared to other siso case and due to the multiple interactions of the input and the output [35].

For example, mode pairs in MIMO system will be originally interpreted as a single mode in SISO. Depending on the application, the smearing of the mode pairs into single modes may adversely affect the control algorithm, depending on the algorithm's sensitivity to the identified resonant frequencies of the system [37]. MIMO excitation is better than SISO excitation as only exciting at a single point may cause poor distribution of input energy throughout the structure and may result in somewhat slightly disturbed frequency responses [42]. A multi input test provides better energy distribution and even better actuation forces [36].

Responses are obtained without control and are compared with the control to show the control effect [40].

It was inferred that without control the transient response was predominant and with control, the vibrations are suppressed. Active vibration scheme was also investigated for the Timoshenko MIMO model by considering the first 3 vibratory modes. The order of the state space matrices obtained was of 6^{th} order [39]. It was found that the responses were almost looking the same like the responses of the system when first two modes were considered. Hence, a fourth order model with the first 2 dominant vibratory modes is sufficient to model a smart beam [41].

5 Conclusions

In this paper, control of vibrations in smart intelligent structures for a multivariable case using fast sampling method was presented. The simulation results show the effectiveness of the method developed for vibration suppression. MIMO dynamic analysis is able to identify pairs of modes that occur at nearly identical frequencies. SISO experiments are not actually reliable when it comes to accurate identification of mode pairs because they are unable to positively decipher mode pairs from signal noise in the measured Frequency Response Functions (FRF). Thus, an integrated finite element model to analyze the vibration suppression capability of a smart cantilever beams with surface mounted piezoelectric devices based on Timoshenko beam theory with multi-input-output interaction with 2 modes is proposed in this paper and is sufficient to characterize the vibrations [38].

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BIOGRAPHIES

Dr. T.C. Manjunath was born in Bangalore, Karnataka, India on Feb. 6, 1967 & received the B.E. Degree (Bachelor of Engg.) from R.V. College of Engg. (Bangalore Univ., B'lore) in the year 1989, M.E. degree in Automation, Control & Robotics from the prestigious Govt.'s LD College of Engg., (Gujarat Univ., Ahmadabad) in the year 1992 and Ph.D. in Systems & Control Engineering from the prestigious Indian Institute of Technology Bombay (IIT Bombay) in the year 2007 respectively. He has got a teaching (academic), research & administrative experience of more than 25+ years in various engineering colleges all over the country (Karnataka, Gujarat, Maharashtra). He has worked in the levels of Lecturer-Asst. Prof. (17 yrs), PG Coordinator, Prof-i/c HOD-Prof. & Head (> 2 yrs), Director-Research, i/c Principal & as Full time Principal (> 6 yrs-Atria IT, BTLITM, HKBKCE, Dr. AIT) in the various institutions where he has worked so far. Currently, he is working as the Principal of the famous NICE group's 'Nandi Institute of Technology & Management Sciences' in Bengaluru, Karnataka. He has also worked as a Project Assistant and as a Research Engineer in the Systems and Control Engineering (IIT Bombay, India) and worked on control of space launch vehicles using FOS feedback technique in IITB. He has published a number of papers in various National, International journals and Conferences in India & abroad and published more than a dozen textbooks, notable among them being ('*Introduction to robotics*' - 1st edition, '*Fast Track to Robotics*' - 4th edition, '*Fundamentals of Robotics*' in 2 volumes, Vol-1 and Vol-2 along with a CD which contains about 200 C / C++ programs for performing various simulations on robotics – 5th edition, '*Examination Security System - Design & Development of Examination Mechanism Using Electronic Box*' from Germany costing around 49 Euros). He has also published a number of '*book chapters*' in various edited books from renowned publishers. He has also published a research monograph in the International level from the Springer-Verlag publishers (Europe) based on his Ph.D. thesis topic titled, "*Modeling, Control and Implementation of Smart Structures*", Vol. 350, LNCIS, costing 114.95 Euros. He is a member of 21 professional societies. Some of them are … He is a member of IEEE for the past 13 years (currently Sr. Member), Sr. member of IIIE, SPIE student member and IOP student member for 4 years, life member of ISSS (India), life member of additive manufacturing society of India (LMAMSI), life member of the ISTE (India), life member of ISOI (India), life member of SSI (India), life member of the CSI (India), Life member of IMAPS, Sr. Member of IACST (Singapore) and life member cum fellow of the IETE (India), AMSI, Chartered Engineer from IE (I) and Fellow of the Institute of Engineers (FIE). He has given a number of guest lectures / expert talks and seminars in many institutions across the country and participated in more than 2 dozen CEP / DEP courses, seminars, workshops, symposiums, besides conducting a few courses in the institutions where he worked. He was awarded with the "Best research scholar award in engineering discipline" for the academic year 2006-07 for the entire institute from the Research Scholars Forum (RSF) from Indian Institute of Technology Bombay (IITB). This award was presented in recognition of the significant contribution to the research (amongst all the researchers in all disciplines) in IIT Bombay. Also, he was conferred with the best paper awards in a number of conferences. He was also conferred with the prestigious Rajiv Gandhi Education Excellence Award, Rashtriya Vidya Gaurav Gold Medal Award & International educational excellence award (in recognition of sterling merit excellence performance and outstanding contribution for the progress of the nation & world-wide) from New Delhi in the year 2013 w.r.t. his achievements in the field of education, academics, administration & research. He was also instrumental in getting Research centres (12 nos.) along with M.Tech. programmes & new UG programmes in the colleges where he has worked so far as the administrative head. He was also responsible for getting AICTE grants under MODROB scheme for the development of the Robotics & Mechatronics Labs in one of the colleges where he worked. Apart from which, he has brought a number of grant-in-aid for the conduction of various events like workshops, conferences, seminars, projects, events, etc., wherever he has worked [from VTU, DST, IETE, CSI, IEEE, IE(I), VGST, KSCST, Vodafone, Uninor, etc.] from different sources. He has visited Singapore, Russia, United States of America, Malaysia and Australia for the presentation of his research papers in various international conferences abroad. His biography was published in 23rd edition of Marquis's Who's Who in the World in the 2006 issue. He has also guided more than 2 dozen projects (B.E. / B.Tech. / M.E. / M.Tech.) in various engineering colleges where he has worked, apart from guiding a couple of research scholars who are doing Ph.D. in various universities under his guidance. Many of his guided projects, interviews, the events what he had conducted have appeared in various state & national level newspapers and magazines (more than 110 times). He has also reviewed many research papers for the various national & international journals & conferences in India & abroad (more than 5 dozen times). He has also organized a number of state & national level sports tournaments like yogasana, chess, cricket, volleyball, etc. He is also an editorial board / advisory board / reviewer member and is on the panel of many of the national & international Journals. He has also served on the advisory / steering / organizing committee member of a number of national & international conferences. He has given many keynote / invited talks / plenary lecturers in various national & international conferences and chaired many sessions, was the judge, special invitee, guest of honor & was the chief guest on various occasions. He has also conducted / organized / convened / coordinated more than 175+ courses / workshops / STTP's / FDP's / Technical paper fests, Student level competitions & Symposiums, etc., in various engineering colleges where he worked so far. He has also taken many administrative initiatives in the college where he has worked as HOD, Principal & also where he is currently working as Principal, besides conducting all the semester university exams successfully as chief superintendent, deputy chief superintendent, squad member, etc. Some of the special administrative achievements as HOD, Principal & Head of the Institution are …. He improved the results of the various branches in East West Inst. of Tech. / New Horizon College of Engg. / Atria Inst. of Tech. / BTL Inst. of Tech. / HKBK College of Engg. / Dr. Ambedkar Inst. of Tech. He gave more importance to the development of in-house projects for the final years. He has also He motivated many of the faculties to take up take up consultancy works & did it efficiently, so that the college got some good income. He made the faculties to take up research (Ph.D) work or do M.Tech. by compelling them constantly to purse for higher studies. As an administrative head, he made the faculties to publish paper in either national / international journals & conferences at least one in an academic year. He started the student chapters in all the branches such as IETE, IEEE, ISTE, CSI, SAE, ISSS, ISOI & also conducted a number of events under their banners. He brought in power decentralization in the institute by developing the habit of making coordinator-ships for various works, getting the work done by monitoring and following it up successively. He was also involved in TEQIP-2 process in Dr. AIT along with the development of many of the autonomy works. He conducted a number of exams from public sectors & private sectors such as GATE exams, CET / COMED-K, KPSC, Police Exams, Inst. of Civil Engineer exams & conducted a number of state & national level examinations like Defense, PG entrance exams, Medical, KPTL in the college so that the college could get some revenue (under the banner of revenue generation scheme). He started the weekly monitoring of the staff & students. He developed the counseling of student data booklets & that of the faculty work-books. All the laboratory manuals were developed in-house, printed & given to the students (both in the hard as well as in the soft copy). He used to conduct the academic & governing council meetings regularly along with the HOD's meetings time to time. He had looked after the NBA process in Fr. CRCE, BTLITM, HKBKCE & in Dr. AIT. He conducted the prestigious 7th IETE ICONRFW & the 28th Karnataka State CSI Student Convention. He introduced the scheme of best lecturer award / best HOD award / best non-teaching award / service awards concept / Principal cup / Departmental cup, etc. in the colleges where he worked as administrative head. He created a record placement of more than 600 students in Atria Inst. of Tech. / BTLITM & in HKBKCE with the help of the placement department. He helped the management to fill up many of the student admissions in the first year of UG (B.E.) & in PG (M.Tech.) course. He created a number of hobby-clubs, EDC cells, Innovation & Incubation centres, centre of excellences in the institute for the staffs & students to work towards development of prototypes, models, and projects. He started the faculty seminar series in the institute so that every faculty gives a lecture of 45 mins with 15 mins discussion at least once in a month. He introduced the concept of coaching class / tutorial classes for the weak students & remedial class concept for the failed students, which yielded successful results apart from the training of top 10 students for getting ranks (9^{th} / 3^{rd} Rank). He made the students to get university ranks in BTL & HKBKCE in UG stream. He started certificate oriented courses of 3 months & 6 months for the various types of people, especially on Saturdays & Sundays. He made the students to participate in competitions outside the college & win a number of prizes, brought laurels to the institution. He helped the students to get some financial assistance using sponsors for the cultural events. He brought a grant of nearly Rs. 3 crore till date in the various organizations where he has worked so far with help of faculties. He developed the Innovation & Entrepreneurship Development Cell in HKBKCE & did a number of programs under its belt. He was responsible for some of the UG students of HKBKCE to make them establish a start-up company in the college itself by name '*pentaP systems*'. He made more than one dozen MOU's with reputed firms & sectors with the college and utilized all the advantages of the signed MOUs with the companies. He streamlined many of the process in the office level & that of the departmental level by developing new formats for the smooth conduction of various processes along with excellent documentation. He developed the culture of making up of small / mini hobby projects by the students. He developed the system documentation of the entire departments & that of the college. Under industry-institute interaction, he conducted a number of industry oriented courses like CADD course, ANSYS course, Oracle course, Infosys campus connect courses (18 batches rolled out in HKBKCE), Software testing, etc. His special areas of interest are Control systems, DSP, AI, IP, Robotics, Signals & systems, Smart Intelligent Structures, Vibration control, Instrumentation, Circuits & Networks, Matlab, etc.…..

Mr. Arun Kumar G (B.E., M.E., (Ph.D.), MISTE, IETE, IAENG) was born in Davanagere, Karnataka, India on Oct. 15th, 1981 & received the B.E. Degree (Bachelor of Engg.) from STJ Institute of Technology, Ranebennur in Karnataka in the year 2004, M.Tech. degree in Digital Communication & Networking from the prestigious UBDT College of Engg., Davanagere in the year 2008 and Pursuing Ph.D. in Electronics in Visvesvaraya Technological University, Belgaum as a research scholar in VTU in the department of ECE. He has got a teaching & administrative experience of more than 8 years in engineering colleges in Karnataka. He has written a number of notes in various subjects as Basic Electronics, AEC, Power Electronics, Communications & his notes are widely famous all over the country. He has attended a number of certificate courses, workshops, FDPs, Symposiums, etc. He has published more than 2 dozen papers in various subjects of engineering field. His current areas of interest are control systems, power electronics, basic electronics, micro-controllers, embedded systems, communications etc.…