Starting from modelling and experimental studies in the field of smart structures, we have diverged to a broad field of enabling technology through synthesis, and subsequently, converging to develop intelligent systems with varied applications. Our Interdisciplinary research experience cuts across the fields of Mechanical, Electrical and Materials Engineering.
Shape and Vibration Control using SMA

Shape Memory Alloy (SMA) wire based shape and vibration control has been widely studied by various researchers for a gamut of active structural systems composed of simple structural elements like trusses, beams and plates. In our research, we demonstrate the shape control of a model parabolic spacecraft antenna reflector surface with the help of SMA (Shape Memory Alloy) wire actuators. It has been demonstrated that a Polycarbonate parabolic antenna surface fitted with curved acrylic stiffeners at the back could be actively deformed by a network of SMA wires. The active transformation of SMA wires lead to the generation of end moments and forces at the control points which can deform the stiffener and thereby the antenna structure. This procedure can generate a maximum deflection greater than 3mm (3000 μm) at the antenna surface and can be used for macro shape control. By controlling the current in the SMA wires selectively one can achieve both inward and outward deflection. Different antenna configurations are generated by activating the SMA wires.

Trajectory Control of Flexible Planar Mechanisms using Smart Actuators

Motor-less flexible planar mechanisms are being increasingly developed for high-precision trajectory tracking and assembly process. Muscle-like materials (Electro-active polymers) have been used for this purpose. Our research started with forward and inverse analyses of the response of a compliant link actuated by a discretely attached SMA wire subjected to a time-varying input voltage. The framework for constrained recovery of the shape memory alloy wire is developed from a robust numerical model. The model for the large deflection of a beam element, due to follower forces resulting from discrete actuation using SMA wire, is coupled with the proposed framework. Thus the response of the link is correlated with the input voltage. Further, a novel smart compliant mechanism is developed for path generation. The mechanism consists of two rigidly connected compliant links, each actuated by an SMA wire attached discretely. The voltage profiles to be applied to the SMA wires to obtain the prescribed response are determined first based on a model. Keeping the theoretically derived voltage profiles as reference, a hybrid controller is developed and implemented in Simulink®. The controller modifies the reference voltage depending on the feedback error. The feedback is obtained analyzing the images of the area of interest captured by a camera. The complex path generating capability of this SMA actuated planar compliant mechanism has been demonstrated through various experimental results.
Dynamic Response based Structural Health Monitoring

Composite materials are currently extensively used in structural applications related to mechanical, civil and aerospace systems. Due to the possibility of inherent damages in the form of delaminations during fabrication process, often the performance of such laminates gets degraded which may even lead to catastrophic failure. The traditional structural health monitoring process mainly deals with the off-line detection of damages by ultrasound scanning techniques. In our research, we have focused on the detection of delamination by using dynamic response of composite laminate which can be used for on-line structural health monitoring. For this purpose, we have taken recourse of two techniques. One is based on dynamic response from an upgraded finite element model of the system. In the numerical analysis, we have identified damage in laminates by observing three different indices: Curvature Mode Shapes, Curvature Damage Factor and Damage Index. Another technique is based on damage prediction by using the operational deflection shape of the laminates obtained from the scanning by 3D Laser Doppler Vibrometer. This technique is also being extended to study the variations of other mechanical property sets like the extent of layer hardening in an induction hardening process.

Pipe-crawling Robots for Health Monitoring

Due to corrosive environment, pipes used for transportation of water and gas at the plants often get damaged. Defects caused by corrosion and cracking may cause serious accidents like leakage, fire and blasts. It also reduces the life of the transportation system substantially. In order to inspect such defects, a Polyvinylidene Fluoride (PVDF) based cantilever smart probe is developed to scan the surface quality of the pipes. The smart probe, during rotation, touches the inner surface of the pipe and experience a broad-band excitation in the absence of surface features. On the other hand, whenever the probe comes across any surface projection, there is a change in vibration pattern of the probe, which causes a high voltage peak/pulse. Such peaks/pulses could give useful information about the location and nature of a defect. Experiments are carried out on different patterns, sizes and shapes of surface projections artificially constructed inside the pipe. The sensor system has reliably predicted the presence and distribution of projections in every case. It is envisaged that the new sensing system could be used effectively for pipe health monitoring.
Projects Completed as Principal Investigator

Development of Hybrid Damper for Rotating Flexible Manipulator, AR&DB
Development of Smart Prosthetic Limbs, MHRD
Calibration of Portable Hardness Testing System, HAL
Development of High Performance Composite, MHRD
Micro-hardness Study of Chrome Coated Metals, HAL
Development of a Novel Turn-Indicator Mechanism using SMA, GM
Development of Force Reflecting Surgical Robot, DST
Control of Flexible & Reconfigurable Parabolic Antenna using SMA, ISRO
Design of a Smart Fully Compliant Mechanism for Trajectory Tracking, DST
Modelling & Development of Multiphase Broadband Damping System, AR&DB
Development of Digital Bore Measuring Instrument, NAIR
Deflection & Vibration Compensation of GAS Pipe Line, GAIL
Modelling, Simulation & Validation of Main & Tail Rotors of LHC, HAL
Design Clinic Initiation at IITK, NID

Projects Carrying out as Principal Investigator

Optimal Vibration Control of Composite Structure, DST-UKIERI
Design of Steel Sluice Gates for Ramganga Barrage, GHANRAM
Integrated Sensing, Monitoring and Healing for Complex Systems UKIERI

International Collaboration

with University of Sheffield, UK

The UK-India research initiative and DST, India have jointly funded a project of Profs. Peter Fleming and Bishakh Bhattacharya in which the delamination in composite laminate could be detected and controlled in real-time by using the dynamic response of the system. The technology is envisaged to be highly demanding in the field of Health monitoring of Composites for Aerospace applications.

with Wasada University, Japan

Through a productive link with Prof. Harutoshi Ogai of Waseda University, Japan, our lab has developed crawler robots for pipe health monitoring. The two robots Mushik and Mogurinko are developed with touch sensors which can sense the faults in pipes precisely.
Recent International Publications

PZT-PDMS Composite for Active Damping of Vibrations, Composites Science and Technology, CSTE-D-12-00227R2; Satinder K. Sharma, Himani Gaur, Manish Kulkarni, Ganesh Patil, Bishakh Bhattacharya and Ashutosh Sharma (Accepted for Publication)


A New Shape Memory Alloy based Smart Encoder for Sensing of Direction and Angular Motion, Sensors and Transducers , Vol. 4, No. 127, pp.45-56, 2011; B. Bhattacharya and O.P. Patel


Patents


A green harvesting device for low power electronic equipment, IN. 232707, 2012, Bishakh Bhattacharya and Atul R Sultane

A new semi autonomous drug infusion system using smart material, IN-811469, 2012, Vimal Kumar and Bishakh Bhattacharya
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