

Application of Smart Materials in Smart Structures

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ABSTRACT: Smart materials are expected to be an important ingredient of third-generation structures. Candidate smart materials for structural applications include optical fiber-based sensors, Ferro-magnetic sensors, shape memory alloys and piezoelectric sensors. As sensor technologies advance, periodical evaluations of their performance should be conducted to identify the best-performing sensors available for the measurement of structural responses (e.g. displacement, velocity, acceleration, strain, and stress) and detecting structural damage (e.g. cracking, fatigue and corrosion). Such evaluations should consider their performance (e.g. reliability, sensitivity, integrity, and robustness) not only as stand-alone sensors but more importantly when externally attached to structural members as well as internally embedded in concrete and FRP materials. In construction, smart materials and systems could be used in 'smart' buildings, for environmental control, security and structural health monitoring e.g. strain measurement in bridges using embedded fiber optic sensors. Magneto-rheological fluids have been used to damp cable-stayed bridges and reduce the effects of earthquakes. In marine and rail transport, possibilities include strain monitoring using embedded fiber optic sensors. The paper discuss about types of smart materials, smart sensing Technology, components of smart structures, various sensors i.e. Fiber optic sensor, smart concrete, smart structure for seismic protection, health monitoring of smart structure.

KEYWORDS: Piezoelectric, sensor, sensitivity.

I.INTRODUCTION

The critical deterioration of transportation infrastructure across the continent, including highways and bridges, has driven the search for new methods of concrete rehabilitation and repair. There has been a new trend in civil engineering called 'smart structures', incorporating sensors in some of the most advanced building materials. The researchers would also like to install smart structures and to develop remote systems that would allow monitoring by centrally located computers, rather than the time and expense involved in sending work crews for on-site inspections.

Scope for Applications

In this competition, in each of the application areas described above, two broad areas of technology are included: Smart Thin Film Coatings, e.g. Electro chromic coatings for energy efficiency measures in the modern built environment Smart Structures, e.g. structures, with integrated sensors and actuator materials, which might eliminate the need for heavy mechanical actuation systems or damping systems through their functionality for shape change or vibration control [1-2].

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

Smart Structures

Key areas of focus for the development of smart structures to include:

- Miniaturization and integration of components, e.g. application of sensors or smart materials in components
- Robustness of the smart system, e.g. interfacial issues relating to external connections to smart structures [3]
- Structural health monitoring, control and lifetime extension (including self-repair) of structures operating in hostile environments, e.g. vibration control in Aerospace and Construction applications. Thermal management of high temperature turbines for power generation. Self-monitoring, self-repairing, low maintenance structures, e.g. Bridges and rail track.

II.SMART MATERIALS

The "smart" or "intelligent" materials respond with a change in shape upon application of externally applied driving forces. Typically this shape change is reflected in an elongation of the sample, thus allowing their use e.g. as a small linear motor [4]. The term "smart materials" describes a group of material systems with unique properties. Some materials systems do not exhibit a shape change, but rather have other significant properties are also called smart materials. Examples of "other" smart materials include electro- and magneto rheological fluids [5]. These fluids can change viscosity over many orders of magnitude upon application of an external magnetic or electric field.

Types of Smart Materials

Smart/Intelligent structure applications are wide ranging from active shape control, vibration and noise control, improved damping and aero elastic stability to change stress distribution. The various types of smart materials used in smart structures are as listed below [6].

- Piezoelectric Materials (PEM)
- Fiber optics
- Shape Memory Alloys (SMA)
- Electro-Rheological Fluids (ERF)
- Magnetostrictive Materials
- Electrostrictive Materials

Smart Sensing Technology

Conventional and smart sensing technologies will be employed in these structures. The sensing materials and technologies that will be used include strain gauges, piezoelectric materials, fiber optics, and TRIP technologies [7].

Strain gauges

Strain gauges will be used to monitor the strain in all of the bridge elements. Because these sensors have been used extensively for many years, they will serve as a basis for comparison in order to monitor and evaluate the performance of the smart sensors. Although strain gauges are not as sensitive, nor as accurate as piezoelectric sensors, the expected strains will be large and the strain gauges will be sufficient [8].

Piezoelectric materials

Piezoelectric materials may be used passively as sensors, or actively as actuators. The piezoelectric sensors that will be used on this bridge include the PZT (lead-zirconate-titanate), a ceramic sensor, and PVDF (polyvinylidene fluoride), a polymeric sensor. The PZT's are extremely sensitive and very accurate, but due to their brittle nature, PZT's are restricted to being point sensors. Likewise, PVDF's are also very sensitive and accurate. However, PVDF's are not as brittle and may

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 4, Issue 7, July 2015

be integrated to perform distributed measurements. Therefore, PZT's will be located primarily in critical areas, whereas the PVDF's will be located along side the strain gauges.

III.SMART STRUCTURES

Smart building is one which monitors itself or that monitors itself and its environment in order to respond to changes in its condition. In large civil engineering structures such as bridges, an integrated instrument system could tell both maintenance in charge or the user of the structure, an enormous amount about both the environmental and traffic loading conditions and the general conditions of the bridge , when and whether it will be in need of structures.

Features of Smart materials and structures

The majority of research focused on the intelligent civil structure has been in two areas:

1. Identification of structural behavior or properties (e.g. deformation, energy usage, damage evaluation etc.).
2. Control of structural response to external (e.g. wind, earthquake) (or) internal (E.g. acoustics, temperature variation) stimuli.

Components of a smart structure

A smart structure is a system that incorporates particular functions of sensing and actuation to perform smart actions in an ingenious way.

The basic five components of a smart structure are summarized as follows,

- **Data Acquisition**(tactile sensing): the aim of this component is to collect the required raw data needed for an appropriate sensing and monitoring of the structure.
- **Data Transmission**(sensory nerves): the purpose of this part is to forward the raw data to the local and/or central command and control units.
- **Command and Control Unit** (brain): the role of this unit is to manage and control the whole system by analyzing the data, reaching the appropriate conclusion, and determining the actions required
- **Data Instructions**(motor nerves): the function of this part is to transmit the decisions and the associated instructions back to the members of the structure.
- **Action Devices**(muscles): the purpose of this part is to take action by triggering the controlling devices/ units.

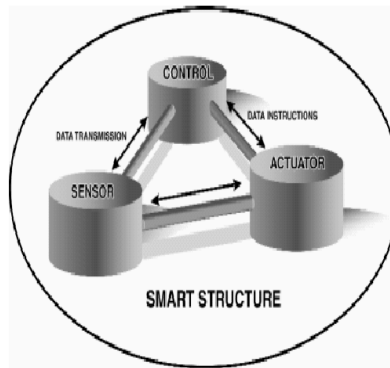


Fig 1 The Basic Components of Smart Structure

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

IV.SMART CONCRETE

Smart concrete was developed by Dr.Deborasd.l.chung from state university of New York at buffalo, smart concrete is reinforced by carbon fiber as much as 0.2% to 0.5% of volume to increase its sense ability to stress or strain while still has good mechanical properties by adding small amount of short carbon fiber into concrete with conventional concrete mixer, the electrical resistance of concrete increases in response to stress or strain. As the concrete is deformed to stressed, the contact between the fiber and cement matrix is affected, thereby affecting the volume electrical resistivity of the concrete. A strain is detected through measurement of the electrical resistance.

Benefits

- Smart concrete is stronger than conventional concrete by use of carbon fibers, the extra cost of material will increase about 30%, and this expense is still significantly cheaper than attaching sensor into structures.
- It takes greater force for smart concrete to bend and it absorbs more energy before fracture.
- The use of smart concrete for the purpose of weighting vehicles on the highways.

V.SMART STRUCTURE FOR SEISMIC PROTECTION

Skyscrapers and long bridges are susceptible to resonance created by high winds and seismic activity. In order to mitigate the resonance effect, it is important to build large dampers into their design to interrupt the resonant waves. If these devices are not in place, buildings and bridges can be shaken to the ground, as is witnessed anytime an earthquake happens. A damping system in a building is much larger and is also designed to absorb the violent shocks of an earthquake. The size of the dampers depends on the size of the building. There are three classifications like,

- Passive
- Active
- Semi-Active

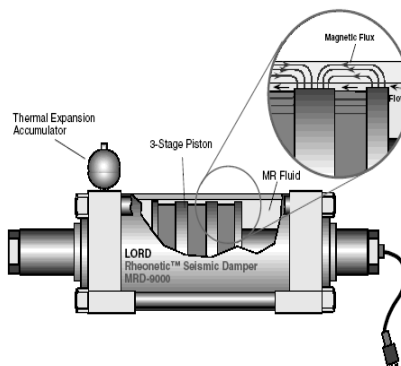


Fig 2 MR-fluid Damper

The above Figure shows a full-scale MR fluid damper that is 1-meter long and weighs 250 kilograms. This one damper can exert 20 tons (200,000 N) of force on a building. Inside the MR fluid damper, an electromagnetic coil is wrapped around three sections of the piston. Approximately 5 liters of MR fluid is used to fill the damper's main chamber. During an earthquake, sensors attached to the building will signal the computer to supply the dampers with an electrical charge. This

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

electrical charge then magnetizes the coil, turning the MR fluid from a liquid to a near-solid. Now, the electromagnet will likely pulse as the vibrations ripples through the building. This vibration will cause the MR fluid to change from liquid to solid thousands of times per second, and may cause the temperature of the fluid to rise. A thermal expansion accumulator is fixed to the top of the damper housing to allow for the expansion of the fluid as it heats up.

The Benefits of Smart structure

1. Less time and expenses in inspections.
2. The response of the structure can be monitored remotely in real time.
3. Performance of the new advanced composite materials can be monitored.

The long-term performance of advanced composite materials can be compared to conventional girders in the bridge, also outfitted with fiber optic sensors.

VI.CONCLUSION

The technologies using smart materials are useful for both new and existing constructions. The many emerging technologies available, the few described here and need further research to evolve the design guidelines of smart structures. Codes, standards and practices should give crucial importance for the further development of smart structures using smart materials.

REFERENCES

1. Dr. K. Muthumani, "structural application of smart materials "
2. Vijayaragavan S.P., Karthik B., Kiran T.V.U., Sundar Raj M., "Robotic surveillance for patient care in hospitals", Middle - East Journal of Scientific Research, ISSN : 1990-9233, 16(12) (2013) pp. 1820-1824
3. Udayakumar R., Khanaa V., Saravanan T., "Analysis of polarization mode dispersion in fibers and its mitigation using an optical compensation technique", Indian Journal of Science and Technology, ISSN : 0974-6846, 6(S6) (2013) pp. 4767-4771.
4. S.K.Kaushik , " Smart materials and Smart structures "
5. Udayakumar R., Khanaa V., Kaliyamurthie K.P., "High data rate for coherent optical wired communication using DSP", Indian Journal of Science and Technology, ISSN : 0974-6846, 6(S6) (2013) 4772-4776.
6. Dr. K.Sukumaran , " Potential applications of Smart Materials and Smart structures "
7. Thooyamani K.P., Khanaa V., Udayakumar R., "An integrated agent system for e-mail coordination using jade", Indian Journal of Science and Technology, ISSN : 0974-6846, 6(S6) (2013) pp. 4758-4761.
8. Saravanan, T., Srinivasan, V., Udayakumar, R., "A approach for visualization of atherosclerosis in coronary artery", Middle - East Journal of Scientific Research, ISSN : 1990-9233, 18(12) (2013) pp. 1713-1717.
9. AR.Arunachalam, Imperceptible Digital Image Watermarking, International Journal of Innovative Research in Computer and Communication Engineering, ISSN(Online): 2320-9801, pp 1321-1326, Volume 1, Issue 6, August 2013.
10. AR.Arunachalam, Spectrum Reuse in Multiple Primary User Environment, International Journal of Innovative Research in Computer and Communication Engineering, ISSN(Online): 2320-9801, pp 1475-1480, Volume 1, Issue 7, September 2013
11. B.Sundar Raj, A Third Generation Automated Teller Machine Using Universal Subscriber Module with Iris Recognition, International Journal of Innovative Research in Computer and Communication Engineering, ISSN (Online): 2320 – 9801, pp 565-571, Vol. 1, Issue 3, May 2013
12. B.Sundar Raj, The Efficiency of the Scalable Architecture for Revealing and Observing the Environment using Wireless Sensor, International Journal of Innovative Research in Computer and Communication Engineering, ISSN (Online): 2320 – 9801, pp 63-67, Vol. 1, Issue 1, March 2013
13. C.Anuradha, An Efficient Detection of Black Hole Attacks in Tactical MANETs, International Journal of Innovative Research in Computer and Communication Engineering, ISSN(Online): 2320-9801, pp 1636-1645, Volume 1, Issue 8, October 2013
14. AR.Arunachalam, Imperceptible Digital Image Watermarking, International Journal of Innovative Research in Computer and Communication Engineering, ISSN(Online): 2320-9801, pp 1321-1326, Volume 1, Issue 6, August 2013.
15. AR.Arunachalam, Spectrum Reuse in Multiple Primary User



ISSN(Online): 2319-8753
ISSN (Print): 2347-6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 7, July 2015

- Environment, International Journal of Innovative Research in Computer and Communication Engineering, ISSN(Online): 2320-9801,pp 1475-1480, Volume 1, Issue 7, September 2013
16. B.Sundar Raj, A Third Generation Automated Teller Machine Using Universal Subscriber Module with Iris Recognition, International Journal of Innovative Research in Computer and Communication Engineering, ISSN (Online): 2320 – 9801,pp 565-571, Vol. 1, Issue 3, May 2013
 17. B.Sundar Raj, The Efficiency of the Scalable Architecture for Revealing and Observing the Environment using Wireless Sensor, International Journal of Innovative Research in Computer and Communication Engineering, ISSN (Online): 2320 – 9801,pp 63-67, Vol. 1, Issue 1, March 2013
 18. C.Anuradha, An Efficient Detection of Black Hole Attacks in Tactical MANETs, International Journal of Innovative Research in Computer and Communication Engineering, ISSN(Online): 2320-9801,pp 1636-1645, Volume 1, Issue 8, October 2013