Chapter

Introductory Chapter: Advances in Structural Health Monitoring

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1. Introduction

Structural health monitoring has emerged as a viable tool for damage detection and preventive maintenance procedures. There is a wide range of proposed applications that were documented in the literature over the past two decades. Recently, the notion of sustainable design has emerged as an important attribute of all engineering designs. Sustainable design is defined as one that would result in systems that are smart, optimum, and reliable.

In this book, the concept of sustainable design is the backbone of the design of a structural health monitoring system. Within the backdrop of the presented definition, this book attempts to present structural health monitoring as a tool that would result in a sustainable engineering system. There are several aspects that are now being introduced to the conventional notion of structural health monitoring which are expected to contribute to such objective. Smart systems, smart materials, wireless sensor networks, conservation of historic cultural heritage, and autonomous systems are some of these aspects.

The book explores the design of smart structural health monitoring systems, using smart technologies and/or materials. It presents the issue of conservation of heritage structures using structural health monitoring tools. It explores the optimum employment of sensor networks that would render the most optimum structural health monitoring system. This book attempts to present such advanced concepts and/or technologies as the new direction of structural health monitoring.

This chapter briefly presents several advanced observations and/or applications that are considered to augment structural health monitoring techniques currently in practice.

2. Sustainable design

Sustainable design is now considered an essential requirement for all engineering systems. Sustainability is introduced as a general feature that reflects a set of objectives that should be achieved within the designed system. A sustainable system is expected to be optimum, smart, reliable, and recyclable. Initially, sustainability was always related to recyclable materials that are used in constructing engineering systems. With the evolution of smart materials, the introduction of smart systems, and the innovation associated with the internet of things, sustainability should now extend to include a much wider set of objectives, as outlined above.

Structural health monitoring, which is designed to provide a mechanism for damage detection and preventive maintenance strategies, contributes to most of this set of objectives in order to attain sustainable engineering systems. Integrating structural health monitoring within engineering systems results in a smart, reliable, and optimum system, smart in the sense that the system can detect damaged components, independently, and can propose recommendations to safeguard against any potential failures; reliable in the sense that such early detection of damage and the resulting recommendations of preventive maintenance activities would directly improve the reliability of engineering systems; and finally, optimum in the sense that such integrated smart systems would result in designs that ultimately would require less materials, less maintenance, and less failure occurrences.

3. Smart structural health monitoring

Structural health monitoring has gained an increased interest and research activity over the past two decades. By definition structural health monitoring comprises four main tasks, namely, damage identification, damage localization, damage severity evaluation, and structural system life expectancy prognosis. All current research activities are concentrating on the first two tasks, i.e., damage identification and localization. The continuous developments and evolutions in the applications of smart materials and technologies lend themselves to ample applications in the development of smart structural health monitoring systems.

Smart structural health monitoring systems are the ones that employ smart materials in designing their sensor networks and/or smart technologies in designing their diagnostic and inference systems. In light of the broad definition of sustainable design, presented earlier, such a smart health monitoring system, when integrated with any given structural system, would result in a sustainable engineering system.

4. Conservation of historic cultural heritage

Historic cultural heritage structures formulate the collective identity of a nation. It is the responsibility of current generations to ensure their safety and integrity in order to be safely maintained for future generations. This includes any conservation and/or retrofitting activities that might be required. It is expected that such structures would pose a unique challenge in that regard due to their age and the extreme environmental conditions they faced over the years. Another significant challenge is the materials used in their construction and the structural systems which in general would be inconsistent with current practices.

The introduction of structural health monitoring, as a conservation tool for such structures, is a state-of-the-art concept that would address most of the identified challenges, presented above. Structural health monitoring systems could be designed to integrate with such historic structures, thus, providing real-time monitoring mechanisms that can detect any damages, as they develop. Such early identification would ensure the timely introduction of maintenance activities that would ensure the safety of the historic structure.

5. Advanced damage assessment techniques

Damage identification is the major function of any structural health monitoring system. There is a wide range of damage assessment methods and techniques that have been employed in the published health monitoring applications. With the development of smart materials and advanced technologies, new damage assessment techniques are introduced every day. Some of these techniques could be successful in certain areas; however, integrating them with structural health monitoring is the new advancement.

Most of the advanced damage assessment techniques fall within the nondestructive evaluation techniques. Some of these advanced techniques are acoustic emission, infrared thermography, ultrasonic guided waves, and wavelet transforms.

The introduction of composite materials and their increasing employment in building engineering systems led to the development of a new breed of damage assessment techniques using microscale strain sensors that are embedded within composite materials.

6. Reliability of monitored engineering systems

The reliability of any designed engineering system is a major concern. Due to the uncertainty inherent in several types of loads and the randomness in material properties, complete safety is not possible to attain. There is always a certain probability of failure that is associated with any designed engineering system. It is only important to ensure that such probability of failure is acceptable in terms of the nature of application at hand. Furthermore, it is important to be able to evaluate such probability and thus relate that to the reliability of any designed system.

The integration of structural health monitoring, within an engineering system, is expected to enhance its reliability. It is important to consider the reliability, of such system, in two main levels, the first is the reliability of the structural health monitoring system itself and the second is the reliability of the monitored engineering system as a whole, including the health monitoring enhancement. There is not enough research activity in the area of reliability of structural health monitoring systems and their impact on the reliability of monitored systems. This requires a targeted research effort in this area which would support the practical implementation of such systems, especially when dealing with the conservation of historic cultural heritage.

7. Summary

The previously presented concepts are some of the new advancements in the design of structural health monitoring systems. It is envisaged that such advancements would lead to smart structural health monitoring that would result in sustainable engineering systems. Sustainability is considered an important objective in today's engineering design that is realized due to the current state of climate change and global warming, which are hugely aggravated by industrial and construction activities. It is intended through the chapters of this book to present demonstrations of and applications for such new advancements in order to encourage further research and implementation of such advanced techniques and technologies in structural health monitoring.

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