Proceedings of the Twenty-third (2013) International Offshore and Polar Engineering **www.isope.org**
Anchorage, Alaska, USA, June 30–July 5, 2013

ISBN 978-1-880653-99–9 (Set); ISSN 1098-6189 (Set)

Methods for Sensing and Monitoring Fatigue Cracks and Their Applicability for Marine Structures

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ABSTRACT

In order to guarantee structural integrity of marine structures in an effective way, operators of these structures seek an affordable, simple and robust system for monitoring detected cracks. Such systems are not yet available and the authors took a challenge to research a possibility of developing such a system. The paper describes the initial research steps made. In the first place, this includes reviewing conventional and recent methods for sensing and monitoring fatigue cracks and discussing their applicability for marine structures. A special attention is given to the promising but still developing new sensing techniques. In the second place, wireless network systems are reviewed because they form an attractive component of the desired system. The authors conclude that it is feasible to develop the monitoring system for detected cracks in marine structures and elaborate on implications of availability of such a system on risk based inspections and structural health monitoring systems.

KEY WORDS: Fatigue crack; nondestructive testing; asset integrity management; marine structures; crack monitoring system.

INTRODUCTION

Although various efforts are undertaken during the design, engineering, fabrication and operation stages of marine structures to avoid fatigue cracks, the operators are obliged to periodically inspect the structures for the presence of cracks. Cracks that are too long for safe operation must be repaired. Cracks of an acceptable length must be followed up during successive inspections. However, the uncertainty of crack growth rates means it is not known when the cracks will reach their critical lengths. Therefore, operators either increase inspection frequency or reduce the allowable crack length, which leads to higher operational cost. Interviews with marine operators revealed that they seek an affordable, simple and robust system for monitoring detected cracks in ship and offshore structures. Such system should only warn the operator when a crack has reached its predefined unacceptable length. The overall costs of the system should be competitive with the cost of additional visual inspection by a surveyor. The paper reviews conventional and recent methods for sensing and monitoring fatigue cracks and discuss their applicability for such a system.

NONDESTRUCTIVE EVALUATION

Methods to detect or monitor fatigue cracks can be subdivided into destructive- and nondestructive methods. For this paper special interest goes to in-service testing of marine structures, which eliminates the destructive testing methods as being suitable. This leaves us with nondestructive testing which was once an empirical technology that required subjective judgment of operators. Examples of such methods are dye penetrant inspection, magnetic particle inspection and imaging techniques like microscopy. For simple applications these methods give quite acceptable results. However, for more advanced applications, like most marine structures, there is a growing need for quantitative measurement techniques, physical models for computational analysis, statistical considerations, quantitative designs of measurement systems, specifications for flaw detection and characterization, system validation and performance reliability (Achenbach, 2000). This gives rise to a growing need for a new engineering discipline, quantitative nondestructive evaluation (QNDE), which is particularly important for the in-service inspection of high-cost structures whose failure could have serious consequences. Other authors also explicitly mention the need for on-line monitoring techniques, especially for monitoring fatigue cracks (Vanlanduit, Guillaume, & Linden, 2003). The disadvantage of off-line monitoring is that the normal operation of the structure has to be interrupted and the device often has to be disassembled.

In the following four sections the most important classes of nondestructive evaluation (NDE) will be discussed, being strain monitoring, ultrasonic testing, radiographic testing and magnetic testing respectively.

STRAIN MONITORING

For testing condition of engineering composites or non-Ferro materials, strain monitoring with surface or embedded strain gauges is applied. Surface strain gauges are bonded to the surface of the