ABSTRACT

Growing applications of high strength steels, which are more sensitive to fatigue, harsher operative environments, and increasing economic value of ship- and offshore structures, such as FPSOs and FLNGs, increase the need for asset integrity management systems. Presently, there are many nondestructive testing methods available. Magnetic methods to monitor fatigue cracks are not yet fully exploited and seem promising due to the possibility of passive monitoring using the Earth magnetic field as source. Measurements and numerical simulations show that magnetic fields in steel structures are affected by the presence of fatigue cracks. A sign change of the out-of-plane magnetic field density can be observed in the vicinity of a crack. Therefore, the crack can be detected by modern Hall probes. This makes it possible to develop a passive crack monitoring system based on magnetism.

KEY WORDS: Nondestructive testing; ferromagnetism; magnetic flux leakage; fatigue crack.

INTRODUCTION

Ship and offshore structures are complex engineering systems ensuring society’s prosperity. To design, operate and maintain these structures safely to public and environment, different requirements have been developed over the decades. Rules and codes containing these requirements allow for defects which do not jeopardize safe operation. Fatigue cracks, which are very common in ship and offshore structures due to cyclic character of wave loading, are examples of such defects. As fatigue cracks initiate and grow, the operators are obliged to inspect the structures for presence of cracks periodically. Cracks which are too long for safe operation have to be repaired. Cracks having acceptable length have to be followed during successive inspections. However, as the crack growth rates are very uncertain it is not known when the cracks reach their critical lengths. Therefore, operators either increase inspection frequency or reduce the allowable cracks length which leads to higher operational cost. Another solution is to monitor detected cracks. This solution is more and more attractive because recent trends are to operate older ship and offshore structures in more harsher and colder environmental conditions. The crack monitoring system should be inexpensive, robust, wireless, latent and easy to install, and should warn the operator when a crack has reached its predefined allowable length. How to sense a fatigue crack is the most important question in developing the crack monitoring system.

MAGNETIC NONDESTRUCTIVE TESTING

There are various methods available to perform nondestructive testing, most of them have been reviewed in (Jiles, 1988) and (Jiles, 1990). Nondestructive testing methods are always being improved and sometimes new physical principles are being used to do structural health monitoring. Recently these new developments in nondestructive testing have been reviewed in a literature study (Van der Horst, Kaminski, & Puik, 2013) which focuses specifically on monitoring fatigue cracks in marine structures. The conclusion from this paper was that magnetic methods are very promising for monitoring fatigue cracks in marine structures, but they are limited to mainly steel structures. All these methods, of which Magnetic Particle Inspection (MPI) is the most simple and most commonly applied method, are based on the ferromagnetic property of steel. The latest and most promising method that was found in the literature was based on measuring the Magnetic Flux Leakage (MFL) in the vicinity of a crack with the only magnetic source being the Earth magnetic field. In the next subsections a very brief recapitulation is given on this method before going into the experimental testing and numerical simulation.

Ferromagnetism

The physical explanation of ferromagnetic materials being hysteretic and therefore having spontaneous magnetization lies in their crystalline structure causing them to have magnetic domains. In each of the domains, all of the atomic dipoles are coupled in a preferential direction. These preferential directions are influenced by applying magnetic fields to them, see Figure 1 (NDT Resource Center). So a ferromagnetic material that was exposed to a magnetic field will behave like a permanent magnet itself.