Using Structural Reliability Analysis in Inspection Planning of Offshore Structures

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ABSTRACT

This paper proposes the practical application of a reliability-based procedure for fatigue inspection planning of fixed offshore structures. This procedure is based on a simplified probabilistic crack growth model for welded tubular joints available in the literature, which encompasses fracture mechanics and S-N curves and uses the results of the original fatigue design. Current techniques for reliability updating are implemented to re-evaluate the fatigue failure probability after inspection campaigns. Target reliability values are defined to be compatible with the simplicity of the procedure. Actual applications illustrate the inspection costs reduction that can be obtained.

KEY WORDS: Offshore Structures, Inspection Planning, Fatigue, Structural Reliability.

INTRODUCTION

Fatigue is an important limit state in the design and operation of steel offshore structures. The fatigue design is usually based on Miner's rule and S-N curves but alternatively a fracture mechanics approach can be employed. There are several uncertainties concerning its evaluation. In-service inspections, using nondestructive tests, are planned and performed in order to assure an adequate safety level and to gather more information about the fatigue process. Fatigue inspection results can be basically summarized in detection or no detection of cracks. Until recently, fatigue inspection planning was based mainly on engineering judgment and usually the results of previous inspections were not accounted for the next ones. However, since the structural reliability analysis has become a practical and widely spread tool this situation has changed.

Some important works on probabilistic inspection planning of offshore structures have been published recently (e.g., Madsen et al., 1987, Kirmmo, 1988, Madsen et al., 1989; Jiao, 1992). These works take into account inspections results and show that it is possible to establish a rational fatigue inspection planning. Relevant practical results of probabilistic inspection planning can be seen also in Pedersen et al. (1992). Most of these works employ a reliability method in connection with a fatigue crack growth model, based on linear fracture mechanics, to evaluate and update the probability of getting a through-thickness crack at any time during the service life of the structure. Inspections are indicated whenever this probability falls above a target value. This target must be established taking into account several issues such as consequence of failure, cost of repair and so on. Since this task is not straightforward, this topic has not been clearly defined. As a matter of fact this target should be stated by standard codes, but up to now there are few ones covering this topic.

This paper focuses on practical inspection planning of fixed offshore structures using a probabilistic approach. It describes the theoretical topics employed in the development of a reliability-based procedure for fatigue inspection planning of fixed offshore structures and illustrates its practical utilization. This procedure uses a probabilistic mixed fracture mechanics/S-N model for crack growth in welded tubular joints proposed by Banon and Zimmerman (1994) and FORM (Madsen et al., 1996) to compute and update after inspections the probability of fatigue failure and its associated reliability index. Due to some approximations involved in the crack growth model and uncertainties in statistical data, these results and the target values are seen as qualitative indicators of reliability in the practical inspection scheduling process of individual tubular joints. Actual applications show the possible inspection costs reduction that can be obtained.

FATIGUE ANALYSIS

Fatigue analysis can be performed basically by two methods (Næss, 1985): 1) Miner's rule and S-N curves (S-N model); 2) Fracture Mechanics (FM model). Traditionally, the fatigue design of welded offshore structures has been based on S-N model while the FM model has been most used in the maintenance of such structures. These two models and their equivalence will be briefly presented below.

S-N Model

The S-N model uses the well-known S-N curves which are obtained from fatigue experiments of tubular joints. An S-N curve is given by

\[ N(S) = K S^{-m} \quad (S > S_0) \] (1)