Proceedings of the Seventeenth (2007) International Offshore and Polar Engineering Conference
Lisbon, Portugal, July 1-6, 2007

ISBN 978-1-880653-68-5; ISBN 1-880653-68-0(Set); ISSN 1098-6189 (Set)

Probabilistic Fracture Mechanics Methodology Applied to Pipes subjected to Multiple Reeling Cycles

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ABSTRACT

A probabilistic fracture mechanics procedure for performing the structural reliability analysis of tubes subjected to multiple reeling cycles was developed. This procedure was based on a fracture mechanics approach, a fatigue formulation and the Monte Carlo method. This methodoloy allows the determination of more realistic maximum tolerable defect sizes than those provided by available methodologies presented in standards and recommended practices.

KEY WORDS: reeling; structural reliability; fatigue; fracture mechanics; crack growth;

INTRODUCTION

Reeling process is one of the methods for installations of linepipes in recent years. Pipes are welded onshore and subsequently bent onto a drum. During installation, the line is unreeled, straightened, and then laid into the sea. The pipe is subjected to severe cyclic plastic deformation.

Due to the characteristics of the process, it is necessary to guarantee the integrity of the components during and after the process. For this reason, structural reliability analyses are essential requirements.

In a previous work (Ernst, Passarella, Bravo, Daguerre, 2006), a fracture mechanics based methodology was developed to obtain a method to assess the structural reliability of reeled pipes. The problem of several reeling cycles was considered. In addition to a fracture mechanics methodology, a formulation considering fatigue crack growth (FCG) controlled by ΔJ parameter was developed. This formulation accounts for the crack growth produced during subsequent reeling cycles.

In another work (Ernst, Schifini, Bravo, Passarella, Daguerre, Tivelli, 2006), a probabilistic fracture mechanics assessment approach to perform the structural reliability analysis of tubes subjected to a reeling process was developed. This procedure takes into account the statistical distributions of the material properties and pipe geometry, using a fracture mechanics approach and the Monte Carlo method.

In this work, the probabilistic fracture mechanics approach was applied for the case of multiple reeling cycles. A particular case of interest was studied and tolerable defect sizes were determined for different number of reeling cycles taking into account the parameters variability.

Reeling of Pipes

Reeling is a fast and efficient method that is often used to install pipelines in offshore applications. This method consists of onshore welded pipe segments that are reeled around a drum and later transported out to the sea. In a standard cycle the welded pipes are reeled onto a drum, reeled off, aligned and straightened.

During installation, the pipes are significantly cyclically strained. High plastic deformation is introduced in the pipe.

Reeling has many advantages because most of the welding, coating and inspection are carried out onshore.

Multiple Reeling Cycles

For only one reeling cycle, the amount of crack extension can be completely described by ductile tearing. Nevertheless, situations may arise (extreme weather conditions, etc.) where the pipe installation must be stopped and retrieved to the reel. In these situations, the pipe is subjected to multiple reeling cycles.

For multiple strain cycles, tearing contributes to crack growth only in the steps where the maximum crack driving force parameter previously reached is exceeded (Ernst, Bravo, Daguerre, Izquierdo, 2005). For the other strain cycles, crack growth occurs by fatigue and a formulation should be considered in order to determine the amount of crack extension produced.