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Fatigue Studies Based on Real-time Strain Measurements on a Stinger Tubular Joint

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ABSTRACT

The paper presents a study related to fatigue performance of a structure, called 'stinger', being used as a support for offshore pipeline during installation from the board of a specialized vessel. Real-time strain measurements were set up on one of the tubular joints of the stinger. The measured data was processed and statistically analyzed after an appropriate filtering technique was developed. The measured nominal and local strain ranges at certain probability of the exceedance were used to derive the strain concentration factors (SNCF's) along the weld toe of the joint. Finite element (FE) models of the tubular joint were built using shell and solid elements, the latter comprising also the weld material. The SNCF values resulted from finite element analysis (FEA) were compared with those derived from measurements. Fatigue damage estimated based on histograms constructed on measured strain during a pipeline installation operation is discussed.

KEY WORDS: Offshore structure; tubular joint; real-time strain measurements; fatigue damage; strain range statistical distribution; strain concentration factor.

INTRODUCTION

In offshore oil and gas pipeline installation, specialized vessels are used. There is a number of ways to install the pipelines (Palmer and King, 2008). In this paper, the so called S-lay type of installation process is considered when a pipeline is assembled horizontally on board of a pipe lay vessel and guided to the seabed. During the installation, pipeline is supported by 'stinger', usually a space frame structure attached to the pipe lay vessel at bow or stern. The stinger overall configuration is adjustable and could contain different number of sections and have different radii depending on the pipe lay project. Though the pipeline installation is limited to certain weather conditions it is performed at different sea states characterized by a combination of sea wave height (H_S), wave period (T_Z) and wave approach angle (or wave heading, θ). Stochastic nature of the environment has an effect on loads experienced by the stinger and hence on fatigue damage accumulation in stinger welded joints.

In order to understand the specifics of loads on tubular joints of a stinger structure, related to their fatigue performance, real-time strain measurements were carried out in 2009 and in the course of the consecutive years the measured data were analyzed with the help of graduation students. The students projects were related to different aspects of stinger tubular joints loading and fatigue resistance. Some results have been published earlier (Ermolaeva et al., 2010; 2012).

The current paper presents the following studies:
(1) The filtering techniques of the measured signal are analyzed and the criteria for the choice of a suitable filter are discussed. This study was originated because of the poor fitting into a statistical distribution of some earlier data (Ermolaeva et al., 2012).
(2) The possible effect of the tail (or outliers) seen in the distributions of measured local strain ranges on the fatigue damage of the joint is discussed.
(3) The comparison of the SNCF values derived from two FE models built using different elements (solid and shell) is done, in order to check the influence of the model type and to include the weld material into the model. The SNCF values from FEA and measurements are also analyzed.

MEASUREMENTS

Measurements set-up

A K-type tubular joint in the vertical plane of the stinger section was chosen for measurements (Fig.1). The joint is typical of the stinger structure comprising circular hollow sections (braces) welded to a bigger circular hollow section (chord). In this joint, diagonal (A) and vertical (B) braces are welded to a top chord of the stinger. There is also an out-of-plane brace (C) connected to the top chord in the area of the considered K-joint. The measurements set-up is