Study of the Static and Fatigue Behaviour of Threaded Pipe Connections

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I. INTRODUCTION

Threaded pipe connections are commonly used in the oil and gas industry in particular to constitute casing strings, drillpipe strings or production and transportation risers and pipelines. Such threaded connections comprise a male threaded pipe and a female threaded coupling, called respectively pin and box. To ensure a good connection without fluid leakage, the pin and box are tightened with a specified torque, called *make-up* torque. The made-up couplings must be able to withstand a variety of service loading conditions. In deep-sea applications, the weight of the pipeline causes a considerable axial load on the pipeline. An additional fatigue load is caused by the environmental conditions in offshore applications or internal pressure changes in the pipeline.

The connections are often the weakest points in the pipeline. This is due to stress concentrations, resulting from the thread geometry. The stress concentration factors depend on different parameters as pipe and coupling dimensions and thread geometry.

For drill pipe connections, standardized design modifications exist to increase joint fatigue strength, but, as was reported by Vaisberg et al [1] up to 73% of all drill string defects were caused by fatigue cracks.

Goal of this study is to gain insight into the influence of the different parameters on the static load distribution and fatigue life of the connections. This is done by a combination of numerical analysis and experimental tests.

II. NUMERICAL MODEL

Finite element modelling is used to calculate the static load distribution and local stresses, which can both give an indication of the fatigue life of the connection. Instead of time-consuming and complicated 3D models, a 2D axisymmetric model is used (see Figure 1), which is common practice when modelling threaded connections [2]. The studied connection is a 1” API Line Pipe coupling.

As can be seen in Figure 1, a high stress concentration appears at the last engaged threads of the pin (indicated by the red arrow), which is caused mainly by axial tensile stress. Additionally high compressive hoop stresses are present in the pin, caused by the make-up torque.

The finite element model is constructed in such a way that parametric studies of the coupling geometry can be carried out easily to quantify the influence on stress concentrations and the thread load distribution.

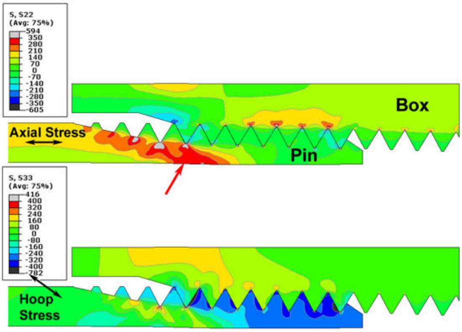

Figure 1: axial and hoop stress resulting from the finite element model

III. EXPERIMENTAL TESTING

A. *Static make-up tests*

To validate the results of the numerical analysis, torque tests were carried out on a threaded pipe sample instrumented with strain gauges [3]. The measured strains were in good agreement with the strains obtained from the numerical model. The results for the hoop strain in the connection are shown in Figure 2.

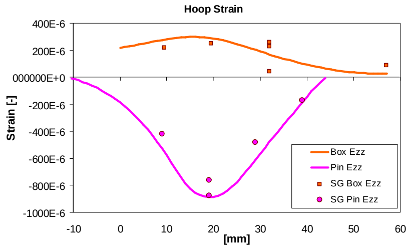

Figure 2: comparison between measured and calculated hoop strain during make-up

B. *Fatigue testing*

To quantify the fatigue life of the connections, four-point bending tests were carried out on a standard fatigue setup [4]. The results are presented in the SN-curves of Figure 3 which gives the number of cycles to failure as a function of the applied stress amplitude.

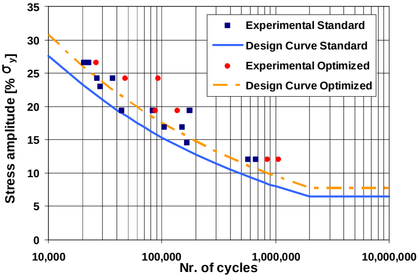

Figure 3: SN-curve for threaded connections

Using the finite element model a first optimization was carried out to obtain a more uniform load distribution over the connection by changing the box geometry. From the corresponding design curves in Figure 3 it can be seen that the optimized shape clearly results in an improved fatigue life of the connection.

IV. CONCLUSIONS

Using a finite element model of an API Line Pipe threaded connection an optimized shape for the connection's box was found. The accuracy of the numerical model was checked by a static make-up test.

Through a series of four-point bending tests, an SN design curve for the standard connection was obtained. Results of tests on an optimized coupling configuration showed that the fatigue life of the connection increases with a more uniform load distribution over the threads. Additional tests will be necessary to establish a further optimization and a more detailed relationship between the thread load and the fatigue life of threaded connections.

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