ANALYSIS OF A PRELOADED CONICAL THREADED PIPE CONNECTION

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1. Introduction

In the oil and gas industry, steel threaded pipe connections are commonly used e.g. as couplings between drill pipes, risers and pipelines. Due to environmental influences, like waves and vortex induced vibrations in offshore applications, these tubular structures are subjected to both static and dynamic loading conditions. To maintain a secure connection, the couplings are installed with a preload to avoid them coming apart. To introduce the preload on the connection, conical threaded connections or rotary shouldered connections are used. These connections are installed by applying the so-called make-up torque.

Due to the combination of the preload and external loading the stress distribution in the connection is complex. Additionally, the stress distribution depends on the coupling's geometry (pipe dimensions and thread type) and material properties (coefficient of friction between the threads). The resulting stress concentrations can initiate fatigue cracks and cause a premature failure of the connection. The influence of the different geometrical and material parameters on the connector's applicability and service life are not well known. However, improved pipe connections are necessary to meet new industrial needs.

This study aims to get a better understanding on the influence of the different parameters on the connection's performance through finite element analyses of different connection types. In this paper the analysis of an API line pipe connection is presented.

2. Modeling of threaded pipe connections

The stress distribution in the connection is calculated by finite element analysis (FEA). A widely used method to model threaded pipe connections is by the use of 2D axisymmetric models [1], [2]. This approach does not take into account the thread helix nor the exact run-out region. However it is known from [3] and [4] that 2D axisymmetric models give accurate results compared to full 3D models. Moreover, axisymmetric models are less time-consuming and hence finer element meshes can be calculated.

FEA were carried out using the software package ABAQUS™. An elastic-plastic material model of AISI 4340 HSLA steel is used. This material has a yield strength of 800 MPa.

To model the preload an initial overlap is given to the male and female part of the connection (pin and box), corresponding to the specified number of make-up turns according to the API standard [5]. This overlap is shown in figure 1 together with a detail of the model's mesh.

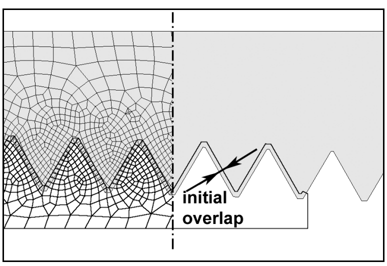

Figure 1: Detail of model mesh and initial overlap to model the make-up torque.

During the first step of the analyses, the overlapping surfaces of pin and box are brought into contact. This results in the von Mises stress distribution as shown in figure 2 a). The stress at the tip of the pin is a hoop stress of about 450 MPa.

An additional external axial load is applied on the connection giving the stress distribution of figure 2 b). As can be expected from [1], the highest stress concentration is located at the root of the last engaged thread of the pin. This stress concentration is mainly caused by axial stress, while the stress state at the tip of the pin is caused by hoop stresses from make-up and opening between the threads of the pin and box.

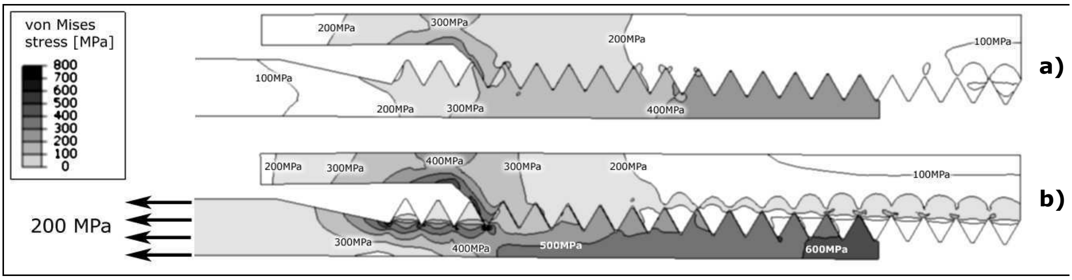

Figure 2. Stress distribution resulting from a) make-up, b) make-up + 200 MPa axial load.

When the wall thickness of the box is increased, the box becomes more rigid. This increases the hoop stresses in the pin. If on the other hand, the wall thickness of the pin is increased, the acting hoop stress on the pin will decrease while the hoop stress in the box will increase.

It can be seen in figure 2 b) that the box has an unthreaded extension at the left side. Due to a combination of hoop stress and bending of the extension, an additional stress concentration is introduced where it is connected to the threaded section of the box. When this extension is left out however, the opening between the threads under load increases together with the hoop stress in the pin, reducing the connection's strength.

It was observed that the opening between pin and box threads is significantly influenced by the coefficient of friction between the threads. Since a larger opening will decrease the static pull-out strength of the connection, it is important to have accurate data of the coefficient of friction. However, this data is generally not present and can only be determined experimentally.

4. Conclusions

A finite element analysis of a preloaded conical threaded connection is presented. Results are consistent with data known from literature. The strength of the connection depends on both geometrical and material properties. The coefficient of friction between the threads should be determined experimentally to predict the connection's behavior accurately.

6. References

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