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Force analysis and tightening optimization of gas sealing drill pipe joints☆

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ABSTRACT

In this article threaded tool joints of gas sealing drill pipes, which are exposed to different tightening turns and tension load, are analyzed using an elaborate finite element modeling through the use of MSC.Marc13.0. The corresponding mechanics model is also established and the reliability of the model is verified by finite element simulation and full scale test. Some conclusive results have been drawn from the analysis including that the force distribution of the gas sealing joints is quite different from the API standard one, and the metal seal structure can greatly improve the seal performance of the joint under tension load. Research also shows that reasonable tightening turns can effectively reduce the thread axial load growth amplitude under the tensile load as a result improving the fatigue life of the tool joints.

1. Introduction

With the further exploitation of oil and gas resources, the increasingly harsh mining environment put forward requirements for the torsional and sealing performance of petroleum drill pipe joints. API drill pipe joints are widely used at present, but their torsional strength is insufficient and sealing performance, especially the gas sealing performance is poor. Meanwhile, the stress distribution of API joints is not reasonable, which results in the short service life of the joints.

In order to solve the technical problems mentioned above, the major drilling tools manufacturer has developed their own special screw thread joints, which can achieve a high performance that API joints cannot make it through their ingenious structural design and precision processing technology. Taking the XT-M tool joint that is developed by GRANT Company as an example, the torsional strength of XT-M is about 70% higher than API joints and the gas sealing performance is satisfactory, which is confirmed by an experiment that XT-M joints can seal 20,000 psi internal pressure and 10,000 psi external pressure load [1].

Many scholars have conducted in-depth research for stress analysis of screw threads of API joints. Hetenyi [2] and Brown [3] demonstrated that the maximum local stresses happen near the root fillet of each tooth in the threaded connections by using the photoblastic method. Pick and Nurns [4] establish a finite element analysis model and proved that the stress distribution in screw threads is parabolic. The first tooth pair from the tool joint shoulder bears the maximum amount of load induced by the make-up torque. Heywood [5] concluded that screw threads suffer not only because of the overload effect but also because of the stress concentration resulting from the notch stress effects present at the root of the threads. S. Baragetti [6] researched effects of taper variation

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Nomenclature

F_i	contact force of the *i*th tooth
F_z	contact force of the main shoulders
F_m	contact force of the sealing surface
F_f	contact force of the second shoulders
F_0	the tensile load
σ_{VME}	the equivalent Von Mises stress
$\sigma_{\max}$	the maximum normal stress
σ_1	the first principal stress
σ_2	the second principal stress
σ_3	the third principal stress
σ_c	contact stress of the sealing surface
θ	the angle between the sealing surface and the axis
α	half of thread angle
E	Young's modulus
ν	Poisson ratio
μ	friction coefficient
P	thread pitch
H	depth of tooth
D	external diameter of the joint
d	inner diameter of the joint
N	tightening turns
$M_{\max}$	the maximum bending moment
$y_{\max}$	the farthest distance from the neutral axis of the tooth
I_z	polar moment of inertia
δ_1	interference of the main shoulders
δ_2	interference of the sealing surface
$I_{sealindex}$	sealing strength
A	contact area of the sealing surface
FEM	finite element method

on load distribution of conical threaded connections and stated that the reduction of the taper value results in a more uniform distribution of load on the threads.

Gas sealing joint analyzed in this paper is shown in Fig. 1 (a), and the main originality of the joint is based on a double shoulder connection, on which a conical sealing surface is added as a primary sealing structure near the small end of the pin and the big end of the box. At the same time, the shoulders and screw threads also play a certain role in sealing, which greatly improves the seal performance of the joints. Shown in Fig. 1 (b) is API NC38 joints. Due to the change of bearing structure (Fig. 1), the stress distribution of the gas sealing joints may be different from the API joints, and the force analysis of the whole joints not only the screw threads is also not common. DI Qin-feng [7] analyzed the torsion distribution of the double shoulder joints during make-up process. He found that the torque of second shoulders rises quickly when they come into contact with each other.

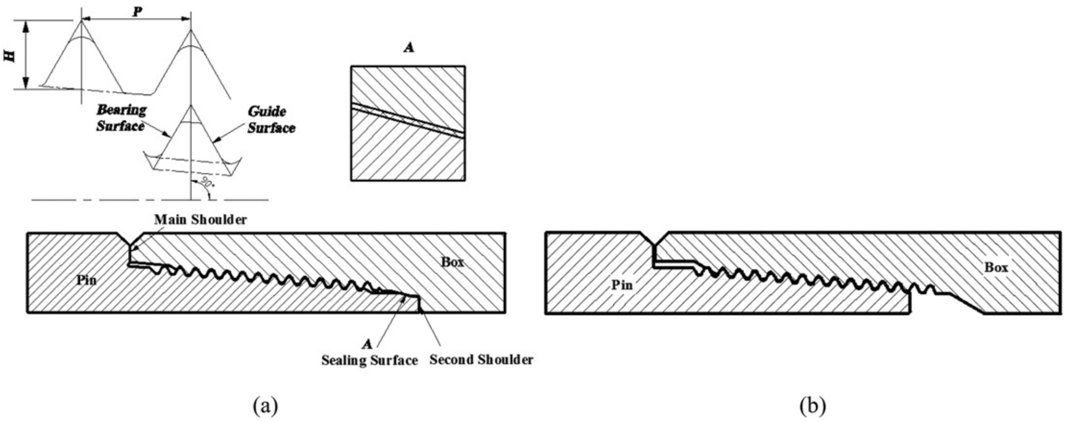

Fig. 1. Structure diagram of tool joints. (a) Gas sealing joints; (b) NC38 joints.