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A study on axial cracking failure of drill pipe body

Yonggang Liu [a,b], Zhanghua Lian [a], Tiejun Lin [a,*], Youdong Shen [c], Qiang Zhang [a]

[a] State Key Lab of Oil and Gas Reservoir Geology and Exploitation, Southwest Petroleum University, Chengdu, Sichuan 610500, China
[b] CNPC Tubular Goods Research Institute, Xi'an, Shanxi 710077, China
[c] PetroMaterials (Cangzhou) Co., LTD, Qingxian, Hebei 062650, China

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ABSTRACT

Frequently happening drill pipe failure accidents in oil and gas wells not only affect drilling speed, but cause enormous economic losses and many safety issues. Most of these accidents are transverse cracking of drill pipe body and pin thread or axial cracking of box thread. Based on the axial cracking failures of drill pipe body in an ultra-deep well in China, this paper give a systematic analysis of axial cracking failure in consideration of service condition, material quality and stress corrosion mechanism. Measurement and inspection are performed on macroscopic and microscopic morphology of crack surface, corrosion products and circumferential residual stress. Then stress corrosion cracking experiments against hydrogen sulfide is conducted. Finally, the critical stress value for sulfide stress corrosion cracking of the drill pipe material is obtained, and the mechanisms of axial cracking failure and corresponding preventive measures are proposed.

1. Introduction

Drill pipe was subjected to a series of complex dynamic and static loads in drilling operation, such as tensile load, bending moment and torque. According to failure statistics, drill pipe failures happen frequently on tool joint thread, upset transition zone and pipe body with corrosion pits or mechanical damage. The main patterns of drill pipe failure were transverse cracking of drill pipe body (including crack, wash out and fracture), transverse cracking of pin thread and the transverse and axial cracking of box thread.

Drill string failures have been studied from various perspectives. Li and Feng [4] concluded the main causes for drill string failures and corresponding preventive measures. Lu et al. [5] gave a detailed investigation on drill pipe wash out and recommended improving internal upset taper configuration and material quality of the drill pipe after a series of tests. Li et al. [6] gave a systematic analysis in consideration of material quality and loading condition on drill strings to clarify the causes for drill pipe wash out failures. Zhu et al. [12] analyzed the drill pipe failure accidents caused by thread gluing and established a 3D drill pipe thread finite element model to analyze various load conditions. Lin et al. [7] established the finite element analysis model of drill pipe and simulated the stress concentration at the upset transition area. Han et al. [2] carried out research about the physical properties, chemical properties and sulfur resistance of S135 drill pipe. They concluded that the failure of drill pipe belonged to a typical sulfide stress corrosion cracking and proposed the application of drill pipe with high strength. However, the axial cracking failure of drill pipe body was seldom studied.

In the drilling process of an ultra-deep well, axial cracking failures took place on several drill pipes, as shown in Fig. 1. In order to clarify the mechanisms of drill pipe axial cracking and corresponding causes, this paper carried out a series of experiments and analysis.

* Corresponding author.
E-mail address: cwctltj@swpu.edu.cn (T. Lin).

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Fig. 1. Visual inspection of axial cracking drill pipes.

2. Basic information of damaged drill pipes

Many 5 7/8 in. × 0.43 in. drill pipes with S135 steel grade failed due to axial cracking. Based on the collected data, H_2S was detected in the mud circulated from bottom hole and the highest concentration of H_2S was 200 ppm at wellhead. Fig. 2 shows the macro-morphology of failed drill pipe specimens. All these specimens had undamaged internal coating and no obvious corrosion pit or mechanical damage was observed on pipe surface.

3. Detection and analysis of drill pipe specimens

3.1. NDT (nondestructive testing)

Magnetic powder inspection was carried out on the external surface of drill pipe. Four axial-extended cracks were detected on one specimen and the cracks were respectively 95 mm, 830 mm, 920 mm and 2295 mm long. Some branching cracks were also observed on the growth path of axial cracks, as shown in Figs. 3 and 4.

3.2. Analysis of crack surface

One crack was opened with mechanical method. Figs. 5 and 6 present the extension morphology of crack surface. Dull black and dark red corrosion products were found on crack surface. In addition, the external surface of crack had obvious tearing ridge, which was the feature of brittle cracking.

SEM shown that the crack width on external surface was less than that on subsurface, as shown in Fig. 7. The distance from subsurface to outer surface was approximately 0.2 mm. According to the crack morphology in Figs. 5 and 6, it was deduced that the crack originated from subsurface to outer surface of drill pipe. Energy spectrum analysis revealed that corrosion products contained abundant oxygen and sulfur, as shown in Figs. 8 and 9.

Fig. 2. The drill pipe specimens.