Engineering Failure Analysis 86 (2018) 44–55

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Fracture failure analysis and research on special taper thread of cardan shaft Shell of PDM

Yang Liu[a], Zhanghua Lian[a], Liqin Qian[c,*], Chengyu Xia[c,*], Jie Zhang[b], Yiliu Tu[c]

[a] State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Southwest Petroleum University, 610500, PR China
[b] School of Mechatronic Engineering, Southwest Petroleum University, 610500, PR China
[c] School of Mechatronic Engineering, Yangtze University, Jing Zhou 434023, PR China

ARTICLE INFO

Keywords:
Special taper thread
Electron microscope scanning
Yield stress
Bending load
Surface defects

ABSTRACT

The secondary crack is located near the main crack as per the macro examination and micro analysis on the fracture of a PDM (Positive Displacement Motor) shell with special taper thread, and serious defects are produced at the bottom of thread surface in the process of main crack fracture. Scanning electron microscopy observation indicates that the shear fracture point is positioned at shear fracture zone and convex of thread bottom tearing crack of sample 1#. Based on field data and type design of special thread, the matching model of special taper thread of cardan shaft shell is established in this paper, and numerical simulation of threaded connection is carried out under three different borehole curvatures. Results indicate that stress and displacement of thread increase with the borehole curvature. When the curvature reaches 30°/30 m, the maximum Von Mises stress is 967.8 MPa, which is close to the yield stress of thread material. The maximum stress occurs at the bottom of the first tooth according to the actual fracture location. Comprehensive analysis reveals that the effect of bending load occurs many times at the bottom of well. Moreover, thread surface defects result in large stress of thread, and form the weakest micro cracks at the bottom of thread. In addition, the crack occurs in the smooth area, and then rapidly extends to the shear lip, which leads to failure and even fracture of threaded connection of shell.

1. Introduction

It is reported that the United States of America is the most successful country in large-scale commercial production of shale gas. The booming of shale gas production since 2006 achieved the basic self-sufficiency of natural gas in USA [1]. According to the assessment results of the Ministry of Land and Resources of the People's Republic of China in 2012, China is rich in shale gas resources and the potential shale gas recoverable resources reaches $25 \times 10^{12} m^3$ [2]. In order to develop shale gas in large scale and high speed, Fuling Shale Gas Co., Ltd. has set up the first demonstration area of shale gas in China. The effective development of shale gas resources involves both horizontal wells and directional wells, for which PDM (Positive Displacement Motor) is normally used as a key downhole tool in the combined drilling operations.

As shown in Fig. 1, the combined drilling technology uses both downhole tools and rotary table to drive bit. In the combined drilling operations, the rotary table drives drill pipe to rotate while the high-pressure drilling fluid drives the PDM. The combined effect of the rotary table and the PDM creates a big torque on bit to break downhole rock. With the development of downhole tools and high-efficient bits, the combined drilling technology is becoming an emerging technology after rotary drilling. Therefore, this

* Corresponding authors.
E-mail addresses: qlq1010@126.com (L. Qian), chenyuxia851003@sina.com (C. Xia).

https://doi.org/10.1016/j.engfailanal.2017.12.007
Received 1 December 2016; Received in revised form 3 December 2017; Accepted 4 December 2017
Available online 05 December 2017
1350-6307/

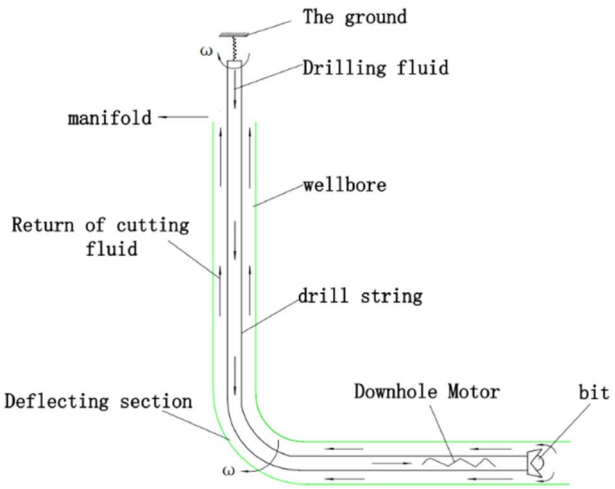

Fig. 1. Schematic diagram of drilling horizontal well.

paper focuses on the PDM drill, which is widely used in the combined drilling technology.

Directional wells and horizontal wells are effective means for the exploitation of shale gas. When the PDM passes through curved section, bending deformation leads to stress concentration at the PDM shell. For this reason, some scholars and experts both at home and abroad have carried out researches on the fracture failure of threaded connection, which is a common problem in the combined drilling operations.

Zhang Jie et al. have conducted failure analysis for the key parts of the PDM, and the results of simulation were corresponded to the actual parts of failure by analysis with FEM [3]. Lin Tengjiao et al. have carried out reliability evaluation of API thread of pipe joint and experimental study on stress field of thread in the make-up process [4–6]. Results indicated that the main failure modes of joint included excessive deformation, fracture and surface damage. Liu Yonggang et al. [7] and Lin Tiejun et al. [8] have determined the stress distribution of the drill collar thread by finite element method, and determined the stress distribution of API drill collar by drill string dynamics, the multi axial fatigue life calculation simulation. Lin Yuanhua et al. [9] and Zhuang Yong et al. [10] have established finite element semi analytical method of thread based on contact mechanics theory, which could be used to optimize size tolerance and torque of double shoulder joint.

Jun Takano et al. have analyzed the stress characteristics of thread using the two-dimensional axisymmetric finite element model [11–13]. The research showed that the stress level of thread at both ends of the external thread was very high, and it took the largest proportion of alternating stress, leading to fatigue crack initiation.

The above references have analyzed the failure of casing, tubing and drill pipe thread. However, no detailed analysis has been carried out on the fracture of cardan shaft of the PDM up to now. Therefore, this paper discusses the fracture failure of special taper thread of the cardan shaft shell based on the lessons from the scholars both at home and abroad on the metal parts of the fracture analysis method [14–19], which provided an effective way to judge the fatigue crack growth of the thread under the condition of stress concentration.

2. Structure and working principle of PDM

PDM drill has become the most widely used downhole tool in oil drilling engineering. As shown in Fig. 2, the PDM is made of four major components, i.e., outlet valve assembly, motor assembly, cardan shaft assembly and drive shaft assembly. In the working process of the PDM, the stator is fixed, and the rotor is driven by the high-pressure drilling fluid to move around the axis of the stator. The cardan shaft assembly transmits the planetary motion to the drive shaft and the drive shaft drives bit to rotate. When drilling in or circulating drilling fluid, the outlet valve is closed and the drilling fluid enters into the motor. The PDM is the tool that converts hydraulic energy of the drilling fluid into mechanical energy of bit, which breaks the rock and drills in.

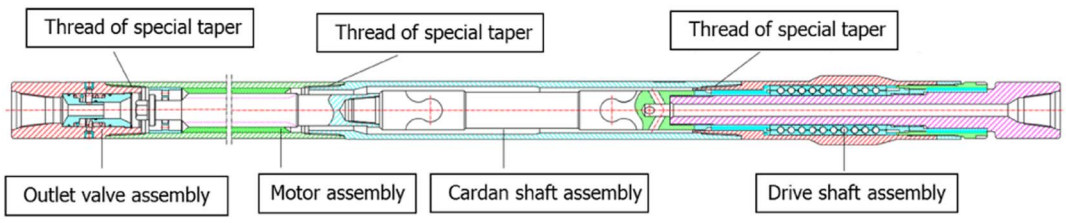

Fig. 2. Composition of positive displacement motor (PDM).