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Research Article

Downhole vibration causing a drill collar failure and solutions

Zhu Quanta[a,*], Zou Zongming[b], Huang Bing[c], Ma Linhu[a], Xia Jiaxiang[d]

[a] Beijing Office of NOV Grant Prideco, Beijing, 100007, China
[b] Chuanxi Division of CNPC Chuanqing Drilling Co., Ltd., Chengdu, Sichuan, 610500, China
[c] Chuandong Division of CNPC Chuanqing Drilling Co., Ltd., Chongqing, 432001, China
[d] Sinopec Southwest Drilling Company, Deyang, Sichuan, 614000, China

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Abstract

In large borehole drilling of some blocks or formations, due to serious downhole vibration, fatigue failure of a drill collar occurs frequently and most washouts and fractures are in thread root. An analysis of the above failure shows that the drill collar fatigue failure is caused by the cyclic bending stress due to serious downhole vibration. Therefore, downhole vibration modes were theoretically analyzed in terms of axial vibration, lateral vibration, stick-slip, and the physical model established by the mechanical vibration field. Then the resonance damage caused by the actual different downhole vibrations and its theoretical basis were analyzed; and according to the downhole drill string lateral vibration and whirling law, the best area to ensure drilling parameter stability based on the given boundary conditions was figured out, and the theory was clarified that in the best area of drilling, the maximum ROP will be achieved by maintaining the drill string stable or eliminating the vibration/stick-slip, meanwhile the stress fatigue of BHA will be reduced or eliminated especially for drill collar. Finally, solutions were provided as follows: (1) According to the special BHA, drilling conditions, together with physical and mathematical models listed above, downhole resonance speed and related parameters to be avoided can be easily figured out. It was also clarified that resonance speed is exactly the vibration speed that need to be avoided; and that the resonance frequency can be avoided with software for vibration analysis in BHA design and application at well sites; (2) V-Stab is a new and efficient tool which can reduce or eliminate downhole lateral vibration and stick-slip.

Keywords: Axial vibration; Lateral vibration; Stick-slip; Resonance; Drill collar; Fatigue failure; Software for vibration analysis; V-Stab

Through technical exchanges, field surveys and workshops related to failures of drilling tools, some common phenomena have been found. For example, frequent fatigue failures of drill collars occurred during drilling in some blocks or formations, especially in the drilling of wells with large diameters. Majority of these failures involved washout with fractures around root sections of screws. Based on surface conditions and drilling parameters, severe downhole vibrations were identified or speculated. Such vibrations may lead to premature fatigue failures of drill collars. Analyses of root causes for failures show that repeated bending stresses induced by severe downhole vibrations are key causes for such fatigue failures. Accordingly, theoretical analyses were made for patterns and threats of downhole vibrations. Eventually, effective solutions with breakthroughs in theoretical developments were identified to reduce and eliminate downhole lateral vibrations and stick-slip.

1. Failures of similar drill collars

1.1. Case 1

Positioned in Yangliusi of Xingyi Town, Fengdu in Chongqing, Well Shifu 1 [1] was initially drilled on Dec. 4. From Dec. 16 to 30, drill collars failed four times during the drilling of large-diameter boreholes at the interval of

* Corresponding author.
E-mail address: quanta.zhu@nov.com (Zhu QT.).
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155−800 m. Two of these failures involve washout of root sections of box ends of the Ø165.1 mm drill collar, breaking of one drill collar and one Ø203.2 mm drill collar, as shown in Table 1.

All of the four failures in the well occurred in intervals shallower than 800 m. Visual inspections over fractures show features of fatigue failures. All these drilling operations involve BHAs equipped with stabilizers, and with torques of 6000−12000 Nm. In addition, extremely severe bit jumping and bouncing happened during drilling, with bit weight of 50−400 kN. Fig. 1-a shows the second breaking of the drill collar in Well Shifu 1.

1.2. Case 2

When Well Moxi 29 [2] was drilled to the depth of 885.42 m at 8:36, Sep. 19, 2013, the string suspending weight reduced from 545 to 486 kN, the pumping pressure decreased from 11.6 to 7.7 MPa, and the pumping rate increased from 105 to 108 strokes/min. No backward rotation was observed during drilling tool lifting. It was determined on site that BHA was broken. After tripping out at 13:50, the first 203.2 mm drill collar broke at 0.13 m below the box end, as shown in Fig. 1-b.

NOV Grant Prideco analysis data acquired in tests for drilling tool fatigue [3] indicate that repeated bending was a common form of drill string fatigue. Being cumulative and irreversible, repeated bending is directly related to application time. However, the application time is not the only factor drilling tool fatigue, but stress is also meaningful [4]. Repeated bending induced by downhole vibrations is the main driver for such fatigue failure, and it is directly related to amplitudes and frequencies of such vibrations.

Researches related to fatigue and relevant failure mechanisms of threaded connection in drill collars show that [5] fatigue failure of drill collars predominantly occurs around the 1−5 threads in the threaded connection, mainly due to the concentration of stress at the root of threads. Through the above analyses and theoretical discussion, it is determined that detection and elimination of downhole vibrations are essential to addressing fatigue failures.

2. Downhole vibrations and solutions

2.1. Classification of downhole vibrations

Downhole operations inevitably involve vibrations. Great progress has been made in researches in this aspect [6].

Table 1
Statistics on failures and fractures of drill collars in Well Shifu 1.

Failed drilling tool	Date	Detection	Application in the well	Failures and solutions
Ø165.1 mm drill collar washout	December 16	Onsite ultrasonic inspection	Deployed on Dec. 10, to drill the interval of 155.2−301.5 m with the total application time of 140.33 h.	On Dec. 16, the well was drilled to the depth of 301.50 m at 11:10 when the standpipe pressure decreased from 12.6 to 12.1 MPa, whereas the pumping rate increased from 164 to 170 strokes/min. Inspections showed no abnormal conditions in surface facilities. After drilling assembly was tripped out, the third Ø165.1 mm drill collar had fractures at 10 cm from the box end and the 4th drill collar had pin end washout
Ø165.1 mm drill collar washout	December 17	Onsite magnetic powder inspection	Deployed on Dec. 11, to drill the interval of 178.8−331.41 m with the total application time of 155.67 h	On Dec. 17, the well was drilled to the depth of 331.41 m at 14:00 when the standpipe pressure decreased from 5.8 to 5.7 MPa, whereas the pumping rate increased from 160 to 165 strokes/min. Inspections show no abnormal conditions in surface facilities. After drilling assembly was tripped out, the 4th Ø165.1 mm drill collar had fractures at 9 cm from the box end.
Ø165.1 mm drill collar broken	December 17	Onsite magnetic powder inspection	Deployed on Dec. 10 to drill the 136.6−383.79 m Interval with the total application time of 218.33 h.	On Dec. 19, the well was drilled to the depth of 383.79 m at 8:50 when the standpipe pressure decreased from 6.5 to 5.1 MPa, whereas the pumping rate increased from 156 to 186 strokes/min and string suspending weight decreased from 547 to 347 kN. Dafter drilling assembly was tripped out, the first Ø165.1 mm drill collar broke at 10 cm to the box end. A taper tap was deployed to capture the fish successfully in one trip.
Ø203.2 mm drill collar broken	December 30	Onsite magnetic powder inspection	Deployed on Dec. 10 to drill the interval of 101.5−787.46 m with the total application time of 496.67 h in the well	On Dec. 30, the well was drilled to the depth of 787.46 m at 17:31 when string suspending weight decreased from 691 to 480 kN. After drilling assembly was tripped out, the third Ø203.2 mm drill collar broke at 7 cm to the box end. A taper tap was deployed to capture the fish successfully in one trip.

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