# Tensile and Torsional Loads Stress Distribution Along the Drill String for Deep Wells

**Lallia Belkacem, Noureddine Abdelbaki, Mohamed Gaceb, Elahmoun Bouali, Hedjaj Ahmed and Mourad Bettayeb**

**Abstract** Common knowledge and rule of thumb tell us that tensile failures will mostly occur in the pipe body, while torsion failures will occur in the tool joints. The total stresses on the drill string should be considered which are induced by combined bending, torsion and tensile stresses. The latter can usually be operating up until 80 % of the pipe body yield stress, a level which is considered as a safe working limit. Moreover, torque and drag are caused by the lateral forces and the friction between the borehole wall and the drill pipe. The lateral forces depend on the weight of the drill string. Torque and drag are sometimes overlooked when drilling simple wells. In deep well this is not acceptable. Proper decision made using correct torque and drag can make all the difference between TD drilling and suspended drilling. Therefore the over pull load plus the torque are the most important points to be considered in deep well drilling, since the resistance of the drill string body to the combined efforts will probably limit its tensional limit. By this I mean, exerting both a tension and torsion load on the drill string of this later will weaken its yield stress consequently applying a high tension effort combined with a significant torque lead to plastifying of the drill pipe body thus reducing its fatigue life. This problem is well observed in back-reaming operation. The results show that fatigue damage from rotation in dogleg during backreaming operation is a significant problem if the severity is greater than the critical value. So the position of drill pipe in the string will influence the amount of fatigue damage it sustains. Furthermore, back reaming can reduce the fatigue life of the drill pipe significantly because of the stress reversal of the drill string under tension in a dogleg.

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# 1 Introduction

This paper outlines practically tensional and torsion loads which affect the drill pipe as a result of frequent back reaming operations. For this reason practical ways of eliminating this trouble or at least reducing this problem are explained in this paper. A better understanding of the stress distribution along the drill string will certainly lead to more optimized drill string designs.

Therefore, this article is based upon experiments on drill string failures which were done before in order to clarify this latter further. Firstly light will be shed on back reaming operation and then a synopsis on failure by torsion and tensile loading due to back reaming operation. This will be completed with few literature on torque and drag calculation via Lubinski model by using soft modeling (well plan software). Give An optimum solution to the problem will finally be given.

## *1.1 Backreaming Operation*

Generally the backreaming is a term given to the backwards drilling to trip out of the hole when there is a problem with pipe pull-back operation freely without rotation and circulation in order to clean the hole to eliminate cuttings accumulation and hole caving [1].

The pipe tension during back reaming is lower than when pulling out of the hole with excessive drag, but torsional stress is introduced. The drill string is subjected to various loads such as: The loads due to contact of the drill string body with the wellbore, and which are known as side loading forces. These side forces are thought to be related to the weight of the string, the geometry of the wellbore, and the rotation of the string (axial, bending, and torsional forces = VON MISES stress) [1].

During backreaming, all drill string stresses are acting simultaneously; namely axial stress caused by tension, bending stress caused by the curvature of the string according to the wellbore tortuosity, and torsional stress caused by rotation.

1. The contact of the drill pipe and BHA components with the wellbore under this stressed condition will increase the friction caused by the tension and rotation, and thus will increase the side forces.
2. The excess side forces induced while backreaming along with incorrect practices can lead to accelerated casing and BHA wear and undesirable situations such as twist offs.
3. Backreaming can reduce the fatigue life of the drill pipe significantly because of the stress reversal of the drill string under tension in a dogleg [1].

## *1.2 BHA Restrictions*

Bits and stabilizers are typically not designed to drill in reverse during backreaming, although some bits are now available that have cutters at the top of the gauge to facilitate the cutting action. It is important that all stabilizers are tapered at the top and the bottom to avoid problems while pulling and backreaming.

It is well known by measurement-while-drilling (MWD) personnel that back-reaming out of hole with a bend in the BHA can lead to high shocks that can result in premature tool failures. Some of the reasons might be that the BHA is not in compression but in tension and is less constrained because there is no fixed end [1].

## *1.3 Drag and Friction Force*

In addition to the drag force which create the friction between the drill string and the borehole wall when moving the BHA through wellbore. In a simple model, drag is the increased/decreased apparent hook-load when tripping plus the observed rotating hook-load at the equivalent depth [2, 3].

Friction force creates a combined motion decomposed into the two directions, axial motion and rotation. The effect of combined motion is well known, for example when rotating the drill string for running easier into the hole either for tripping in or out or back-reaming; a high rotational speed reduces axial drag considerably so we assume that during tripping operations an over pull may occur due to tight hole conditions. Further, research indicated that under the combined actions of axial load, centrifugal force and torque, the axis of the rotating drill string has a sinusoidal shape with changing wave length, and rotates as a rigid body, with the same speed and direction of the rotary table [2, 3].

## *1.4 Well Plan Torque and Drag Module*

Normal Analysis involves calculating the torque, drag, normal force, axial force, buckling force, neutral point, stress and other parameters for a work string in a three-dimensional wellbore. With a Normal Analysis, all calculations are performed with the bit at one position in the wellbore, and with one set of operational parameters. One may choose to perform the analysis using either the soft or stiff string model. However, for now we will use the soft string model [2].

## 2 Engineering Overview of Back Reaming for 8½″ Hole Section

Basic on the quick review conducted for the history of 8½″ hole of two wells drilled in Algeria, it is imperative to point out that the severe wellbore instability, high torque peaks and stuck pipe problems encountered previously on this interval are still suspected to be one of the major challenges to encounter while drilling the 8½ hole section which is the longest one, approximately 2500 m. The possible root causes for the different hole problems encountered on the 8½ of well 1 and well 2 may be attributed to the following major factors: well 1 as an example.

1. Formation Nature and Characteristics (Dipping and Anisotropy)
2. Hole Geometry (Spiraling—Wellbore Tortuosity 8½″)
3. Inharmonic in Drilling String and Parameters (WOB, RPM, BHA design, Bit selection) and Drilling Practice
4. Fluid characteristics (Fluid Density, Rheology, Salinity, Lubricity)
5. Frequent Reaming and Hard back Remaining while tripping (3200–5300 m)
6. Continuous Tight hole and high Over pull situation—specially when MW (<1.35 SG)
7. High torque peaks, while drilling and back reaming (12–18 KIb), specially from 4400 to 5100 m.
8. Sign of formation losses (seepage—partial) from 4450 to 4460 (Gedinnian)
9. Hole cleaning issues (Suspected specially at the start of section towards Trias Carbonate and Lias Argiulex due to the low range of rheological properties maintained (YP 10)
10. Stuck Pipe (Twice) while drilling 8½ Hole in each well 1
11. Tectonic stress of the well bore [4].

### 2.1 Load Summary

From the load summary (Table 1), it is clearly seen that the drill-string is subjected to fatigue failure due to back reaming operation. This is confirmed within the well path curve, showed a variation in wall trajectory via tortuosity. This planned deviation with a dogleg of 5.88°/30 m has been created during side track operation of 8½ new hole, starting from 3171 to 4573 m where increased MW from 1.30 to 1.33 SG for improving hole stability. This dogleg regarded as an optimum angle to pass the drill string even the casing without any damage in drilling operation.

The problem will be intensified when the string is submitted to the more rigorous conditions present due to cyclic movement of the drill string due to tension and torsion load from back reaming operation which may lead to fatigue failure enhancement (As exposed in Figs. 1, 2 and 3).

**Table 1** Load summary

| Load condition | STF | B | Torque at the rotary table (ft/ib)f | Total windup with bit torque (rev)s | Total windup without bit torque (revs) | Measured weight (tonne) | Total stretch (m) | Axial stress = 0 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Distance from surface (m) | Distance from bit (m) |
| Backreaming | F | – | 6722.2 | 4.0 | 3.8 | 205.72 | 12.43 | 4791.82 | 356.58 |

(-) No buckling, *S* sinusoidal, *H* helical, *L* lockup stress, *T* torque, *F* fatigue, *X* exceeds 90 % of yield, *Y* yield reached. Max over pull = 5.91 t over pull at bit = 11.00 t Torque at Bit = 200 ft-Ibf

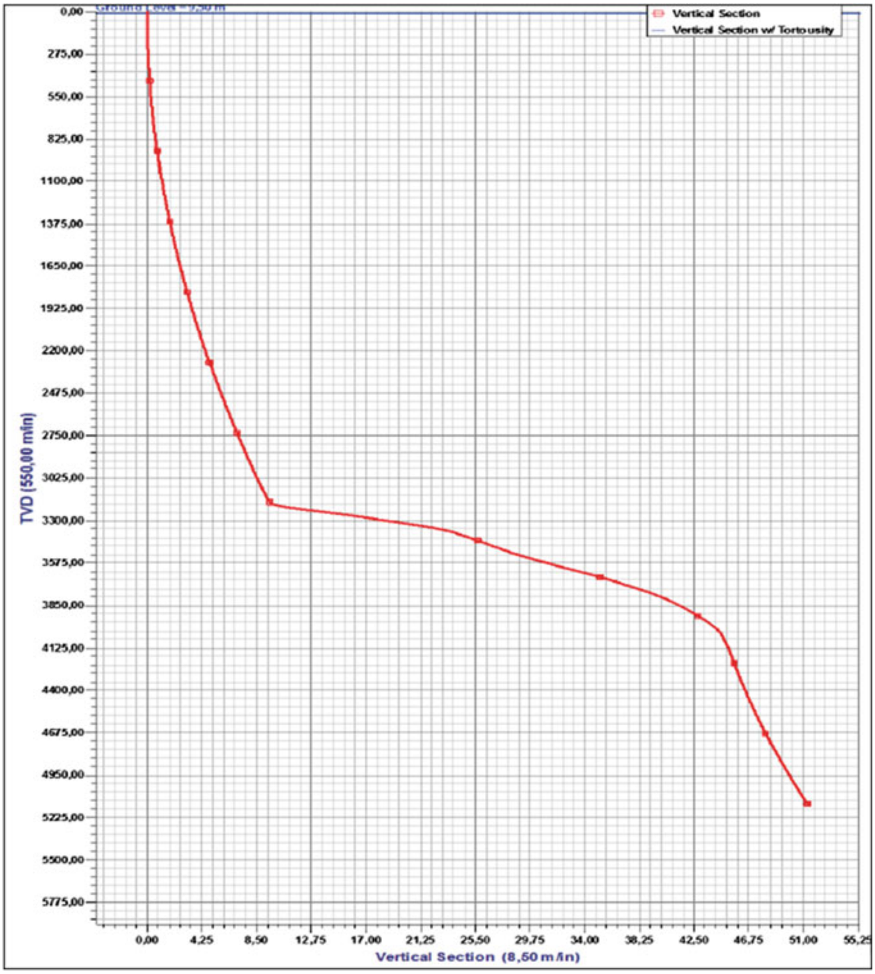


**Fig. 1** Well path

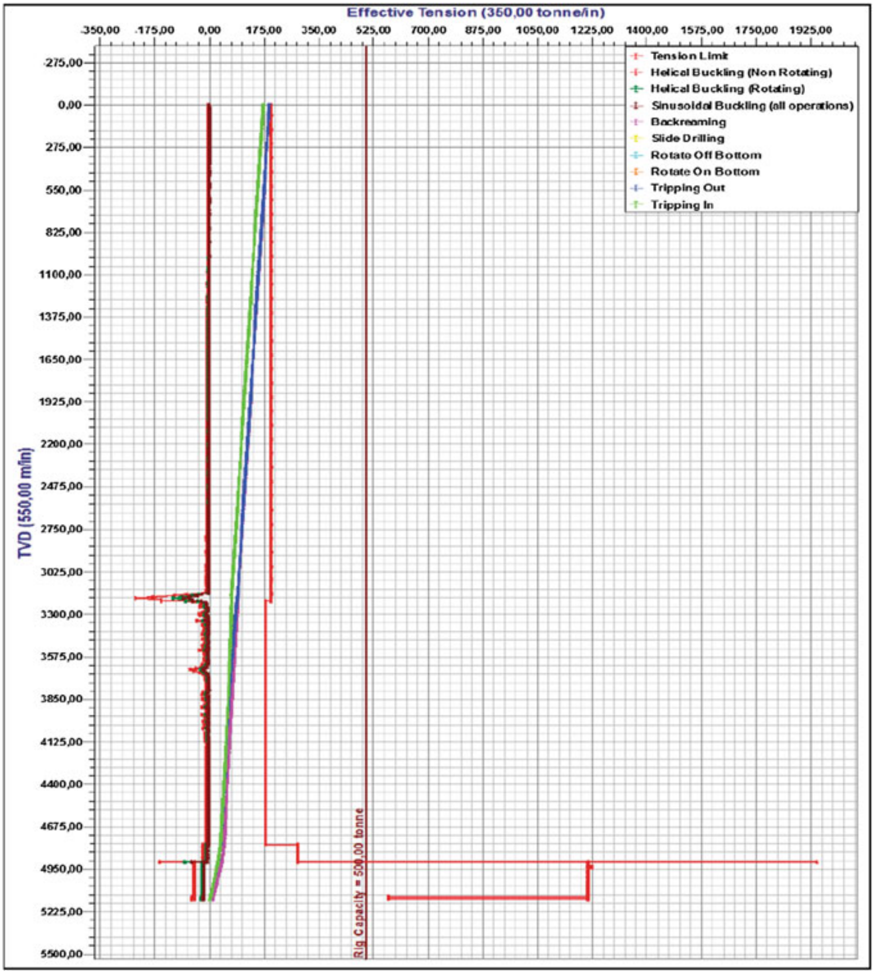


**Fig. 2** Effective tension limits

Drill pipe fatigue damage occurs under cyclic loading conditions due to, for instance, rotation in a dogleg region. As a result, this dog leg makes the high stress concentration areas susceptible to fatigue damage in drill pipe which led to increase in fatigue ratio up to about 1.375 (minimum fatigue ratio is 1) as depicted in Fig. 4.

This minimum fatigue ratio about 1 is based on Lubinski torque and drag model which has defined curves where the permissible dogleg severity, below which no fatigue damage of drillpipes may occur, can be estimated from the tensile load and the drill pipes characteristics. These curves used to prevent static failure are the basis of the “API-RP-7G”.

To illustrate, these loads on drill string due to cyclic stresson drill pipe at depths between 3213.52 m and 3186.13 m are presented in back reaming load Table 2 showed in below.

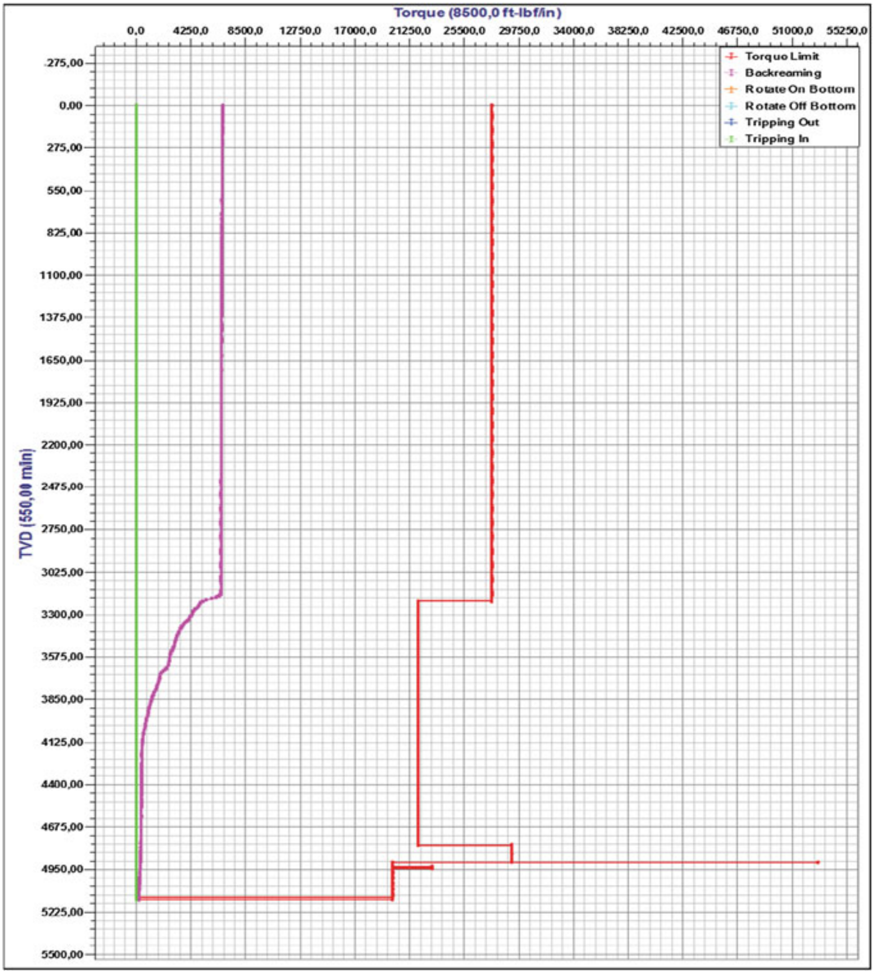


**Fig. 3** Torque limits

Additionally, the measured torque data shows high fluctuations which can refer to drill string dynamics such as slip/stick vibration, restoring moment, torsional resistance as well as axial and lateral vibrations.

## *2.2 Analysis of Back Reaming Stresses*

It is evidently seen from the Table 3 in below that the pipe section at the dogleg region may fail under the combined effects of axial tensile stress, radial stress, torsional stress and alternating repeated bending stress due to rotation. Failure at

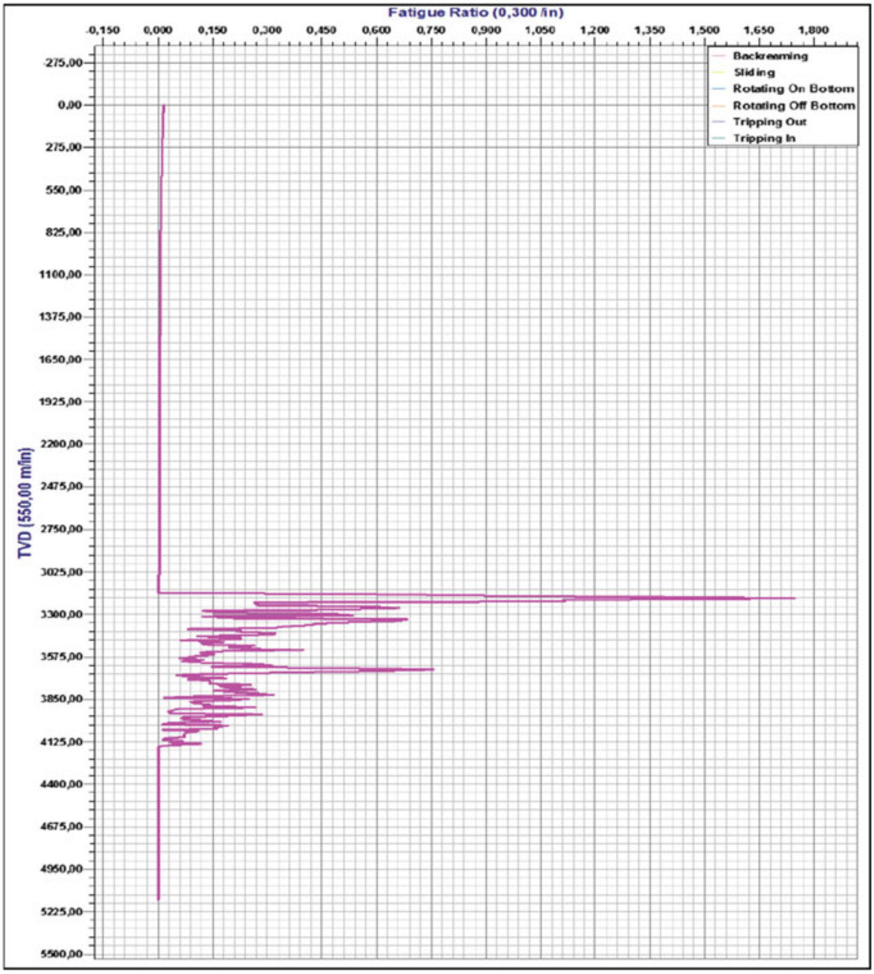


**Fig. 4** Fatigue ratio

this section can be assessed by the VON MISES method of for equivalent yielding under combined loads [5].

Using 5.5″ drill pipe with nominal weight of 21.9 lb/ft grade S135 in the cased hole and 5″ grade G105 may reduce drill string failure due to cyclic tensile/torsional loads [6]. The Table 4 illustrates the decreasing of the number of pipes subjected to fatigue failure.

**Table 2** Load data for backreaming

| Measured Depth (m) | Component Type | Distance from Bit (m) | Internal Pressure (psi) | External pressure (psi) | Axial force | | Drag (tonne) | Torque (ft-Ibf) | Twist (revs) | Sinusoidal buckling (tonne) | Helical buckling (Rotating) (tonne) | B | STF | Contact force /9,45 (m) (Ibf, length) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Pressure Area (tonne) | Buoyancy (tonne) | | | | | | | | |
| 3,331.44 | DP | 1,816.96 | 6,158.36 | 6,158.36 | 69.52 | 86.32 | 0.00 | 4,102.2 | 0.4 | −3.75 | −5.31 | ~ | ~ ~ ~ | 1934 |
| 3,322.37 | DP | 1,826.03 | 6,141.78 | 6,141.78 | 69.82 | 86.57 | 0.00 | 4,146.9 | 0.4 | −5.48 | −7.75 | ~ | ~ ~ ~ | 611 |
| 3,313.30 | DP | 1,835.10 | 6,122.58 | 6,122.58 | 70.11 | 86.81 | 0.00 | 4,172.7 | 0.4 | −6.05 | −8.55 | ~ | ~ ~ ~ | 354 |
| 3,304.23 | DP | 1,844.17 | 6,105.06 | 6,105.06 | 70.41 | 87.06 | 0.00 | 4,282.8 | 0.4 | −10.61 | −15.00 | ~ | ~ ~ ~ | 1506 |
| 3,295.16 | DP | 1,853.24 | 6,088.05 | 6,088.05 | 70.70 | 87.31 | 0.00 | 4,378.2 | 0.4 | −12.16 | −17.20 | ~ | ~ ~ ~ | 1304 |
| 3,286.09 | DP | 1,862.31 | 6,075.23 | 6,075.23 | 71.00 | 87.57 | 0.00 | 4,407.5 | 0.4 | −7.91 | −11.19 | ~ | ~ ~ ~ | 401 |
| 3,277.02 | DP | 1,871.39 | 6,054.83 | 6,054.83 | 71.29 | 87.81 | 0.00 | 4,435.9 | 0.5 | −5.26 | −7.43 | ~ | ~ ~ ~ | 388 |
| 3,267.94 | DP | 1,880.46 | 6,038.13 | 6,038.13 | 71.59 | 88.06 | 0.00 | 4,536.4 | 0.5 | −4.78 | −6.76 | ~ | ~ ~ ~ | 1375 |
| 3,258.87 | DP | 1,889.53 | 6,022.22 | 6,022.22 | 71.88 | 88.31 | 0.00 | 4,672.9 | 0.5 | −4.81 | −6.80 | ~ | ~ ~ ~ | 1866 |
| 3,249.80 | DP | 1,898.60 | 6,006.20 | 6,006.20 | 72.18 | 88.56 | 0.00 | 4,798.0 | 0.5 | −11.25 | −15.90 | ~ | ~ ~ ~ | 1712 |
| 3,240.73 | DP | 1,907.67 | 5,991.19 | 5,991.19 | 72.47 | 88.81 | 0.00 | 4,854.5 | 0.5 | −7.74 | −10.90 | ~ | ~ ~ ~ | 772 |
| 3,231.66 | DP | 1,916.74 | 5,974.05 | 5,974.05 | 72.77 | 89.06 | 0.00 | 4,904.0 | 0.5 | −10.57 | −14.94 | ~ | ~ ~ ~ | 677 |
| 3,222.59 | DP | 1,925.81 | 5,956.30 | 5,956.30 | 73.06 | 89.31 | 0.00 | 4,953.0 | 0.5 | −10.29 | −14.95 | ~ | ~ ~ ~ | 670 |
| 3,213.52 | DP | 1,934.88 | 5,937.56 | 5,937.56 | 73.36 | 89.55 | 0.00 | 5,170.8 | 0.5 | −27.34 | −38.66 | ~ | ~ ~F | 2978 |
| 3,213.52 | DP | 1,934.88 | 5,937.56 | 5,937.56 | 71.16 | 89.55 | 0.00 | 5,170.8 | 0.5 | −54.55 | −77.14 | ~ | ~ ~F | 2978 |
| 3,204.39 | DP | 1,944.01 | 5,921.40 | 5,921.40 | 71.50 | 89.84 | 0.00 | 5,450.3 | 0.5 | −54.40 | −76.94 | ~ | ~ ~F | 3445 |
| 3,195.26 | DP | 1,953.14 | 5,903.86 | 5,903.86 | 71.85 | 90.14 | 0.00 | 5,892.0 | 0.5 | −83.65 | −118.29 | ~ | ~ ~F | 5443 |
| 3,196.13 | DP | 1,962.27 | 5,886.98 | 5,886.98 | 72.19 | 90.42 | 0.00 | 6,232.1 | 0.5 | −63.67 | −90.03 | ~ | ~ ~F | 4191 |
| 3,177.00 | DP | 1,971.40 | 5,870.10 | 5,870.10 | 72.53 | 90.71 | 0.00 | 6,446.3 | 0.6 | −39.96 | −56.51 | ~ | ~ ~ ~ | 2641 |
| 3,167.87 | DP | 1,980.53 | 5,854.31 | 5,854.31 | 72.87 | 91.00 | 0.00 | 6,595.8 | 0.6 | −25.84 | −36.54 | ~ | ~ ~ ~ | 1841 |
| 3,158.74 | DP | 1,989.66 | 5,836.33 | 5,836.33 | 73.21 | 91.29 | 0.00 | 6,595.8 | 0.6 | −3.22 | −4.56 | ~ | ~ ~ ~ | 1 |
| 3,149.61 | DP | 1,998.79 | 5,819.45 | 5,819.45 | 73.56 | 91.58 | 0.00 | 6,595.9 | 0.6 | −3.22 | −4.55 | ~ | ~ ~ ~ | 1 |

**Table 3** Backreaming stresses

| Measured depth (m) | Component type | Distance from Bit (m) | Hoop stress (psi) | Radial stress (psi) | Torsional stress (psi) | Shear stress (psi) | Axial stress (psi) | Buckling stress (psi) | Bending stress (psi) | BSMF | VonMises stress (psi) | VonMises ratio | Fatigue ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,422.15 | DP | 1,726.25 | −6,342.9 | −6,342.9 | 4,222.4 | 425.3 | 35,331.5 | 0.0 | 3,702.7 | 3.868 | 45,950.7 | 0.438 | 0.321 |
| 3,413.08 | DP | 1,735.32 | −6,306.9 | −6,306.9 | 4,278.3 | 275.3 | 35,488.5 | 0.0 | 2,496.4 | 3.876 | 45,909.9 | 0.428 | 0.217 |
| 3,404.00 | DP | 1,744.40 | −6,289.5 | −6,289.5 | 4,339.5 | 301.1 | 35,645.5 | 0.0 | 2,615.2 | 3.885 | 45,182.8 | 0.430 | 0.228 |
| 3,394.93 | DP | 1,753.47 | −6,274.9 | −6,274.9 | 4,361.3 | 106.9 | 35,802.4 | 0.0 | 943.3 | 3.893 | 43,679.2 | 0.416 | 0.082 |
| 3,385.86 | DP | 1,762.54 | −6,255.8 | −6,255.8 | 4,447.1 | 422.3 | 35,959.4 | 0.0 | 3,669.3 | 3.902 | 46,532.3 | 0.443 | 0.321 |
| 3,386.79 | DP | 1,771.61 | −6,239.4 | −6,239.4 | 4,542.2 | 467.5 | 36,116.5 | 0.0 | 4,042.9 | 3.910 | 47,068.0 | 0.448 | 0.355 |
| 3,367.72 | DP | 1,780.68 | −6,222.9 | −6,222.9 | 4,655.4 | 557.0 | 36,273.2 | 0.0 | 4,825.6 | 3.918 | 48,013.4 | 0.457 | 0.424 |
| 3,358.65 | DP | 1,789.75 | −6,206.4 | −6,206.4 | 4,771.4 | 570.6 | 36,430.1 | 0.0 | 4,920.6 | 3.927 | 48,279.9 | 0.460 | 0.434 |
| 3,349.58 | DP | 1,798.82 | −6,191.1 | −6,191.1 | 4,915.8 | 709.9 | 36,586.9 | 0.0 | 6,126.2 | 3.935 | 49,655.0 | 0.473 | 0.541 |
| 3,340.51 | DP | 1,807.89 | −6,174.5 | −6,174.5 | 5,089.9 | 856.5 | 36,743.5 | 0.0 | 7,442.6 | 3.944 | 51,147.9 | 0.487 | 0.659 |
| 3,331.44 | DP | 1,816.96 | −6,158.4 | −6,158.4 | 5,271.6 | 893.9 | 36,900.2 | 0.0 | 7,703.1 | 3.952 | 51,599.5 | 0.491 | 0.683 |
| 3,322.37 | DP | 1,826.03 | −6,141.8 | −6,141.8 | 5,329.1 | 282.6 | 37,056.7 | 0.0 | 2,379.1 | 3.960 | 46,505.4 | 0.443 | 0.212 |
| 3,313.30 | DP | 1,835.10 | −6,122.6 | −6,122.6 | 5,362.3 | 163.4 | 37,213.2 | 0.0 | 1,391.5 | 3.969 | 45,682.3 | 0.435 | 0.124 |
| 3,304.23 | DP | 1,844.17 | −6,105.1 | −6,105.1 | 5,503.8 | 695.9 | 37,370.0 | 0.0 | 5,976.7 | 3.977 | 50,376.6 | 0.480 | 0.534 |
| 3,295.16 | DP | 1,853.24 | −6,088.0 | −6,088.0 | 5,626.3 | 602.6 | 37,526.5 | 0.0 | 5,278.4 | 3.985 | 49,865.6 | 0.475 | 0.472 |
| 3,286.09 | DP | 1,862.31 | −6,075.2 | −6,075.2 | 5,664.0 | 185.6 | 37,682.8 | 0.0 | 1,775.2 | 3.993 | 46,579.2 | 0.444 | 0.159 |
| 3,277.02 | DP | 1,871.39 | −6,054.8 | −6,054.8 | 5,700.5 | 179.2 | 37,839.4 | 0.0 | 1,392.0 | 4.002 | 46,351.1 | 0.441 | 0.125 |
| 3,267.94 | DP | 1,880.46 | −6,038.1 | −6,038.1 | 5,829.7 | 635.5 | 37,996.1 | 0.0 | 5,388.2 | 4.010 | 50,455.3 | 0.481 | 0.486 |
| 3,258.87 | DP | 1,889.53 | −6,022.2 | −6,022.2 | 6,005.0 | 862.3 | 38,152.4 | 0.0 | 7,338.5 | 4.018 | 52,573.9 | 0.501 | 0.663 |
| 3,249.80 | DP | 1,898.60 | −6,006.2 | −6,006.2 | 6,165.8 | 791.2 | 38,308.4 | 0.0 | 6,718.4 | 4.026 | 52,156.5 | 0.497 | 0.608 |
| 3,240.73 | DP | 1,907.67 | −5,991.2 | −5,991.2 | 6,238.4 | 357.0 | 38,464.6 | 0.0 | 3,050.7 | 4.034 | 48,723.7 | 0.464 | 0.277 |
| 3,231.66 | DP | 1,916.74 | −5,974.1 | −5,974.1 | 6,302.0 | 312.9 | 38,620.7 | 0.0 | 2,967.6 | 4.043 | 48,801.9 | 0.465 | 0.270 |
| 3,222.59 | DP | 1,925.81 | −5,956.3 | −5,956.3 | 6,365.0 | 309.8 | 38,777.0 | 0.0 | 2,916.9 | 4.051 | 48,911.8 | 0.466 | 0.266 |
| 3,213.52 | DP | 1,934.88 | −5,937.6 | −5,937.6 | 6,644.9 | 1,376.5 | 38,933.9 | 0.0 | 12,217.2 | 4.059 | 58,286.1 | 0.555 | 1.116 |

(continued)

**Table 3** (continued)

| Measured depth (m) | Component type | Distance from Bit (m) | Hoop stress (psi) | Radial stress (psi) | Torsional stress (psi) | Shear stress (psi) | Axial stress (psi) | Buckling stress (psi) | Bending stress (psi) | BSMF | VonMises stress (psi) | VonMises ratio | Fatigue ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,213.52 | DP | 1,934.88 | −5,937.6 | −5,937.6 | 5,377.5 | 1,243.8 | 34,127.2 | 0.0 | 13,090.6 | 3.429 | 54,008.2 | 0.514 | 1.108 |
| 3,204.39 | DP | 1,944.01 | −5,921.4 | −5,921.4 | 5,668.2 | 1,447.9 | 34,291.0 | 0.0 | 13,121.6 | 3.437 | 54,288.0 | 0.517 | 1.113 |
| 3,195.26 | DP | 1,953.14 | −5,903.9 | −5,903.9 | 6,127.5 | 2,287.8 | 34,457.1 | 0.0 | 20,546.9 | 3.446 | 61,952.4 | 0.590 | 1.746 |
| 3,186.13 | DP | 1,962.27 | −5,887.0 | −5,887.0 | 6,481.2 | 1,761.8 | 34,618.4 | 0.0 | 15,803.6 | 3.454 | 57,498.1 | 0.548 | 1.346 |
| 3,177.00 | DP | 1,971.40 | −5,870.1 | −5,870.1 | 6,704.0 | 1,109.9 | 34,782.8 | 0.0 | 9,930.0 | 3.462 | 51,934.1 | 0.495 | 0.848 |

**Table 4** Load data for backreaming with 5.5″ drill pipe grade S135

| Measured depth (m) | Component type | Distance from bit (m) | Internal pressure (psi) | External pressure (psi) | Axial force | | Drag (tonne) | Torque (ft-lbf) | Twist (revs) | Sinusoidal buckling (tonne) | Helical buckling (Rotating) (tonne) | B | STF | Contact force /9.45 (m) (Ibf,length) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Pressure area (tonne) | Buoyancy (tonne) | | | | | | | | |
| 3,330.25 | DP | 1,818.15 | 6,155.46 | 6,155.46 | 69.56 | 86.35 | 0.00 | 3,388.9 | 0.4 | −3.61 | −5.10 | ~ | ~ ~ ~ | 1118 |
| 3.321.17 | DP | 1,827.23 | 6,138.65 | 6,138.65 | 69.86 | 86.60 | 0.00 | 3,421.6 | 0.4 | −5.62 | −7.95 | ~ | ~ ~ ~ | 429 |
| 3,312.09 | DP | 1,836.31 | 6,121.78 | 6,121.78 | 70.15 | 86.85 | 0.00 | 3,443.1 | 0.4 | −6.06 | −8.56 | ~ | ~ ~ ~ | 275 |
| 3,303.01 | DP | 1,845.39 | 6,103.90 | 6,103.90 | 70.45 | 87.10 | 0.00 | 3,523.1 | 0.4 | −12.70 | −17.96 | ~ | ~ ~ ~ | 1075 |
| 3,293.94 | DP | 1,854.46 | 6,086.72 | 6,086.72 | 70.74 | 87.35 | 0.00 | 3,629.5 | 0.4 | −13.09 | −18.52 | ~ | ~ ~ ~ | 1436 |
| 3,284.86 | DP | 1,863.54 | 6,072.97 | 6,072.97 | 71.04 | 87.60 | 0.00 | 3,642.4 | 0.4 | −7.14 | −10.10 | ~ | ~ ~ ~ | 158 |
| 3,275.78 | DP | 1,872.62 | 6,053.25 | 6,053.25 | 71.33 | 87.84 | 0.00 | 3,659.4 | 0.4 | −5.26 | −7.44 | ~ | ~ ~ ~ | 213 |
| 3,266.70 | DP | 1,881.70 | 6,036.49 | 6,036.49 | 71.63 | 88.09 | 0.00 | 3,763.2 | 0.4 | −4.59 | −6.49 | ~ | ~ ~ ~ | 1400 |
| 3,257.62 | DP | 1,890.78 | 6,020.08 | 6,020.08 | 71.92 | 88.34 | 0.00 | 3,905.6 | 0.5 | −12.78 | −18.07 | ~ | ~ ~ ~ | 1928 |
| 3,248.55 | DP | 1,899.85 | 6,003.63 | 6,003.63 | 72.22 | 88.59 | 0.00 | 3,980.9 | 0.5 | −9.44 | −13.35 | ~ | ~ ~ ~ | 1011 |
| 3,239.47 | DP | 1,908.93 | 5,987.64 | 5,987.64 | 72.51 | 88.84 | 0.00 | 3,982.3 | 0.5 | −7.65 | −10.82 | ~ | ~ ~ ~ | 0 |
| 3,230.39 | DP | 1,918.01 | 5,971.79 | 5,971.79 | 72.81 | 89.10 | 0.00 | 3,983.6 | 0.5 | −10.50 | −14.85 | ~ | ~ ~ ~ | 0 |
| 3,230.39 | DP | 1,918.01 | 5,971.79 | 5,971.79 | 67.01 | 89.10 | 0.00 | 3,983.6 | 0.5 | −26.58 | −37.59 | ~ | ~ ~ ~ | 0 |
| 3,221.26 | DP | 1,927.14 | 5,955.73 | 5,955.73 | 67.35 | 89.37 | 0.00 | 4,061.4 | 0.5 | −26.46 | −37.42 | ~ | ~ ~ ~ | 841 |
| 3,212.14 | DP | 1,936.26 | 5,935.73 | 5,935.73 | 67.68 | 89.63 | 0.00 | 4,246.5 | 0.5 | −99.24 | −140.34 | ~ | ~ ~ ~ | 2027 |
| 3,203.01 | DP | 1,945.39 | 5,919.99 | 5,919.99 | 68.01 | 89.91 | 0.00 | 4,556.8 | 0.5 | −100.06 | −141.49 | ~ | ~ ~ ~ | 3409 |
| 3,193.89 | DP | 1,954.51 | 5,902.02 | 5,902.02 | 68.35 | 90.18 | 0.00 | 5,022.1 | 0.5 | −167.38 | −236.69 | ~ | ~ ~ ~F | 5121 |
| 3,184.76 | DP | 1,963.64 | 5,885.13 | 5,885.13 | 68.68 | 90.45 | 0.00 | 5,426.5 | 0.5 | −102.07 | −144.35 | ~ | ~ ~ ~F | 4448 |
| 3,175.64 | DP | 1,972.76 | 5,868.24 | 5,868.24 | 69.02 | 90.72 | 0.00 | 5,648.8 | 0.5 | −74.74 | −105.70 | ~ | ~ ~ ~ | 2436 |
| 3,166.51 | DP | 1,981.89 | 5,852.06 | 5,852.06 | 69.35 | 90.99 | 0.00 | 5,749.9 | 0.5 | −39.48 | −55.83 | ~ | ~ ~ ~ | 1099 |

**Table 5** Drill pipes 5.5 in grade S

| Load condition | STF | B | Torque at the rotary table (ft/ibf) | Total windup with bit torque (revs) | Total windup without bit torque (revs) | Measured weight (tonne) | Total stretch (m) | Axial stress = 0 | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Distance from surface (m) | Distance from bit (m) |
| Backreaming | F | – | 6419.5 | 3.3 | 3.1 | 199.74 | 11.63 | 4791.82 | 356.58 |
| Max over pull: 80.77 tonne | | | | Over pull at bit 11.00 tonne | | | | Torque at bit 200 ft-Ibf | |

## 2.3 Total BHA Stretch

From the comparison of two Tables (1 and 5) it is clearly seen that the drill pipe grade S135 is more suitable in mechanical characteristics than grade G105. This conclusion is confirmed from total stretch of the bottom hole assembly which was reduced by 0.8 m.

# 3 Conclusion

To sum up, the pipe section at the dogleg region may fail under the combined effects of axial tensile stress, radial pressure, torsional stress and alternating repeated bending stress due to rotation. For this the position and grade of drill pipe in the drill string will influence the amount of fatigue damage since continually rotated at severe dog-leg angle, such as a kick-off point will accumulate fatigue at a much higher amount for this; a permanent damage is appeared.

Furthermore, the over pull load plus the torque are the most important points to be considered in deep well drilling and back reaming, since the resistance of the drill string body to the combined efforts will limit probably its tensional limit by using mixed drill pipes G105 class premium in the 8.5″ section, 5.5″ in the cased hole and 5″ in the open hole, has some limitation due to the axial loads for this drilling deep section requires stronger drill pipe to withstand the operational loads including appropriate design factors. Therefore using 5.5″ drill pipe with nominal weight of 21.9 lb/ft grade S135 is necessary.

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