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

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Abstract

Common knowledge and rule of thumb tell us that the tensile failures will mostly occurs in the pipe body, while torsional failures will occurs 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 later can usually be operating up until 80% of the pipe body yield stress which is considered as 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 limit probably its tensional limit. By this I mean; exerting both a tension and torsion load on the drill string the yield stress of this later will weaken consequently applying a high tension effort combined with a significant torque lead to plastified the drill pipe body thus reducing fatigue life of the drill pipe. This problem is well observed in back-reaming operation.

The results shows, fatigue damage from rotation in dogleg during back reaming operation is a significant problem if the severity is greater then the critical value. So the position of drill pipe in the string will influence the amount of fatigue damage it sustains .besides that Back reaming can reduce the fatigue life of the drill pipe significantly because of the reversal stress of the drill string under tension in a dog leg.

Introduction

This paper outlines practically tensional and torsional loads which affecting the drill pipe as a result of frequent practices of back reaming operation. For this reason a practical ways of eliminating this trouble are explained in this paper, or at least reducing this problem. Since 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 experiences about the drill string failures which were done before in order to more clarify this later. So firstly I will shad the light on back reaming operation and then give an synopsis on failure due to torsion and tensile loading due to back reaming operation, followed by few literature torque and drag calculation via Lubinski model by using soft modeling (well plan software), finally give an optimum solution for the problem.

•Backreaming operation

Generally the backreaming is the drilling backwards to trip out of the hole when there is a problem with pulling the pipe freely without rotation and circulation in order to clean the hole to eliminate cuttings accumulation and hole caving.

While backreaming, the pipe tension is lower than when pulling out of the hole with excessive drag, but torsional stress is introduced. The drill string is subjected to diverse forces such us:

1. the contact of the drill string body with the wellbore which is named a side forces. 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).
2. During backreaming, all drill string stresses are taking place: 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.
3. 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.
4. 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.
5. Backreaming can reduce the fatigue life of the drill pipe significantly because of the reversal stress of the drill string under tension in a dogleg.[5]

•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.[5]

•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.

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. [1]

•Well plan torque and drag module

Normal Analysis calculates 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 well bore, and with one set of operational parameters. You may choose to perform the analysis using either the soft or stiff string model. However, for now use the soft string model

Engineering overview of back reaming for 8 ½" hole section

Established upon the quick review conducted for the history of 8 ½" hole of two wells drilled in Algeria, it is imperative to highlight 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 8 ½ hole section which is the longest one, approximately 2500 meters. The possible root causes for the different hole problems encountered on the 8 ½ of well1and well 2 could be attributed to the followings major factors: well 1 as an example.

1. Formation Nature & Characteristics (Dipping & Anisotropic)
2. Hole Geometry (Spiraling - Wellbore Tortuosity 8 ½ ")
3. Inharmonic in Drilling String & Parameters (WOB, RPM, BHA design, Bit selection) & Drilling Practice.
4. Fluid characteristics (Fluid Density, Rheology, Salinity, Lubricity).
5. Frequent Reaming g & Hard back Remaining while tripping (3200- 5300m)
6. Continual Tight hole and high Over pull situation – specially when MW (<1.35 SG)
7. High torque peaks , while drilling &and back reaming (12 -18 Klb) , specially from 4400m to 5100m.
8. Sign of formation losses (seepage –partial) from 4450 - 4465 (Gedinnian)
9. Hole cleaning issues (Suspected specially at the start of section towards Trias Carbonate &Lias Argiulex due to the low range of rheological properties maintained (YP 10)
10. Stuck Pipe (Twice) while drilling 8 ½ Hole in each well)
11. Tectonic stress of the well bore.

•Load summary

Table 1: load summary

Load condition	STF	B	Torque at the rotary table (ft/lbf)	Total windup with bit torque (rev)s	Total windup without bit torque (revs)	Measured Weight (tone)	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= 5.91t over pull at bit =11.00 t Torque at Bit=200 ft-Ibf									

From the load summary table; it is clearly seen that the drill-string is subjected to fatigue failure due to backreaming operation. This is confirmed within the well path curve, showed a variation in wall trajectory via trotusity. This planned deviation with a dogleg of 5.88°/30m has been created during sidetrack operation of 8 ½ new hole starting from 3171m to 4573 m where increased MW from 1.30 to 1.33 sg for improving hole stability. This dog leg regarded as a 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 led to enhance fatigue failure.

(As mentioned in Figure 1, 2,3)

Figure 1: Well path

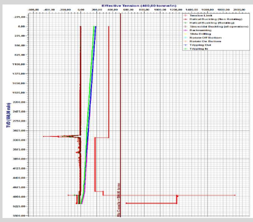

Figure 2: Effective tension limits

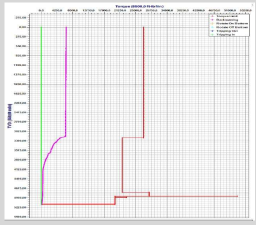

Figure 3: Torque limit

Drill pipe fatigue damage occurs under cyclic loading conditions due to, for instance, rotation in a dogleg region . As a result; this dog leg make the high stress concentration area susceptible to fatigue damage in drill pipe which led to increase in fatigue ratio about of 1.375(minimum fatigue ratio is 1)to illustrate loads on drill string due to cyclic stress on drill pipe between 3213.52m and 3186.13 m are presented in back reaming load table in below .

Table 2:Load Data For Back reaming

Measured Depth (m)	Component Type	Distance from Bit (m)	Internal Pressure (psi)	External Pressure (psi)	Axial Force: Pressure Area (tonne)	Axial Force: Buoyancy (tonne)	Drag (tonne)	Torque (ft-lbf)	Twist (revs)	Sinusoidal Buckling (tonne)	Helical Buckling (Rotating) (tonne)	B	STF	Contact Force /9,45 (m) (lbf/length)
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	-10,94	~	~~~	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	-14,95	~	~~~	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	-14,55	~	~~~	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
3 186,13	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	5 854,81	5 854,81	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

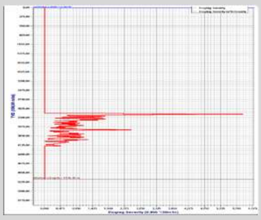

Figure4: Dogleg Severity

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

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 drill pipes 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".

•Analysis of back reaming stresses

It is evidently seen from the table in below that the pipe section at the dogleg region may fail under the combined effects of axial , radial, torsional and alternating repeated bending stresses due to rotation. Failure at this section can be assessed by the method of Von Mises for equivalent yielding under combined loads

Table 3:back reaming 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	-6 324,9	-6 324,9	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	44 909,9	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
3 376,79	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
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	57 488,1	0,548	1,340
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

Using drill pipe 5.5" with nominal weight of 21.9 lb/ft grade S 135 in the cased hole and 5" grade G105 may reducing drill string failure due to cyclic tensile and torsional loads. The table in below illustrates the decreasing of number of pipe subjected to fatigue.

Measured Depth (m)	Component Type	Distance from Bit (m)	Internal Pressure (psi)	External Pressure (psi)	Axial Force: Pressure Area (tonne)	Axial Force: Buoyancy (tonne)	Drag (tonne)	Torque (ft-lbf)	Twist (revs)	Sinusoidal Buckling (tonne)	Helical Buckling (Rotating) (tonne)	B	STF	Contact Force /9,45 (m) (lbf/length)
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

•Total BHA stretch

➢ **Drill pipe 5.5 in grade G :**Table 5

Torque at the Rotary Table (ft-lbf)	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)	Axial Stress = 0: Distance From Bit (m)	Neutral Point Distance from Surface (m)	Neutral Point Distance from Bit (m)
6 722,2	4,0	3,8	205,72	12,43	4 791,82	356,58	5 148,40	0,00
Max Overpull: 5,91	tonne		Overpull at Bit:	11,00	tonne		Torque at Bit: 200,0	ft-lbf

➢**Drill pipe 5.5 in grade S :** Table 6

Torque at the Rotary Table (ft-lbf)	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)	Axial Stress = 0: Distance From Bit (m)	Neutral Point Distance from Surface (m)	Neutral Point Distance from Bit (m)
6 419,5	3,3	3,1	199,74	11,63	4 791,82	356,58	5 148,40	0,00
Max Overpull: 80,77	tonne		Overpull at Bit:	11,00	tonne		Torque at Bit: 200,0	ft-lbf

From the comparison of two tables it is clearly seen that the drill pipe grade S135 is more suitable in characteristic mechanic than grade G105, this conclusion is confirmed from total stretch of the bottom hole assembly which was reduced by 0.8 m.

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 a 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.

Accordingly; by using mixed drill pipes G 105 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 drill pipe 5.5" with nominal weight of 21.9 lb/ft grade S 135 is necessary.

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