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Drillstring Buckling Prediction and Its Impact on Tool-Joint Effects in Extended Reach Wells

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Abstract: The mechanism of buckling has been extensively studied in pipes and tubings. But these studies more often has been restricted to continuous or straight body pipes. In reality most pipes and other drillstring elements have end couplings or connections known as tool joint. Tool joint presence changes the annular geometry, hydraulics and stress distribution of the pipe or tubulars in the wellbore. Modelling drillstring in highly deviated wells with no regards to the tool joint effects has been a major source of error in many drilling mechanics analysis. This has often led to misleading information on buckling and bending of the pipe which could lead to drilling and completion problems and costly well interventions. Thus it becomes necessary to model tool joint effect in the drillstring as it is subjected to downhole forces and stresses. In this study, emphasis is made on the determination of tool joint effect on pipe buckling for highly deviated extended reach wells (ERWs). WellPlan T&D spreadsheet software was used for the simulation. The simulation was runned for pipe with tool joint and the same pipe with the tool joints removed. Results show that jointed pipes has similar buckling behaviour with continuous straight body pipes with buckling starting from sinusoidal buckling mode and gradually entering the helical buckling mode for both types of pipes. Furthermore, result revealed that tool joint presence increases the critical buckling force by an average of 28.9% for helical as well as (AWA) sinusoidal buckling modes.

Keywords: Wellbore, Tubular, Modelling, Trajectories, Helical,Sinusoidal

1. Introduction

With the increasing complexity of petroleum geological formations, and the decreasing oil price, it becomes paramount to optimize AWA gas operations. One area of this optimisation is in drilling and completions [1]. Drilling in oil and gas asset development requires high investment cost [2, 3]. Owing to this, operators seek ways to efficiently reach target depths at least overall drilling costs [3]. The development of longer reach or ERWs enables maximum contact with reservoirs allowing more drainage area and requiring less number of platforms on new development assets. ERWs are wells in which the horizontal departure is at least two times the true vertical depth [1, 4]. These high angle wells prove very challenging to drill and complete especially during tripping and sliding operations. The complexity of ERWs becomes more pronounced as the well becomes three-dimensional in shape, in this case, both the azimuth and inclination is changing continuously with the wellbore path.

In ERWs, Excessive torque and drag, buckling of drillstring and tubulars are commonly encountered due to complex wellpath, and also due to doglegs and tortuosities which are usually connected with extended reach drilling (ERD) architectures. Engineers are faced with the challenge of designing safe operational practices and windows to ensure that acceptable design factors are met at least operating costs [1, 5]. In ERWs, due to high angle, there is tendency for high compression generated in the drillstring during tripping and sliding operations. At some point, these compressive forces may rise and exceed the critical buckling loads leading to buckling of the drillstring or tubulars. It is then advisory to evaluate pre-buckling and post-buckling periods in the pipe elements. This will serve to check if the pipe will be able to withstand forces downhole so as to reach target depth on prevalent circumstances given the drag, torque and stress encountered by the pipe as it travels.

While a great number of researches have been conducted to evaluate buckling in vertical, inclined and curved wellpaths, nearly all have focused on straight body pipe configurations by applying a simplistic approach; little has been done by researchers to investigate the effect of buckling on jointed pipes (i.e. pipes with tool joints). Tool joints' presence changes the annular geometry of the pipe thus leading to reduced radial clearance. In this situation, the contact of the wellbore wall with the jointed pipes is usually at the tool joints especially in curved wellbore sections. Tool joints cause casing wears due to torque and drag forces and buckling [6]. This results from interaction between the pipe tool joints and the casing string. Due to complex trajectories as encountered in extended reach wells, the degree of such contact might increase leading to additional loads on the casing when buckled.

Many studies have been conducted on the subject of buckling. Most of these were extensively done for completely straight body pipes neglecting tool joints or couplings. Only a few recent studies focus on the determination of equations for buckling of jointed pipes. One of the earliest pioneering works on buckling was conducted by [7]. Lubinski formulated mathematical equations for effect of sinusoidal buckling in pipes for vertical wells. Later on that year Lubinski and Athouse went further to formulate equations for helical buckling of pipes in vertical wells. Paslay and Bogy (1964) worked oncircular pipes and their work helped in determining circular pipes' stability when constrained in a cylinder that is inclined [8]. Ziegler (1977) studied shaft buckling using end torque. He considered only fixed-fixed boundary conditions. His analyses demonstrated that buckling is not caused only by compression but can be caused by tension when the pipe is under applied torque [9]. Mitchell (1982); Mitchell (1986) contributed immensely to buckling analyses. He applied boundary conditions AWA friction effects and revolutionilize the subject of buckling [10-11]. Mitchell (1988) proposed stability criterion for sinusoidal AWA helical buckling [12]. Mitchell (1999); Mitchell (2000) developed analytical connections for buckling of pipe with connectors. The equations described 3D buckling of pipe. He provided the contact force between the connector and wellbore [13-14]. In 2006, Mitchell and Miska went further to develop the equations for pipes helical buckling with connectors AWA torque [15]. Recently Menand *et al*., (2008) utilized simplified quasi-static models to study friction effect on critical load value with drill pipes that are rotating [16]. Menand *et al*., (2008); Gao and Liu (2013) recently provided new concepts for buckling limit factor that considers wellbore tortuosity, borehole stability and shape that is used to better calibrate buckling equations [16-17]. Gao and Huang (2015); Gao *et al.,* (2002) revealed the instability of sinusoidal buckling but showed that helical buckling is stable in vertical wellbores [18-19].

The topic of tool joint effects on pipe buckling has only attracted recent attention. Mitchell (1999) gave 3D beam column equations for a buckled pipe that is helical in configuration and as well has connectors (tool joints and couplings). The equation includes the contact force between the connector and the wellbore [13]. Mitchell (2000) extended his 1999 work by analyzing lateral buckling of pipes with connectors for horizontal wells [14]. Later on, Gao (2006) used energy method to analyze pipe helical buckling with tool joints and demonstrated that the tool joints presence increase the buckling loads by 20-40% while pipe pads reduce the contact force by 10-30% [20]. Tikhonov *et al.,* (2000) provided experimental evidence to collaborate tool joint effects on buckling/post buckling behaviour of drill pipes constrained in straight horizontal wellbores [21]. Duman *et al.,* (2003a) experimentally determined tool joint effect on axial AWA and contact force transfers in horizontal wellbores [22].

2. Pipe Buckling Equations

2.1. Effective Tension Is Given by

$$F_e = F_t + P_o A_o - P_i A_i \quad (1)$$

Where

$F_e = Effective\ tension, lbs$

$F_t = true\ tension, lbs$

P_o and P_i- are the hydrostatic pressures at a depth, D, of a column of mud for outer and inner sections of the pipe.

2.2. The True Tension Is Given by

$$F_t = \sum[L w_{air} cos\alpha + F_D + \Delta F_{area}] - F_{bottom} + WOB \quad (2)$$

When the drill string is rotating off-bottom, the weight on bit (WOB) is zero.

If the drill string is on bottom, then F_t is a compressive force equal to WOB

Where:

w_{air}=weight per foot of the drill string in air in lb/ft,,

L - Length of drill string hanging below point in feet,

α=inclination in degrees,

F_{bottom}=bottom pressure force,

F_{bs}=buckling stability force.

The bottom pressure force is a compressive force due to fluid pressure applied over the cross sectional area of the bottom component.

ΔF_{area}=the change in force due to a change in area.

The force due to fluid pressure applied is at the bottom of the pipe. The bottom force should be equal to the stability force at the bottom of the pipe. This bottom force is applied throughout the pipe uniformly, whereas the buckling stability force is calculated using the same equation but with different depths. The depth of interest when calculating bottom force is the bottom of the wellbore while in buckling stability force, the depth is the depth of the tubular in the wellbore

$$F_{bottom} = P_e(A_o - A_i) \quad (3)$$

P_e is the pressure at the bottom depth

The force necessary to buckle a pipe is given by the buckling force. This is a compressive force, equal but opposite in sign to the\ effective force.

$$F_b = -F_e \quad (4)$$

Buckling analysis is analyzed with regards to the well type. The critical angle is the angle above which the hole is no longer considered to be vertical. The critical inclination angle determines if the wellbore path is vertical or deviated and is given by

$$\theta_c = \sin^{-1}\left[\left(\frac{1.94}{2}\right)^2 r_c \left(\frac{W_b}{EI}\right)^{1/3}\right] \quad (5)$$

If $\theta > \theta_c$ wellbore is deviated
If $\theta < \theta_c$ wellbore is vertical

2.3. Critical Buckling Force for Deviated Wellbore

i. Sinusoidal buckling

$$F_s = 2\sqrt{\frac{EIW_b \sin\theta}{r_c}} \quad (6)$$

ii. Helical buckling

$$F_H = \sqrt{2}to\left(2\sqrt{2} - 1\right)\sqrt{\frac{4EIW_b \sin\theta}{r_c}} \quad (7)$$

Where: F_H = critical helical buckling force, lbs
F_s = critical sinusoidal buckling force, lbs
$\theta = angle\ of\ inclination\ with\ the\ vertical, degrees$

2.4. Torque Created by Helical Buckling

When helical buckling has occurred in a pipe it creates torque which is given as:

$$\tau_{buck} = \pm \frac{F_b r_c^2 \beta}{2\sqrt{1 - r_c^2 \beta^2}} \quad (8)$$

$\tau_{buck} = buckling\ induced\ torque, lb.$ in

$$\beta = \pm\sqrt{\frac{F_b}{2EI}} \quad (9)$$

Torque caused by buckling is usually small and can be neglected. But in cases where there tubing diameter is small and the radial clearance is large, the buckling induced torque may be considerably large when compared with the make-up torque for the connections

2.5. Additional Side Force Due to Buckling

Once buckling has occurred, there is an additional side force due to increased contact between the wellbore and the string. For the soft string model, the following calculations are used to compute the additional side force. These calculations are not included in a stiff string analysis because the Stiff String model considers the additional force due to buckling in the derivation of the side force.

i. Sinusoidal Buckling Mode

$$F_{asin} = \frac{r_c F_b^2}{2EI} \quad (10)$$

Total Contact force in sinusoidally buckled pipe is given as

$$F_T = F_n + F_{asin}$$

ii. Helical Buckling Mode

$$F_{ahel} = \frac{r_c F_b^2}{4EI} \pm \frac{r_c M_t F_b}{2EI}\beta \quad (11)$$

Total Contact force in helically buckled pipe is given as

$$F_T = F_n + F_{ahel}$$

Where:EI − stiffness of pipe bending
$F_{ahel} = additional\ contact\ force\ due\ to\ helical\ buckling, lbs$
$F_{asin} = additional\ contact\ force\ due\ to\ sinusoidal\ buckling, lbs$
r_c −radial distance existing between constraining pipe and borehole wall

2.6. Buckling in Pipes with Tool Joints

Pipes with tool joints have discontinuous flow conduits. As such there is reduced radial clearance, increased weight, and more pressure loss at the tool joint sections. For curved wellbores, the tubular makes contact with the wellbore at the tool joint leading to increased contact force at the tool joint.

In buckling analysis, there is variation of tool-jointed pipes with straight body pipe because of tool joint effects. As such the following pipe parametres are changed: the cross-sectional area, diameter or radius, radial clearance and pipe weight. These parametres affects the subsequent parametres that requires their input for their determination.

i. Radius of pipe with tool joints

When there is tool joints then radius r of the pipe is given by:

$$r = 0.95r_b + 0.05r_j \quad (12)$$

$$r^2 = 0.95r_b^2 + 0.05r_j^2 \quad (13)$$

Where: $r_j\ and\ r_b$ − $are\ the\ respective\ radii\ of\ tool\ joints\ and\ pipe\ body$

ii. Diameter of pipe with tool joints

When there is tool joints then diameter D of the pipe is given by:

$$D = 0.95D_b + 0.05D_j \quad (14)$$

$$D^2 = 0.95D_b^2 + 0.05D_j^2 \quad (15)$$

Where:
$D_j\ and\ D_b\ are\ the\ respective\ diameters\ of\ tool\ joints\ and\ pipe$ body

iii. Cross sectional area of pipe element with tool joint

For outer wall of pipe

$$A_o = \frac{\pi}{4}\left(0.95D_{bo}^2 + 0.05D_{jo}^2\right) \quad (16)$$

For inner wall of pipe

$$A_i = \frac{\pi}{4}\left(0.95D_{bi}^2 + 0.05D_{ji}^2\right) \quad (17)$$

D_{bo} and D_{bo} are the diameter of pipe body in inhes,
A_o and A_i are the outer and inner pipe wall cross sectional area, in^2

D_{jo} and D_{jo} are outer and inner diameter of pipe tool joint, inch

iv. Radial clearance for Pipe with Tool Joints

The radial clearance for pipe with tool joint differs from that of straight body pipes

Note: It is assumed that the tool joint length is 5% of the entire pipe length.

Radial clearance (in) for section with too joint is given using the relations below:

For pipe body

$$r_{clb} = \frac{1}{2}(D_h - D_b) \quad (18)$$

For tool joint

$$r_{clj} = \frac{1}{2}(D_h - D_j) \quad (19)$$

Effective radial clearance combining the straight pipe body section and the tool joint section is

$$r_{cle} = 0.95 r_{clb} + 0.05 r_{clj} \quad (20)$$

Where

r_{cl}=radial clearance, in

r_{cle} = effective radial clearance, in

r_{cle} is utilized when tool joint effect is considered

r_{clj} = radial clearance between wellbore wall and tool joint, in.

D_h=Hole diameter, in

D_b=outer diameter of drill string section without tool joint, in.

D_j =Outer diameter of tool joint, in.

OD=drill string element outer diameter

v. Moment of Inertia for Pipe components with tool joint

For components with tool joints, the constraints, 0.95 and 0.05 are used to assume 95% of the component is length body and 5% is tool joint body.

A pipe with tool joints has straight pipe body and tool joint sections. Two moments are evaluated:

a) Moment of inertia for circular pipe for straight pipe body length

$$I_b = \frac{\pi}{64}(D_{bo}^4 - D_{bi}^4) \quad (21)$$

b) Moment of inertia for circular pipe for tool joint section of the pipe

$$I_j = \frac{\pi}{64}(D_{jo}^4 - D_{ji}^4) \quad (22)$$

Total moment of inertia for pipe length and tool joint

$$I = \frac{I_b I_j}{0.05 I_b + 0.95 I_j} \quad (23)$$

vi. Critical sinusoidal force for pipe with tool joint

$$F_{stj} \geq 0.9955 F_s \quad (24)$$

Where

F_{stj}=critical force to initiate sinusoidal buckling for pipe with tool joint,lbf

F_s=critical force to initiate sinusoidal buckling for pipe without tool joint,lbf

3. Model Validation

3.1. Drill String Elements

The drill string elements data for this study is given in table 1 below and the model was validated using the stated data of table 1.

Table 1. *Drillstring Data.*

Type	Name	Size	Nom Weight	Length	Body		Mtr	Grade (YS)	Class	Tool Joint / Stabilizer blades				TJ sep
					OD	ID				Connection		OD	ID	
		[in]	[lb/ft]	[ft]	[in]	[in]		[psi]		Top	Bottom	[in]	[in]	[ft]
BIT	KGR50	6	0.00	0.36	6.000					3 1/2 Reg P				
PDM	4 3/4-5/6-8.3	4 3/4	42.91	26.25	4.750	2.000	CS	110000		3 1/2 IF B	3 1/2 IF B			29.9
Stabilizer	IBS	4 3/4	40.00	1.15	4.750	2.250	CS	110000		3 1/2 Reg B	3 1/2 Reg P	5.750	2.190	3.3
Hevi-Wate DP	GP - Spiral	3 1/2	25.00	10.10	3.500	2.250	CS	55000		NC 38 B	NC 38 P	4.750	2.188	20.0
MWD	MWD	4 3/4	50.00	61.55	4.750	1.920	SS	110000		NC 38 B	NC 38 B			29.9
Hevi-Wate DP	GP	3 1/2	25.00	30.51	3.500	2.063	CS	55000		NC 38 B	NC 38 P	4.750	2.125	20.0
Drill Pipe	Drill Pipe	3 1/2	13.30	2577.59	3.500	2.764	CS	135000	P	3 1/2 IF B	3 1/2 IF P	4.812	2.125	29.9
Hevi-Wate DP	GP	3 1/2	23.20	367.29	3.500	2.250	CS	55000		NC 38 B	NC 38 P	4.750	2.313	20.0
Jar	Dailey	4 3/4	37.50	31.99	4.750	2.062	CS	110000		3 1/2 IF B	3 1/2 IF P			20.0
Hevi-Wate DP	GP	3 1/2	23.20	1010.10	3.500	2.250	CS	55000		NC 38 B	NC 38 P	4.750	2.313	20.0
Hevi-Wate DP	SMFI	5	49.70	370.70	5.000	3.000	CS	55000		NC 50 B	NC 50 P	6.500	3.000	20.0
Drill Pipe	Drill Pipe	5	19.50	4362.47	5.000	4.276	CS	135000	P	5 XH B	5 XH P	6.312	2.750	28.9

3.2. Hole Data

The hole data also utilized for the modeling are given below for both openhole and cased hole:

Casing: 9 5/8 OD, 8.65 ID, 47ppf, from top to 7254 ft of Hole

Openhole section: 7 in hole size, from 7254 ft to 8850.06 ft of hole depth.

3.3. Simulation

The simulation was done using wellPlan T&D spreadsheet software design for torque and drag analyses in wellbores. The simulation procedure is summarized in the diagram below.

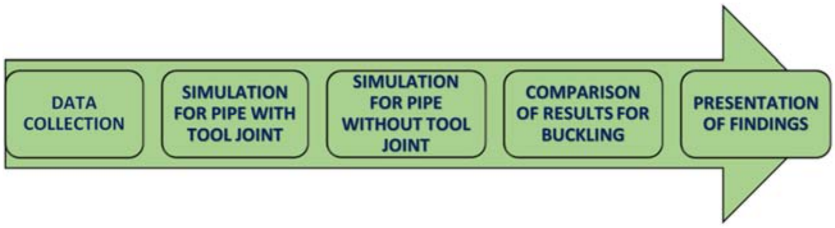

Figure 1. *Simulation Workflow.*

4. Results and Discussions

The result for simulation analyses using WellPlan T&D software for torque and drag analysis are given below. The results show the force variations with depth in sinusoidal and helical buckling mode for various well operations such as tripping in, tripping out and sliding. The results are given for drillstring with tool joint and comparisons were made for tool-jointed drillstring and straight body drillstring or drill string

4.1. Effect of Tripping out on Buckling

During trip, there was axial or translational movement of the pipe but no rotational movement. Thus the pipe is not rotating and only drag is experienced. For trips torque is considered to be zero because there is no rotational movement. The weight of the drillstring measured during tripping out is the pickup weight (PUW) which is the downward force on the weight indicator as the drill string is pulled out of the hole.

From figure 2, it can be observed that none of the pipe sections were subjected to buckling either sinusoidal or helical during tripping. This was because the pipe was in tension and the axial and effective tensile forces were very high. Onsite of buckling was not experienced. For tripping out, the force distributions without tool joints are depicted in figure 2 with axial and effective force at the surface being231636.3 lbf and 187309.2 lbf respectively.

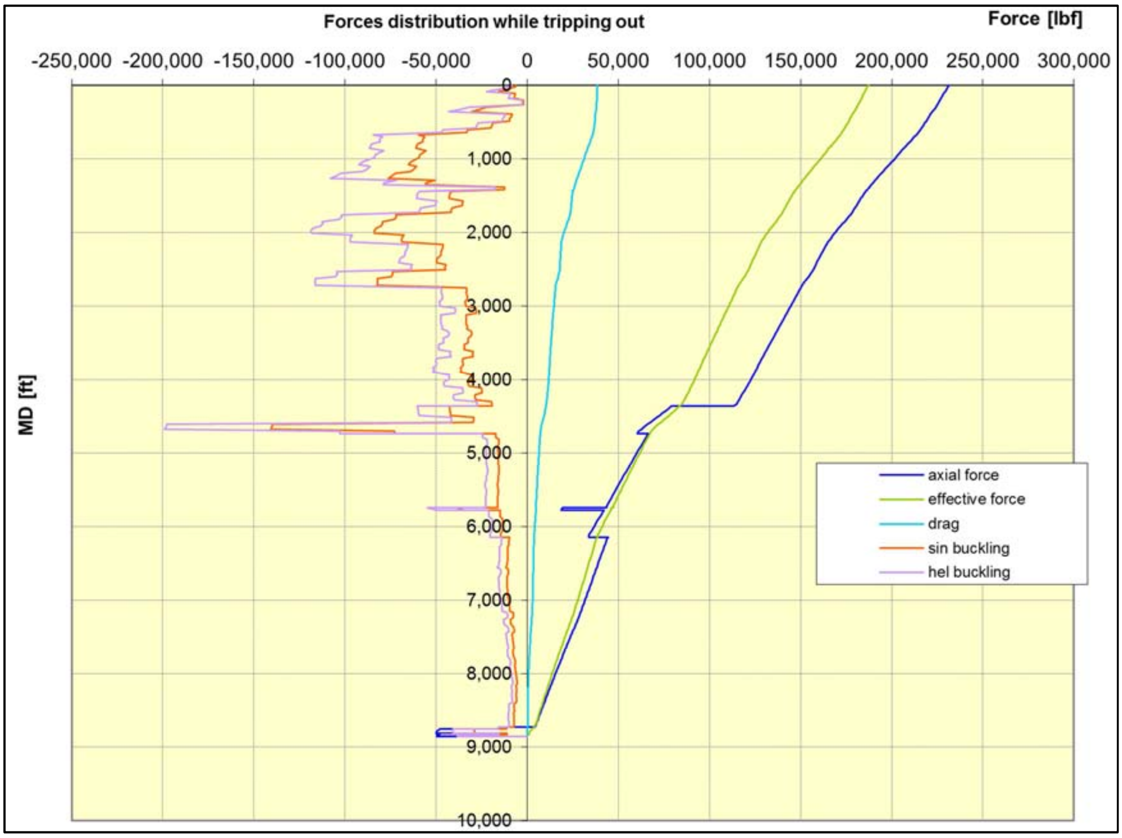

Figure 2. *Forces distribution while tripping out cum effect of tripping out on buckling.*

4.2. Effect of Tripping in on Buckling

In trip in, there is axial motion of the drillstring into the well. Thus only drag is experience and no torque occurs because there is no rotation of the drillstring. In trip in the drag force has a negative sign while the weight of the drillstring appears less than the buoyed weight of the drillstring at the depth considered. From figure 3, it can be observed that the drag force on the pipe is lower and negative. The force on the pipe sections are in tension and are not able to induce buckling on the pipe sections. Thus none of the pipe element is buckled at any depth. For tripping in, the force distributions without tool joints are depicted in figure 3 with axial and effective forces at the surface being 164070.6 lbf and 119743.5 lbf respectively.

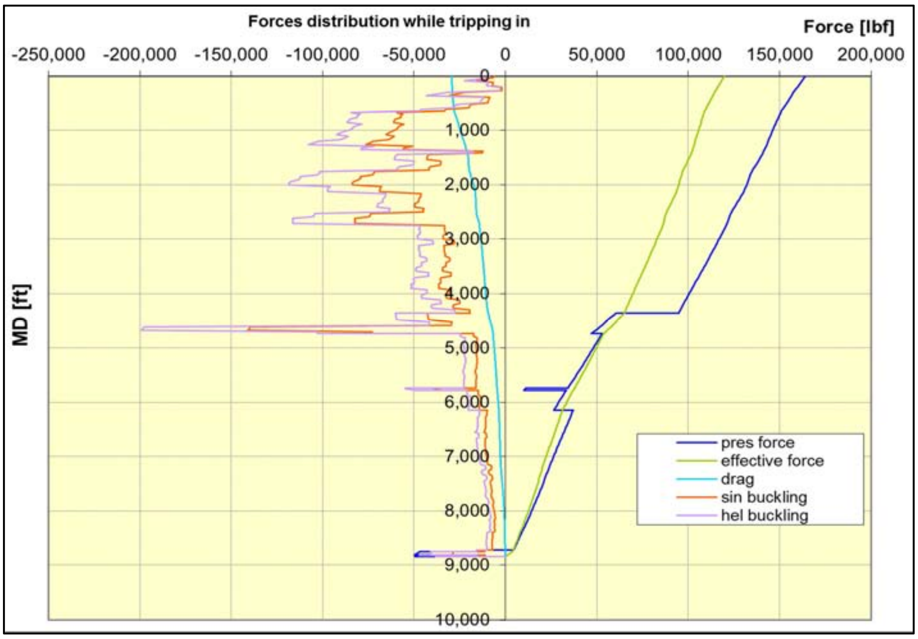

Figure 3. *Forces distribution while tripping in cum effect of tripping in on buckling.*

4.3. Sliding

In sliding or slide drilling, there is rotation but the rotation is not from the surface. Thus the rotary table is not being turned. Turning is at the point of contact in the wellbore usually at the swivel or mud motor. There is not high rotary speed because the rotary table is not used. From figure 4, it it is evident that, there is combined axial and rotational movement of the drill string and the bit makes contact with the formation. For sliding, the force distributions are depicted in figure 4 with axial and effective force at the surface standing at 154607.2 lbf and 110280.2 lbf respectively.

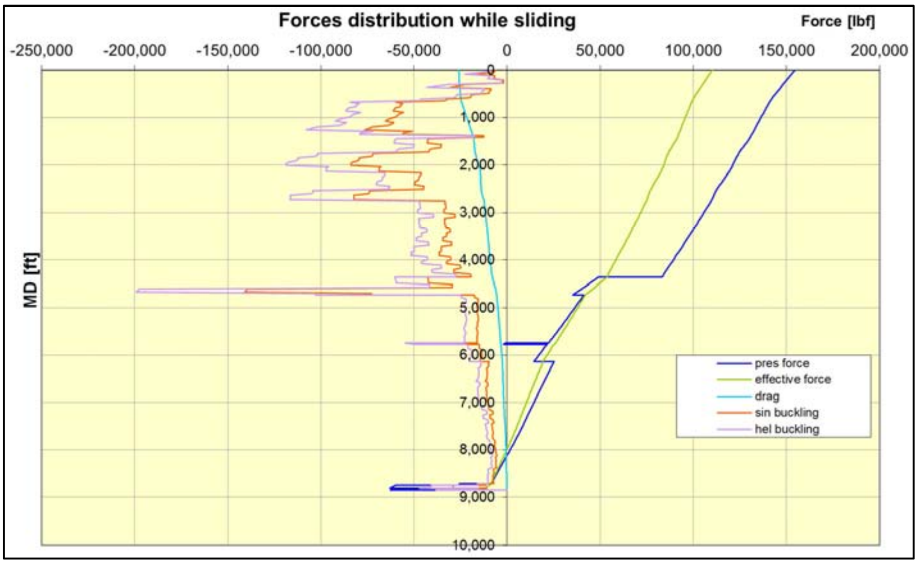

Figure 4. *Forces distribution while sliding out cum effect of sliding on buckling.*

4.4. Effect of Drillstrngwith and Without Tool Joints on Buckling

To evaluate tool joint effects on buckling, the utilized drillstring elements were used as depicted above except that all the drillstringelements were considered to be continuous and straight when simulation was run without tool joints. This was necessary for effective comparison of the critical buckling force for jointed and continuous or straight body drillstring elements or pipes.

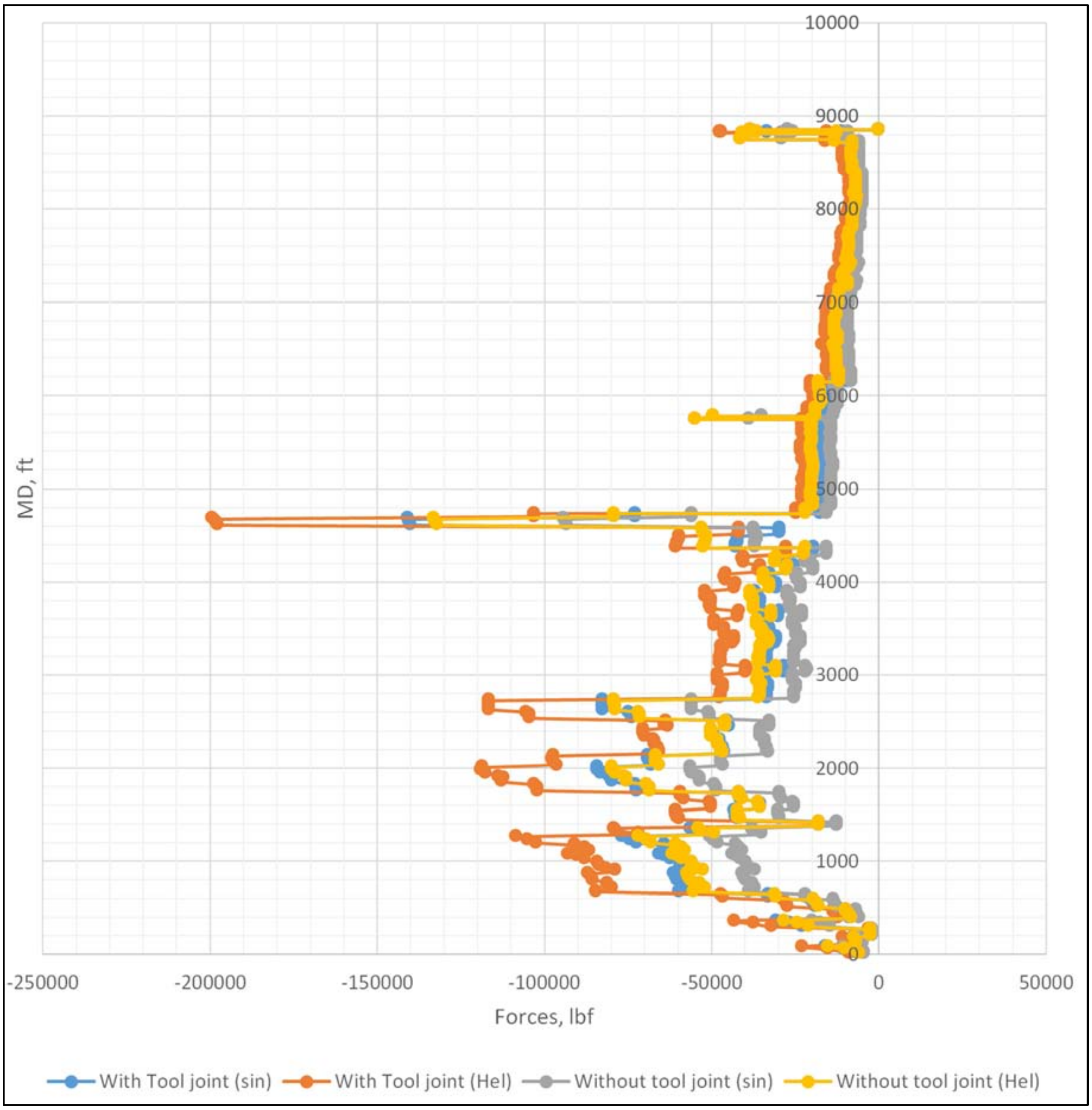

Figure 5. *Analyses of Forces distribution for tool-joint and straight body pipes for all buckling modes.*

Figure 5 shows the critical forces required to initiate sinusoidal and helical buckling for continuous straight body drillstring type and also tool-jointed drillstring configurations. From figure 5, it can be observed that higher compressional force is required to buckle drillstring with tool joint than straight body elements. In continuous straight body drillstring type AWA tool-jointed drillstring configurations, the shape of buckling is from top to bottom and follows both the sinusoidal AWA helical variation incorporated to the trajectory.

The figure reveals change in transfer efficiency of the axial force with the difference existing between the bottom and that of top load which is related to the friction forces' magnitude between wellbore wall and the pipe. During the process of loading, bottom and top load difference is usually positive. The difference continues to be closely constant until there is occurrence helical buckling. Once there is pipe helical buckling, the difference then becomes larger. Duman *et al.,* (2003a); Duman *et al.,* (2003b) pointed out that 40% higher frictional forces are obtainable during pipe helical buckling in continuous straight bodypipes when compared to tool jointed pipes [22-23].

During the process of unloading, there is a reversal of the pipe movement direction AWA that friction forces. Thus, there exist a point at which thetop force is lower than thebottom force, and at that point negative values are recorded as revealed in figure 5.

It is important to evaluate the ratio of the critical force for initiating buckling in straight body and tool jointed pipes.

Table 2. *Simulation summary.*

Load	Torque At		Axial Force	Effective Force	Average Critical Buckling	Average Critical Buckling
	Surf	Bit	At Surf	At Surf	Load Increase Due To TJ	Force Ratio
	[Lbf*Ft]	[Lbf*Ft]	[Lbf]	[Lbf]	%	1.28
Tripping Out	0.00	0.00	231636.3	187309.2	28.90	1.28
Tripping In	0.00	0.00	164070.6	119743.5	28.90	1.28
Sliding	0.00	- 2,400.00	154607.2	110280.2	28.90	1.28

Table 2 show that there is increase in critical force to buckle a tool jointed pipe or drillstring element than a straight pipe or drillstring element. From table 2 it can be observed that the average critical buckling force ratio for pipe with tool and pipe without tool joint is 1.28. This means that the critical force needed to initiate buckling for a tool-jointed pipe is 1.28 times the force needed to initiate buckling in straight body pipe. This is in consonance with the findings of Mitchel that predicts that the critical force to sinusoidally buckle a tool-jointed pipe must be more than or equal to 0.9955 times the critical force to sinusoidally buckle a straight body pipe.

5. Conclusion

The following conclusion were drawn from the study

1. Buckling of pipe is affected by hole operations such as tripping in, tripping out, sliding etc.
2. The highest surface weight is recorded during tripping out operation.
3. Buckling behaviour of jointed pipes resembles that of continuous pipes. They are both initially subjected to sinusoidal buckling and then gradually reaches the helical buckling mode as axial force increases.
4. The presence of tool joint increases the critical buckling force by an average of 28.9% for both helical and sinusoidal buckling modes.
5. The ratio of critical buckling force of continuous straight pipe to tool jointed pipe is around 1.28.

Nomenclature

AWA - As well as
ERWs - Extended reach wells
ERD - Extended reach drilling
WOB – Weight on bit

Appendix

Survey information for the well.

Table 3. *Survey information showing MD, inclination and Azimuth.*

MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)
8850.063	6.510	5.540	6528.870	22.930	359.300	4888.450	27.490	355.610	3248.031	32.950	333.760	1607.611	16.800	338.810
8826.441	6.530	5.760	6496.061	22.900	359.450	4855.642	27.670	355.490	3215.222	33.000	333.700	1574.803	16.540	338.750
8727.032	6.620	6.660	6463.253	22.860	359.590	4822.833	27.840	355.380	3182.414	33.050	333.670	1541.994	16.280	338.700
8628.607	6.640	5.370	6430.444	22.850	359.580	4790.025	28.020	355.260	3149.605	33.110	333.650	1509.186	15.980	337.560
8530.181	6.690	5.840	6397.636	22.830	359.570	4757.217	28.020	355.180	3116.797	33.160	333.620	1476.378	15.670	336.430
8398.948	6.890	4.680	6364.828	22.820	359.550	4724.408	28.020	355.100	3083.989	33.420	333.600	1443.569	15.370	335.290
8267.714	7.790	3.330	6332.019	22.810	359.540	4691.600	28.020	355.020	3051.180	33.690	333.590	1410.761	15.440	331.730
8136.481	8.890	2.200	6299.211	22.790	359.440	4658.791	27.860	353.320	3018.372	33.950	333.570	1377.952	15.520	328.170
8005.247	10.460	2.800	6266.402	22.770	359.340	4625.983	27.710	351.620	2985.563	34.000	333.540	1345.144	15.300	325.650
7972.439	10.860	2.940	6233.594	22.830	359.160	4593.175	27.550	349.920	2952.755	34.050	333.500	1312.336	15.080	323.120
7874.014	12.000	2.880	6200.786	22.900	358.990	4560.366	27.650	346.710	2919.947	34.100	333.470	1279.527	14.600	321.630
7775.588	13.400	2.660	6167.977	22.960	358.810	4527.558	27.750	343.500	2887.138	34.190	333.440	1246.719	14.020	317.970
7746.061	13.740	2.660	6135.169	23.080	358.540	4494.749	27.850	340.290	2854.330	34.280	333.410	1213.910	13.450	314.300
7742.780	13.780	2.660	6102.361	23.200	358.260	4461.941	28.170	339.280	2821.522	34.370	333.380	1181.102	12.870	310.640
7709.972	14.150	2.650	6069.552	23.320	357.990	4429.133	28.490	338.270	2788.713	34.450	333.370	1148.294	12.290	307.640
7677.163	14.520	2.650	6036.744	23.550	357.580	4396.324	28.810	337.260	2755.905	34.540	333.370	1115.485	11.720	304.640
7644.355	14.950	2.670	6003.935	23.790	357.180	4363.516	29.130	336.250	2723.096	34.620	333.360	1082.677	11.140	301.640
7611.546	15.410	2.410	5971.127	24.020	356.770	4330.707	29.440	335.230	2690.288	34.580	335.190	1049.868	10.810	297.170
7578.738	15.860	2.140	5938.319	24.320	356.430	4297.899	29.760	334.220	2657.480	34.540	337.020	1017.060	10.470	292.700
7545.930	16.320	1.880	5905.510	24.630	356.100	4265.091	29.940	334.210	2624.671	34.500	338.850	984.252	10.140	288.230
7513.121	16.780	1.710	5872.702	24.930	355.760	4232.282	30.110	334.200	2591.863	34.280	337.320	951.443	9.590	284.690
7480.313	17.240	1.540	5839.893	25.090	355.640	4199.474	30.290	334.190	2559.054	34.070	335.800	918.635	9.030	281.150
7447.505	17.700	1.370	5807.085	25.260	355.510	4166.666	30.620	334.300	2526.246	33.850	334.270	885.827	8.480	277.610

MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)	MD (ft)	inc (deg)	Azi (deg)
7414.696	18.390	1.230	5774.277	25.420	355.390	4133.857	30.950	334.410	2493.438	33.610	334.440	853.018	7.610	277.120
7381.888	19.080	1.080	5741.468	25.450	355.430	4101.049	31.280	334.520	2460.629	33.360	334.620	820.210	6.740	276.630
7349.079	19.770	0.940	5708.660	25.470	355.470	4068.240	31.340	334.580	2427.821	33.120	334.790	787.401	5.870	276.140
7316.271	20.240	0.790	5675.851	25.500	355.510	4035.432	31.390	334.640	2395.012	32.740	334.910	754.593	5.040	276.370
7253.935	21.130	0.510	5643.043	25.520	355.560	4002.624	31.450	334.700	2362.204	32.360	335.040	721.785	4.200	276.600
7250.654	21.180	0.490	5610.235	25.550	355.620	3969.815	31.590	334.680	2329.396	31.980	335.160	688.976	3.370	276.830
7217.846	21.690	0.380	5577.426	25.570	355.670	3937.007	31.730	334.650	2296.587	31.640	335.290	656.168	2.480	274.690
7185.037	22.200	0.260	5544.618	25.650	355.660	3904.198	31.870	334.630	2263.779	31.300	335.410	623.359	2.030	277.890
7152.229	22.710	0.150	5511.810	25.720	355.640	3871.390	31.830	334.550	2230.971	30.960	335.540	590.551	1.570	281.080
7119.421	22.850	0.090	5479.001	25.800	355.630	3838.582	31.800	334.480	2198.162	30.640	335.710	557.743	1.310	281.110
7086.612	22.980	0.030	5446.193	25.820	355.630	3805.773	31.760	334.400	2165.354	30.320	335.890	524.934	1.050	281.140
7053.804	23.120	359.970	5413.384	25.830	355.620	3772.965	31.740	334.400	2132.545	30.000	336.060	492.126	0.790	281.170
7020.995	23.210	359.950	5380.576	25.850	355.620	3740.156	31.710	334.390	2099.737	29.210	336.440	459.317	0.700	279.790
6988.187	23.290	359.930	5347.768	25.930	355.580	3707.348	31.690	334.390	2066.929	28.410	336.810	426.509	0.600	278.420
6955.379	23.380	359.910	5314.959	26.010	355.530	3674.540	31.860	334.370	2034.120	27.620	337.190	393.701	0.510	277.040
6922.570	23.370	359.860	5282.151	26.090	355.490	3641.731	32.020	334.340	2001.312	26.510	337.340	360.892	0.440	218.720
6889.762	23.360	359.810	5249.342	26.230	355.410	3608.923	32.190	334.320	1968.503	25.390	337.500	328.084	0.380	160.410
6856.954	23.350	359.760	5216.534	26.370	355.330	3576.115	32.200	334.320	1935.695	24.280	337.650	295.276	0.310	102.090
6824.145	23.300	359.720	5183.726	26.510	355.250	3543.306	32.210	334.330	1902.887	23.210	337.790	262.467	0.320	114.230
6781.494	23.230	359.670	5150.917	26.620	355.270	3510.498	32.220	334.330	1870.078	22.150	337.940	229.659	0.340	126.370
6758.528	23.190	359.640	5118.109	26.730	355.300	3477.689	32.280	334.250	1837.270	21.080	338.080	196.850	0.350	138.510
6725.720	23.120	359.590	5085.300	26.840	355.320	3444.881	32.350	334.180	1804.461	20.120	338.230	164.042	0.320	152.460
6692.912	23.040	359.530	5052.492	26.960	355.390	3412.073	32.410	334.100	1771.653	19.170	338.370	131.234	0.300	166.400
6660.103	22.970	359.480	5019.684	27.090	355.450	3379.264	32.550	334.030	1738.845	18.210	338.520	98.425	0.270	180.350
6627.295	23.020	359.430	4986.875	27.210	355.520	3346.456	32.700	333.960	1706.036	17.830	338.630	65.617	0.180	120.230
6594.486	23.060	359.380	4954.067	27.300	355.550	3313.647	32.840	333.890	1673.228	17.440	338.750	32.808	0.090	60.120
6561.678	23.110	359.330	4921.259	27.400	355.580	3280.839	32.890	333.830	1640.420	17.060	338.860	0.000	0.000	0.000

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