An Analytical Model for Axial Force Transfer and the Maximum Compression Point of Work Strings in Extend Reach Drilling

Boyun Guo and Rashid Shaibu*

Department of Petroleum Engineering, University of Louisiana, Lafayette, USA

Submission: November 15, 2020; Published: December 18, 2020

*Corresponding author: Rashid Shaibu, Department of Petroleum Engineering, University of Louisiana, Lafayette, USA

Abstract

Complex work string dynamics are often observed when one is investigating the limit of Extended Reach Drilling (ERD), yet the underlying physical causes of anomalous problems are often not fully understood and is thus a topic of ongoing research interest. Theoretical models capturing tubular dynamics have been previously proposed to analyze force transfer in work strings, yet there is significant confusion regarding these models because their published versions are not entirely consistent and, in many cases, do not meet engineering requirement. Further confusion is introduced through variations in pin-pointing locations where axial compression in the work strings should be checked for mechanical integrity. A simple and yet rigorous mathematical model is essential for adequate prediction of axial compression profiles in work strings for ERD. This article presents a simplified tubular mechanics model for describing axial force transfer under ERD conditions. We discuss the model in finding the point of peak compression in casing strings. This point is predicted to be in the arc section near the heel of a horizontal wellbore, under borehole drilling, and casing running conditions. The exact location of the peak axial compression changes with pipe-wall friction coefficient. For the friction coefficient in the range of 0.15 to 0.35, this point occurs in the range of inclination angle between 70.7° and 81.5°, averaging 76.1°. The model can also be used for other purposes, including prediction of depth limit, bottom hole assembly (BHA) design, and locking up analysis of coiled tubing (CT) strings.

Keywords: Extended-reach-wells; Casing design, Work strings; Drilling; Stability

Introduction

Extended reach wells (ERW) are horizontal wells used for reaching oil and gas resources located laterally and far from well location. ERW has become a common practice over the last two decades for improving field economics. Extended Reach Drilling (ERD) is a technique to drill directional/horizontal wells beyond the routine capabilities of drilling rigs and tools. ERD was initiated in 1980's and rapidly evolved during the 1990's [1-4]. Naegel et al. [5] reported an ERD well with a 20,341.2 ft horizontal departure at 5,577 ft true vertical depth (TVD). ERD continued in the past two decades with new record updated every a few years [6-11]. Armstrong and Evans [12] reported planning and execution of an offshore ERD well with a total measured depth (MD) of 37,165 ft with TVD of 6,938 ft, and horizontal displacement (HD) of 33,682 ft. Tskhadaya et al. [13] presented a design of ERD for an Arctic well depth of 49,212.6 ft and horizontal borehole depth of 4,921.3 ft.

Special technical issues in ERD include rig requirement, borehole stability, cuttings transport, data acquisition, and drill string design. In the particular topic of our ongoing research interest, i.e., tubular mechanics of work strings (drill string, coiled tubing string, and casing string), Nixon et al. [14] presented techniques to solve the problems associated with excessive torque during ERD. Hill et al. [15] discussed designing and qualifying drill strings for ERD while Mason and Judzis [16] discussed the limit of ERD, and Suggett and Smith [17] addressed the issue of ERD limit for rig capacity. Bell et al. [18] reported an application of significant increases in the lateral reach of a number of ERW’s. Samuel [19] presented a new well-path design that can extend the reach of ERW through reducing torque and drag using curvature and torsion discontinuities. Agbaji [20] presented an algorithm that would set forth design for drilling programs suitable to ERD. Vestavik et al. [21] presented a potential application of Reelwell Drilling Method (RDM) to widen the envelope of ERD through reductions of torque and drag and Equivalent Circulating Density (ECD) gradient, and optimization of hydraulic weight on bit. Newman et al. [22] explained that for ERD with coiled tubing (CT) where a limitation on the horizontal displacement occurs due to
frictional forces, the friction can cause helical buckling and lead
to lockup of the CT strings, thus limiting reach. Gupta et al. [23]
discussed several key challenges in ERD, including high torque
and drag due to high friction forces.

Theoretical models capturing tubular dynamics have been
previously proposed to analyze force transfer in the work strings
used in ERD, yet there is significant confusion regarding these
models because they are not entirely consistent and, are hard
to use due to model complexity. Also, no model has been found
to have the capacity of pin-pointing the locations where the axial
compression in work strings should be checked for mechanical
integrity. A simple and rigorous analytical solution in closed
form is presented in this work for adequate prediction of axial
compression profiles in the work strings for ERD. We discuss
the model in finding the point of peak compression in casing
strings. This point is predicted to occur in the arc section, near
the heel of a horizontal wellbore, under borehole drilling and
casing running conditions. The model can also be used for other
purposes, including prediction of depth limit, BHA design, and
lockup condition analysis of CT strings.

**Mathematical Model**

Figure 1 illustrates a simplified configuration of a work
string (drill string, casing string, or coiled tubing string) used in
horizontal well construction engineering. Two-dimensional well
trajectory of build-and-hold type is considered. The string is
assumed to contact the lower side of borehole due to gravity in the
curve and slant/horizontal sections without buckling. Owing to its
large length-to-diameter ratio, the string is considered to be rope-
like without stiffness. It is subjected to axial tension/compression
but not bending moment.

The axial compression force in the vertical section of string
increases with depth due to gravity. Its value at the kick-of-point
(KOP) is expressed as:

\[ F_0 = w_v V T \]

Where \( F_0 \) is the axial compressive force in the string at KOP, \( w_v \)
is the weight per length of the string in the vertical section, \( V \) is
the length of vertical string section, and \( T \) is the tension at the surface
(hook load). In the down-ward motion, the axial compression
force in the horizontal section increases with the distance from
the end of string (toe of horizontal well) due to friction. The axial
compression force at the heel reaches to

\[ F_{\theta_2} = \mu w_h H \sin(\theta_2) - w_h H \cos(\theta_2) + W_B + A_h p_f \]

Where \( F_{\theta_2} \) is the axial compressive force in the string at the
heel of horizontal well, \( \mu \) is the friction coefficient between the
string and borehole wall, \( w_h \) is the weight per length of the string
in the slant/horizontal section, \( H \) is the length of string in the
slant/horizontal section, \( \theta_2 \) is the inclination angle at the heel
point, \( W_B \) is the force acting back by the borehole bottom (weight
on bit in drilling condition), \( A_h \) is the cross-sectional area of string
in the horizontal section, and \( p_f \) is the fluid pressure in the bottom
hole. If the slant section is truly horizontal (\( \theta_2 = \pi/2 \)), Eq. (2)
degenerates to

\[ F_{\pi/2} = \mu w_h H + W_B + A_h p_f \]

where \( F_{\pi/2} \) is the axial compressive force at the heel.

Because the axial compression force in the string is a
continuous function of length, its value is expected to reach a
maximum between \( F_0 \) and \( F_{\pi/2} \) in the curved section. The axial
compression force in the curve section is expressed as (see
Appendix A for derivation):

\[ F_{\theta} = F_0 + w_c R [\sin(\theta) - \mu (1 - \cos(\theta))] \]

or

\[ F_{\theta} = F_{\pi/2} - w_c R [1 - \sin(\theta) - \mu \cos(\theta)] \]

Figure 1: Configuration of work string used in horizontal well engineering.
Where \( w_c \) is the weight per length in the curved section, and \( R \) is the radius of curvature.

Equation (5) is plotted in Figure 2 for \( F_{\pi/2} = 20,000 \text{ lb} \), \( w_c = 17 \text{ lb/ft} \), and \( R = 1,000 \text{ ft} \) for friction coefficient values ranging from 0.15 to 0.40. It indicates that a maximum value of axial compression exists near the heel, depending on friction coefficient.

Figure 2: Model-calculated axial force profiles in the curved section.

The maximum axial compression force occurs at a point where the function is stationary. The derivative of this function is

\[
\frac{dF}{d\theta} = w_c R (\cos(\theta) - \mu \sin(\theta))
\]

Setting \( \frac{dF}{d\theta} = 0 \) gives

\[
\theta = a \tan \left( \frac{1}{\mu} \right)
\]

Therefore, the peak force is given by

\[
F_{\text{max}} = F_0 + w_c R \left( \sin \left[ a \tan \left( \frac{1}{\mu} \right) \right] - \mu \cos \left[ a \tan \left( \frac{1}{\mu} \right) \right] \right)
\]

or

\[
F_{\text{max}} = F_{\pi/2} - w_c R \left( 1 - \sin \left[ a \tan \left( \frac{1}{\mu} \right) \right] - \mu \cos \left[ a \tan \left( \frac{1}{\mu} \right) \right] \right)
\]

For \( \mu = 0.15 \sim 0.35 \) in horizontal well engineering, the maximum axial compression occurs with \( \theta = 70.7^\circ \sim 81.5^\circ \), averaging 76.1°. Based on Eqs. (4) and (5), this corresponds to the average peak force of

\[
F_{\text{76.1°}} = F_0 + 0.78w_c R
\]

or

\[
F_{\text{76.1°}} = F_{\pi/2} + 0.031w_c R
\]

Model Applications

This mathematical model can be used in casing design, drill string design, and coiled tubing stability analysis in horizontal well engineering. Two examples are illustrated in this section.

Casing Design. Casing strings for horizontal wells are designed considering multiple stress components that cause:

a) Burst failure due to net burst pressure
b) Collapse failure due to net collapse pressure
c) Tensile/compressive failure due to axial forces (gravity, friction, and bending)

The axial compression force can reduce the casing’s burst resistance performance. Suppose a 5½” J-55, 17 lb/ft, production casing is selected to run in the curve section of the borehole shown in Figure 3. The mud weight is 12.5 ppg and friction coefficient is 0.30. It is required to check the reduced burst pressure resistance of the casing due to axial compression.

The API burst pressure resistance of the casing is [24]:

\[
P_{br} = 0.875 \frac{2t}{d_n} \sigma_{\text{yield}}
\]

\[
= 0.875 \frac{2(0.304)}{5.5} (55,000)
\]

\[
= 5,320 \text{ psi}
\]

Where \( t \) is the thickness, \( d_n \) is the nominal pipe diameter, and \( \sigma_{\text{yield}} \) is the yield stress.

Radius of curvature is [24]:
Axial compression at heel is

\[ R = \frac{5,730}{B} = \frac{5,730}{5} = 1,146 \text{ ft} \]

The maximum axial compression is

\[ F_{\max} = F_{\pi/2} - w_c R \left( 1 - \sin \left( \frac{1}{\mu} \right) \right) - \mu \cos \left( \frac{1}{\mu} \right) \]
\[ = 24,586 - (17)(1,146) \left( 1 - \sin \left( \frac{1}{0.3} \right) \right) - \mu \cos \left( \frac{1}{0.3} \right) \]
\[ = 25,444 \text{ lb} \]

\[ \sigma_{\max} = \frac{F_{\max}}{A} \]
\[ = \frac{3.14}{4} \left( 0.3 \right)^2 \]
\[ = 5,130 \text{ psi} \]

Bending stress is

**Figure 3:** Schematic of a horizontal well.

**Figure 4:** Model-calculated axial force profile.
\[ \sigma_b = \frac{E d_s}{R} \]
\[ \approx \frac{5.5}{2 \times 1.146 \times 1} \]
\[ = 5,999 \text{ psi} \]

Where \( \sigma_b \) is the bending stress, and \( E \) is the Young's modulus of elasticity.

The total axial compression is
\[ \sigma_a = \sigma_{\text{max}} + \sigma_b \]
\[ = 5,130 + 5,999 \]
\[ = 11,129 \text{ psi} \]

API tangential stress factor for burst is [24]:
\[ \left( \frac{\sigma_t}{\sigma_{\text{yield}}} \right) = \frac{1}{2} \left( \frac{\sigma_a}{\sigma_{\text{yield}}} \right) + \frac{3}{4} \left( \frac{\sigma_a}{\sigma_{\text{yield}}} \right)^2 \]
\[ \left( \frac{\sigma_t}{\sigma_{\text{yield}}} \right) = \frac{1}{2} \left( \frac{-11,129}{55,000} \right) + \frac{3}{4} \left( \frac{-11,129}{55,000} \right)^2 \]
\[ = 0.8834 \]

Where \( \sigma_t \) is the tangential stress.

Reduced burst pressure resistance of the casing is [24]:
\[ P_{br}\sigma = \left( \frac{\sigma_t}{\sigma_{\text{yield}}} \right) P_{br} \]
\[ = (0.8834)(5,320) \]
\[ = 4,699 \text{ psi} \]

which means that the axial compression will reduce burst pressure resistance of the casing from 5,320 psi to 4,699 psi, or by 12%.

Drill String Design. Drill strings for horizontal wells consist of drill collar design, considering friction forces in the curved and horizontal sections, under drilling conditions (downward motion), and drill pipe design considering over-pull under, tripping-out conditions (upward motion).

Consider the situation shown in Figure 5. Design parameters are given in Table 1. Equation (2) gives

Table 1: Parameters for drill string design for a horizontal well.

| Parameter                     | Value                          |
|-------------------------------|--------------------------------|
| Well depth                    | 10,000 ft                      |
| Effective buoyancy factor     | 1.0 (w/ bending friction)      |
| Maximum weight on an 8¾“ bit  | 35,000 lbf                     |
| Borehole friction coefficient | 0.25                           |
| Lower drill pipe              | 5”, 16.25 lb/ft x 3,000’       |
| Drill collar size             | 6½” x 2-13/16”                 |
| Upper drill pipe              | 5”, 19.5 lb/ft, Grade E        |
| Radius of curvature           | 800 ft                         |
| Excess collar length          | 15%                            |
| Over pull for the upper drill pipe | 100,000 lb               |
| Drill pipe strength design factor | 1.15                        |

![Figure 5: Schematic of drill string for horizontal well drilling.](image)
\[ F_{80^\circ} = (0.25)(16.25)(3,000) \sin(80^\circ) - (16.25)(3,000) \cos(80^\circ) + 35,000 \]
\[ = 38,532 \text{lb} \]

Equation (4) yields
\[ F_0 = F_{80^\circ} + (16.25)(800) \left[ \sin(81^\circ) - (0.25)(1 - \cos(81^\circ)) \right] \]
\[ = 28,415 \text{lb} \]

The required drill collar weight is \((1.15)(28,415)\) or \(32,677 \text{ lb}\). Based on the unit weight of \(92 \text{ lb/ft}\) of the drill collar, the required drill collar length is \((32,677)/(92)\) or \(356 \text{ ft}\).

For drill pipe design, the curved linear length of the arc section is \((800)(80)/(57.3)\) or \(1,117 \text{ ft}\). The weight of the lower drill pipe is \((16.25)(3,000+1,117)\) or \(66,900 \text{ lb}\). Based on the tensile capacity of Grade G steel pipe, \(436,000 \text{ lb}\), the maximum pull on the Grade G drill pipe with design factor is \((436,000)/(1.15)\) or \(379,130 \text{ lb}\). The maximum permissible weight of Grade G pipe string with over pull of \(100,000 \text{ lb}\) is
\[ 379,130 - 66,900 - 32,677 = 179,553 \text{ lb} \]

The maximum permissible length of this pipe string is \((179,553)/(19.5)\) or \(9,208 \text{ ft}\), which is greater than the needed length of
\[ 10,000 - 3,000 - 1,117 - 356 = 5,527 \text{ ft}, \]

**Conclusion**

An analytical model for axial force transfer and the maximum compression point in work strings for ERD was developed in this investigation. The following conclusions are drawn.

a) The maximum axial compression point is in the arc section near the heel of a horizontal well when the work string is in down-ward motion. The exact location of the maximum axial compression changes with casing-wall friction coefficient. For \(\mu = 0.15 \sim 0.35\) in horizontal well engineering, the maximum axial compression occurs with \(\theta = 70.7^\circ \sim 81.5^\circ\), averaging 76.1°.

b) When applied to casing design, the maximum compression point model can be easily used to evaluate the reduction of the casing’s burst resistance performance. Results show that the casing’s burst resistance performance can be significantly reduced due to axial compression (12% in the illustrative example).

c) When applied to drill string design, the axial force transfer model can be easily utilized to determine the required drill collar weight and length, which is further used for selecting drill pipe string.

d) Future studies should validate the mathematical model and investigate the applicability of the model to CT stability analysis and predict the depth limit of ERD.

**Nomenclature**

\[ A \quad \text{Cross sectional area} \]
\[ A_s \quad \text{Cross-sectional area of string in the horizontal section.} \]
\[ BHA \quad \text{Bottom hole assembly} \]
\[ CT \quad \text{Coiled tubing} \]
\[ d_n \quad \text{Nominal diameter} \]
\[ E \quad \text{Young’s modulus of elasticity} \]
\[ ECD \quad \text{Equivalent circulating density} \]
\[ ERD \quad \text{Extended reach drilling} \]
\[ ERW \quad \text{Extended reach wells} \]
\[ F_0 \quad \text{Axial compressive force in string at KOP} \]
\[ F_{\text{max}} \quad \text{Peak force} \]
\[ F_{80^\circ} \quad \text{Axial compressive force at the heel.} \]
\[ f_a \quad \text{Frictional force in the axial direction} \]
\[ H \quad \text{Length of string in the slant/horizontal section.} \]
\[ HD \quad \text{Horizontal displacement} \]
\[ KOP \quad \text{Kick of point} \]
\[ N_a \quad \text{Normal force} \]
\[ T \quad \text{Tension at the surface} \]
\[ t \quad \text{Thickness} \]
\[ TVD \quad \text{Total vertical depth} \]
\[ V \quad \text{Length of vertical string section.} \]
\[ W_b \quad \text{Force acting back by the borehole bottom (weight on bit in drilling condition).} \]
\[ w_s \quad \text{Weight per length of string in the slant/horizontal section.} \]
\[ w_c \quad \text{Weight per length of string in the curved section} \]
\[ w_v \quad \text{Weight per length of string in the vertical section.} \]
\[ R \quad \text{Radius of curvature} \]
\[ P_{\text{br-red}} \quad \text{Reduced burst pressure resistance} \]
\[ P_{\text{br}} \quad \text{Burst pressure resistance} \]
\[ p_i \quad \text{Fluid pressure in the bottom hole.} \]
\[ ppg \quad \text{Pound per gallon} \]
\[ \sigma_a \quad \text{Total axial compression} \]
\[ \sigma_b \quad \text{Bending stress} \]
σ_{max} Maximum axial stress
σ_t Tangential stress
θ Inclination angle
θ_2 Inclination angle at the heel point
μ Friction coefficient

**Acknowledgment**

This research was supported by the U.S.-Israel Center of Excellence in Energy, Engineering and Water Technology through the project “Safe, sustainable, and resilient development of offshore reservoirs and natural gas upgrading through innovative science and technology: Gulf of Mexico – Mediterranean.”

**Appendix A: Derivation of Axial Force Transfer Model for Work Strings in the Arc Section of Horizontal Well Trajectory**

A method for predicting the transfer of axial load in the work string can be derived for rope-like strings (no stiffness). Consider an element of the curve section of string with length d, = Rdθ as shown in Figure A1.

![Figure A.1: Free-body diagram of a portion of a rope-like string in a curved hole section.](image)

**Force balance in the axial direction gives:**

\[ \sum F_a = 0 : \quad dF_\theta = W_\theta \cos(\theta) - f_\theta \quad (A.1) \]

Where \( F_\theta \) is the force in the axial direction, \( W_\theta \) is the weight of the element, \( f_\theta \) is the frictional force in the axial direction, \( \theta \) is the inclination angle,

\[ W_\theta = w_c R d\theta \quad (A.2) \]

And

\[ f_\theta = \mu N_\theta = \mu W_\theta \sin(\theta) \quad (A.3) \]

Where \( w_c \) is the weight per unit length in the curved section, \( R \) is the radius of curvature, \( \mu \) is the friction coefficient, \( N_\theta \) is the normal force.

Substituting Eqs. (A.2) and (A.3) into Eq. (A.1) yields:

\[ dF_\theta = w_c R [\cos(\theta) - \mu \sin(\theta)] d\theta \quad (A.4) \]

Integration of Eq. (A.4) takes the form of

\[ \int F_\theta = \int \frac{\theta_1}{\theta} \left[ w_c R \left[ \cos(\theta) - \mu \sin(\theta) \right] d\theta \right] \quad (A.5) \]

Which gives

\[ F_{\theta_2} = F_{\theta_1} + w_c R \left[ \sin(\theta_2) - \sin(\theta_1) + \mu \cos(\theta_1) \right] \quad (A.6) \]

If \( F_{\theta_1} = F_0 \) at \( \theta_1 = 0 \) is known, Eq. (A.6) gives

\[ F_{\theta_2} = F_0 + w_c R \left[ \sin(\theta_2) - \mu (1 - \cos(\theta_2)) \right] \quad (A.7) \]

If \( F_{\theta_2} = F_{\pi/2} \) at \( \theta_2 = \pi/2 \) is known, Eq. (A.6) degenerates to

\[ F_{\theta_1} = F_{\pi/2} - w_c R \left[ 1 - \sin(\theta_1) - \mu \cos(\theta_1) \right] \quad (A.8) \]

If \( F_{\theta_1} = F_0 \) at \( \theta_1 = 0 \) and at \( F_{\theta_2} = F_{\pi/2} \), Eq. (A.6) yields

00145

**How to cite this article:** Boyun G, Rashid S. An Analytical Model for Axial Force Transfer and the Maximum Compression Point of Work Strings in Extend Reach Drilling. Insights Min Sci technol.2020; 2(4): 555592. DOI: 10.19080/IMST.2020.02.555592.
\[ F_0 = F_{\pi/2} - w_c R (1 - \mu) \]  \hspace{1cm} (A.9)

**References**

1. Mueller MD, Quintana JM, Bunyak MJ (1991) Extended-Reach Drilling from Platform Irene. Society of Petroleum Engineers.
2. Eck Olsen J, Sletten H, Reynolds JT, Samuell JG (1993) North Sea Advances in Extended Reach Drilling. Society of Petroleum Engineers.
3. Ryan G, Reynolds J, Raitt F (1995) Advances in Extended Reach Drilling - An Eye to 10km Stepout. Society of Petroleum Engineers.
4. Dolan SP, Crabtree RC, Drury RF, Gogan R, Hattersley G, et al. (1998) Planning, Execution and Lessons Learned from the GWA13 Extended Reach Drilling Well - Goodwyn Gas/Condensate Field, NWS, Australia. Society of Petroleum Engineers.
5. Naegel M, Pradie E, Beffa K, Ricaud J, Delahaye T (1998) Extended Reach Drilling at the Uttermost Part of the Earth. Society of Petroleum Engineers.
6. Elsborg CC, Power AK, Schuberth PC (2005) Hibernia Record Well Breaks Extended Reach Drilling and Completion Envelope. Society of Petroleum Engineers.
7. McDermott JR, Viktorin RA, Schamp JH, Barrera MW, Fleming JM, et al. (2005) Extended Reach Drilling (ERD) Technology Enables Economical Development of Remote Offshore Field in Russia. Society of Petroleum Engineers.
8. Algu D, Landgrave S, Esquinace B, Volokitin Y, Derise B (2005) Extended Reach Drilling in the GOM - Ram Powell Case Study. Society of Petroleum Engineers.
9. Woodfine M, Ottesen S, Trend S, Bolivar N (2011) Hibernia Well Overcomes Challenges to Further Extend Worldwide Extended Reach Drilling (ERD) Envelope. Society of Petroleum Engineers.
10. Walker MW (2008) Extended-Reach Drilling - Offshore California: An Operator’s Experience with Drilling a Record Extended-Reach Well. Society of Petroleum Engineers.
11. Walker MW, Veselka AJ, Harris SA (2009) Increasing Sakhalin Extended Reach Drilling and Completion Capability. Society of Petroleum Engineers.
12. Armstrong NR, Evans AM (2011) Extended Reach Drilling - Offshore California. Extending Capabilities and Improving Performance. Society of Petroleum Engineers.
13. Tskhadaya ND, Buslaev GV, Buslaeva ON, Molokanov DR (2013) Development of Onshore Drilling Complex of XXI Century for Extended Reach Drilling in the Arctic. Society of Petroleum Engineers.
14. Nixon JU, Nims D, Rodman DW, Swietlik G (1996) Extended Reach Drilling Limitations - A Shared Solution. Offshore Technology Conference.
15. Hill TH, Gould GJ, Summers MA (1996) Designing and Qualifying Drill Strings for Extended Reach Drilling. Society of Petroleum Engineers.
16. Mason CJ, Judzis A (1998) Extended-Reach Drilling – What is the Limit? Society of Petroleum Engineers.
17. Suggett JC, Smith T (2005) Performing Extended-Reach-Drilling Operations with Limited Rig Capability. In International Petroleum Technology Conference. International Petroleum Technology Conference.
18. Bell R, McKee R, Zwold E, Lewis D, Suryanarayana PV (2006) Single-Diameter Technology Capable of Increasing Extended-Reach Drilling by 50%. Offshore Technology Conference.
19. Samuel R (2010) A new well-path design using clothoid spiral (curvature bridging) for ultra-extended-reach drilling. SPE Drilling & Completion 25(3): 363-371.
20. Agbaji AL (2010) Optimizing the Planning, Design and Drilling of Extended Reach and Complex Wells. Society of Petroleum Engineers.
21. Vestavik O, Egorenkov M, Schmalhorst B, Falcao J (2013) Extended Reach Drilling - new solution with a unique potential. Society of Petroleum Engineers.
22. Newman K, Kelleher PE, Smalley E (2014) Extended Reach: Can We Reach Farther? Society of Petroleum Engineers.
23. Gupta VP, Yeap AHP, Fischer KM, Mathis RS, Egan MJ (2014) Expanding the Extended Reach Envelope at Chayvo Field, Sakhalin Island. Society of Petroleum Engineers.
24. Bourgoine AT, Millheim KK, Chenevert ME, Young FS (1986) Applied drilling engineering. 2.

This work is licensed under Creative Commons Attribution 4.0 License
DOI: 10.19080/IMST.2020.02.555592

Your next submission with Juniper Publishers will reach you the below assets
- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats (Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission
https://juniperpublishers.com/online-submission.php