

Torque & Drag & Buckling

Soft-string vs Stiff-string Models

The aim of this presentation is to show the main differences between the 2 types of model used for Torque & Drag & Buckling analysis in the drilling industry.





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Why using stiff-string model is highly recommended

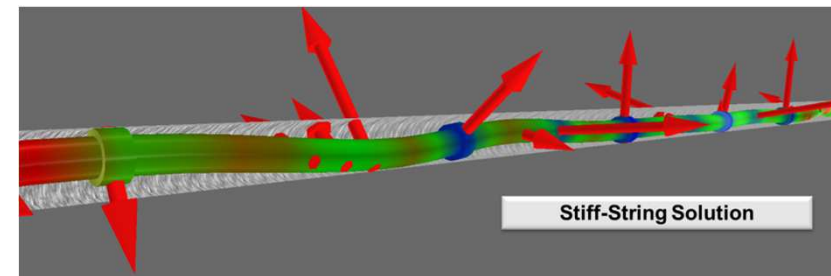
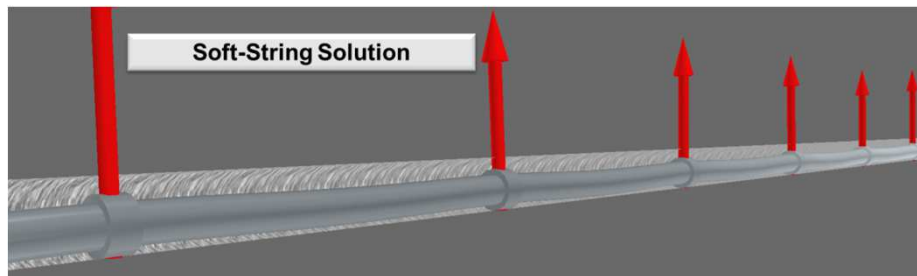
Besides the scientific modeling differences between the 2 models, numerous analyses and case studies have shown that:

-  **Soft-string does not predict Buckling onset**
-  **Soft-string can under-estimate drill string Torque**
-  **Soft-string model does not estimate properly Contact Side Forces on the drill string**
-  **Soft-string cannot monitor drill string Mechanical Integrity.**

➡ This lack of accuracy may lead to a risk of failure, lock-up, drilling issues, casing wear and poor overall drilling performance.

➡ A stiff-string model with contact point calculation is highly recommended to estimate properly drill string loads

Soft-String vs Stiff-String



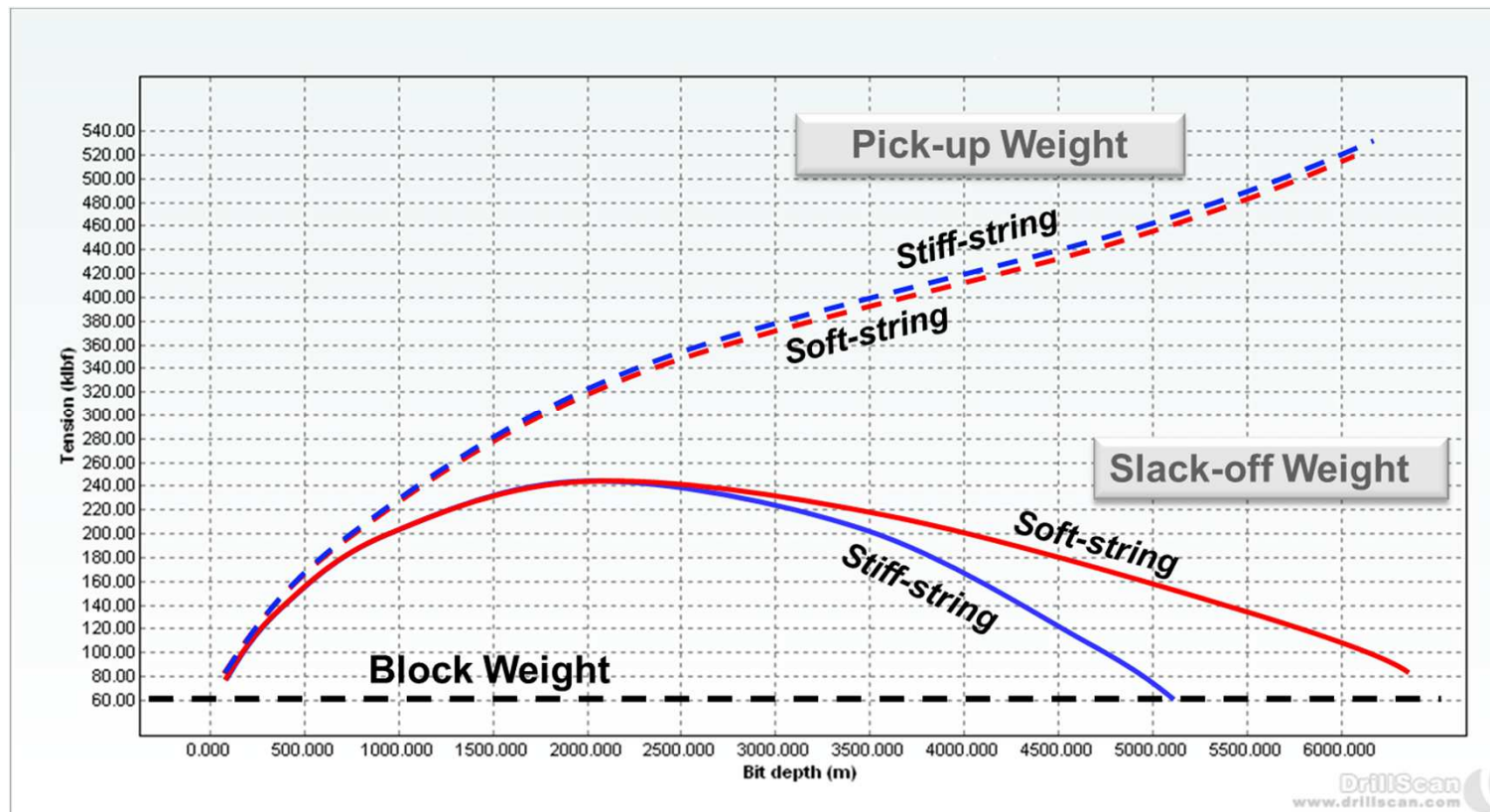
Engineering Features	Soft-string	Stiff-string
Clearance / Hole Size	✗	✓
Stiffness / Bending	✗	✓
Contact Calculation	✗	✓
Mechanical Integrity	✗	✓

Soft-string models ignore the clearance (gap between the tubular and the bore hole) effect. A simulation in a 17 ½ inch hole or in a 8 ½ inch will produce same hook-load and torque according to the soft-string model. Field observations have shown that hook-load and torque are different.

Drill pipe or casing stiffness is ignored in the soft-string model. Studies have shown that above a dog leg severity of 3 deg./ 30 m, stiffness effects start to play a great role, and may add some torque and drag friction on the drill string. Moreover, high bending moments can lead to failure due to fatigue phenomenon.

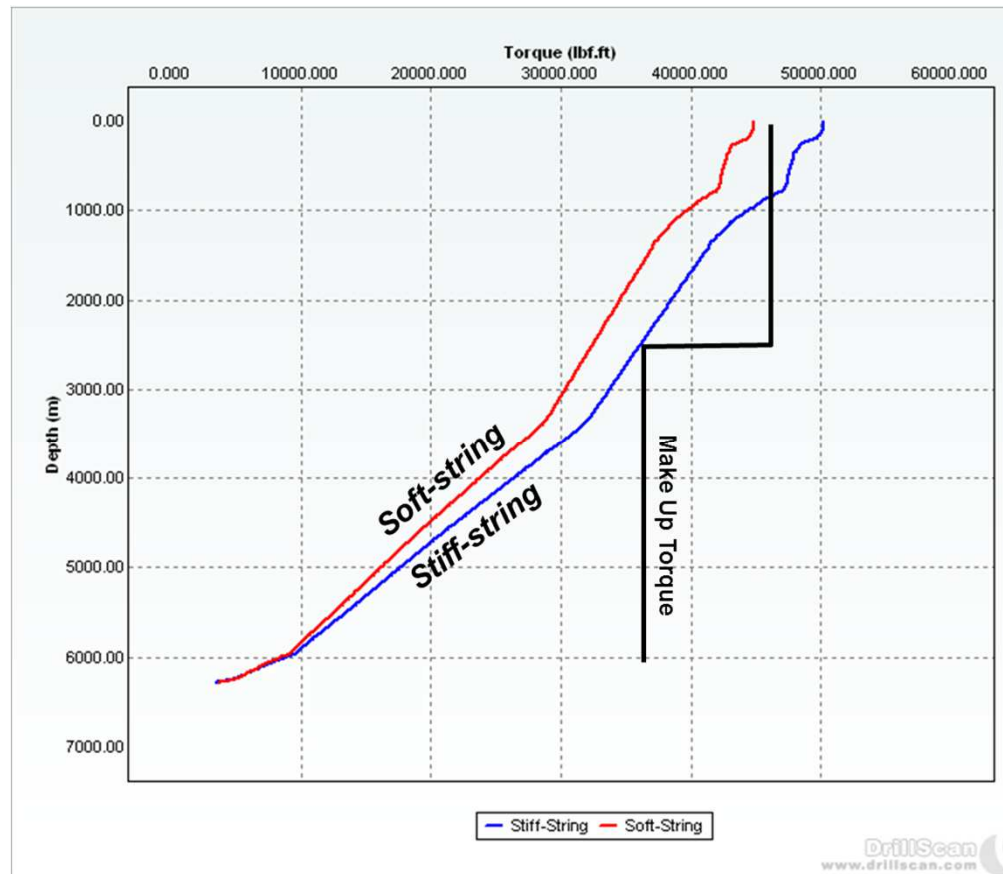
Contact point location between the drill string and the bore hole is not calculated in the soft-string but imposed on the low-side of the bore-hole. Lab and Field evidences have shown that contact location may be on any point along the bore hole (low-side, high-side, left-side or right-side) depending on the well geometry and operating parameters.

Inability of the soft-string model to predict lock-up



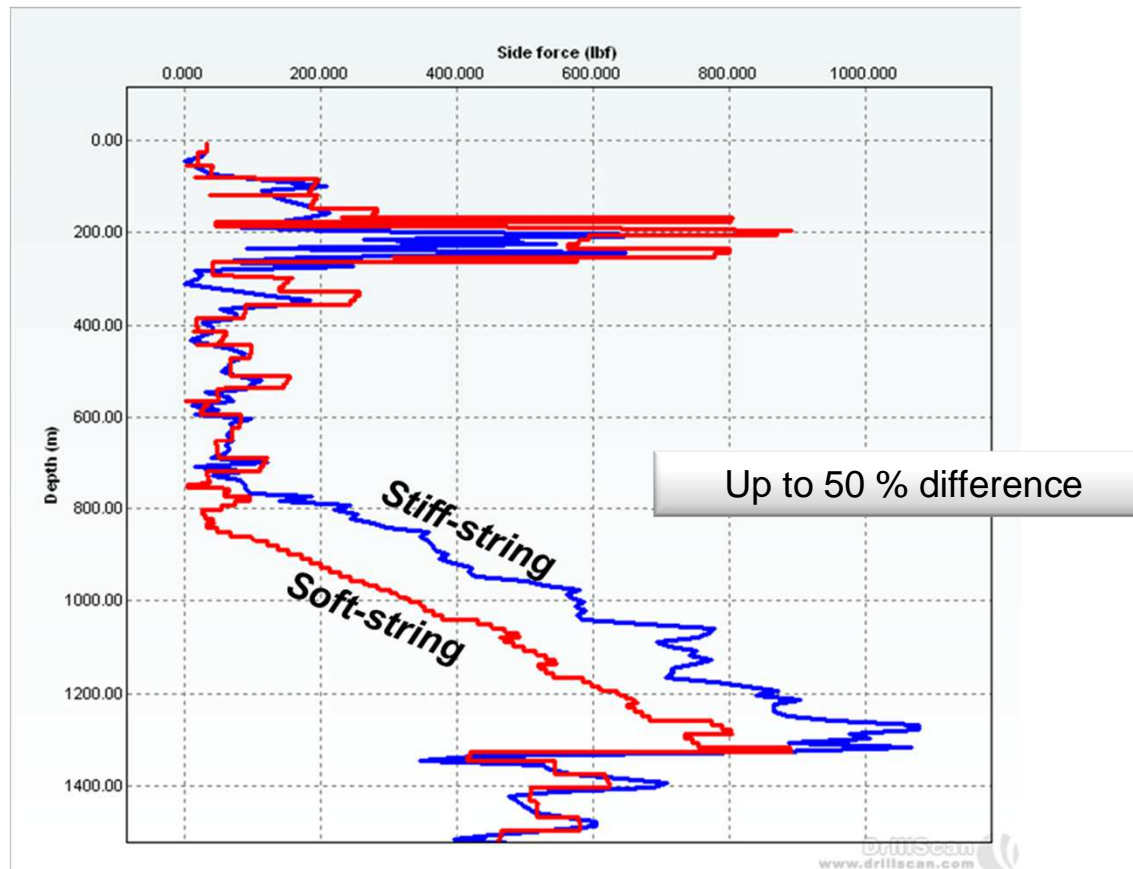
Soft-string does not predict buckling onset, that can lead to a risk of failure or lock-up. This plot shows pick-up and slack-off weight for a horizontal well. As inclination increases with bit depth, drag friction increases a lot leading to a slack-off weight that decreases dangerously to the block-weight. A slack-off equal to the block weight means that no more weight is available at surface to run the drill string in the hole: this is the lock-up. As soft-string inaccuracy increases with drill string compression, the model may not predict lock-up, as additional compression causes higher contact side force and thus higher drag. On the contrary, stiff-string model enables to take this effect into account and predict a more realistic slack-off weight than the soft-string model. The consequence of lock-up are numerous: risk of failure, risk of drill pipe stuck, extra trip to change the drill string design, etc ...

Soft-string model may under-estimate torque while drilling



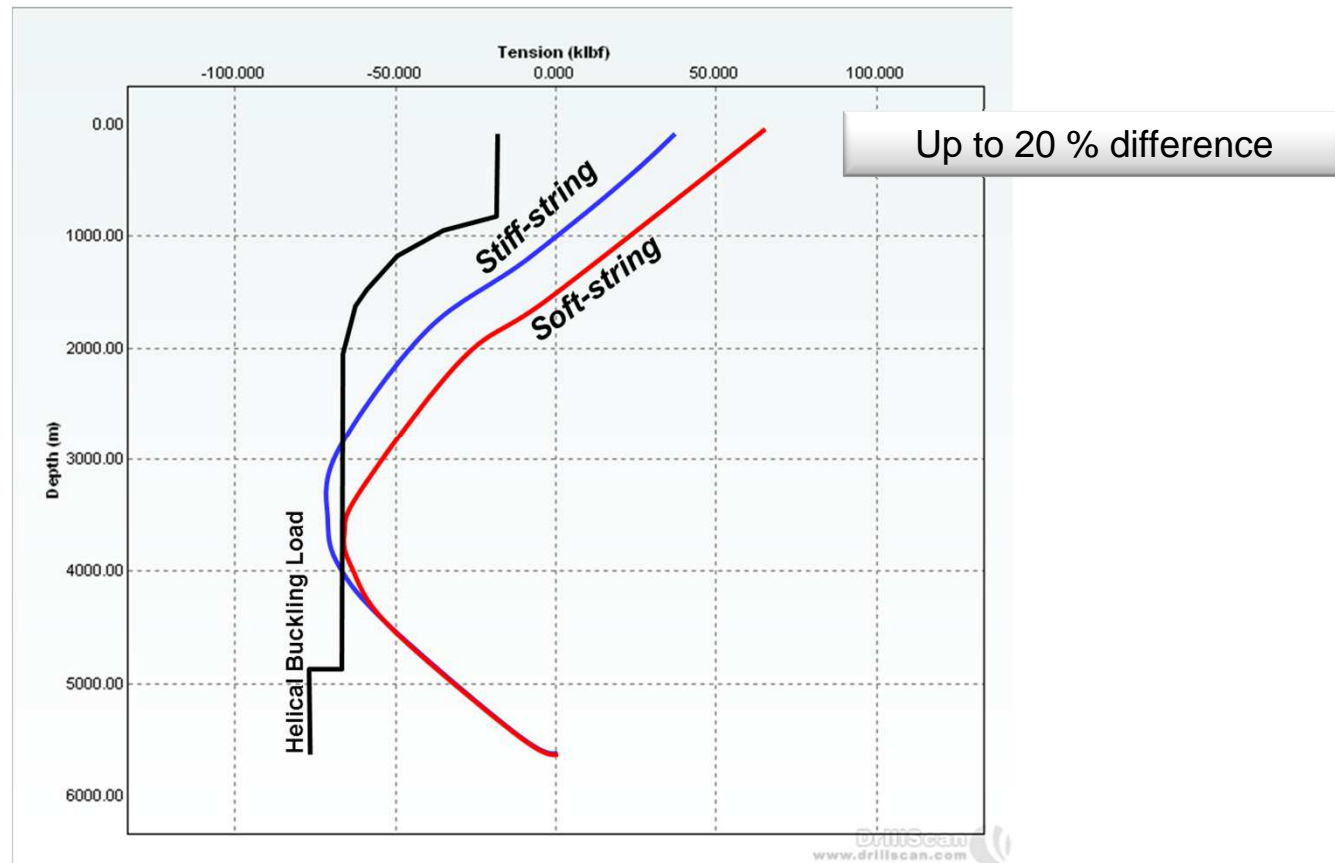
Soft-string may under-estimate drill string Torque (up to 20%). This under-estimation may lead to an improper connection selection in order that maximum torque while drilling does not reach the make up torque. This plot shows that, according to the soft-string model, the torque while drilling does not exceed the make up torque of the connection. On the contrary, stiff-string model shows that the torque while drilling may exceed the make up torque of the connection that can lead to a failure. Using a stiff-string model enables to better select the connection design to avoid exceeding the make-up-torque.

Soft-string model does not calculate properly the side forces



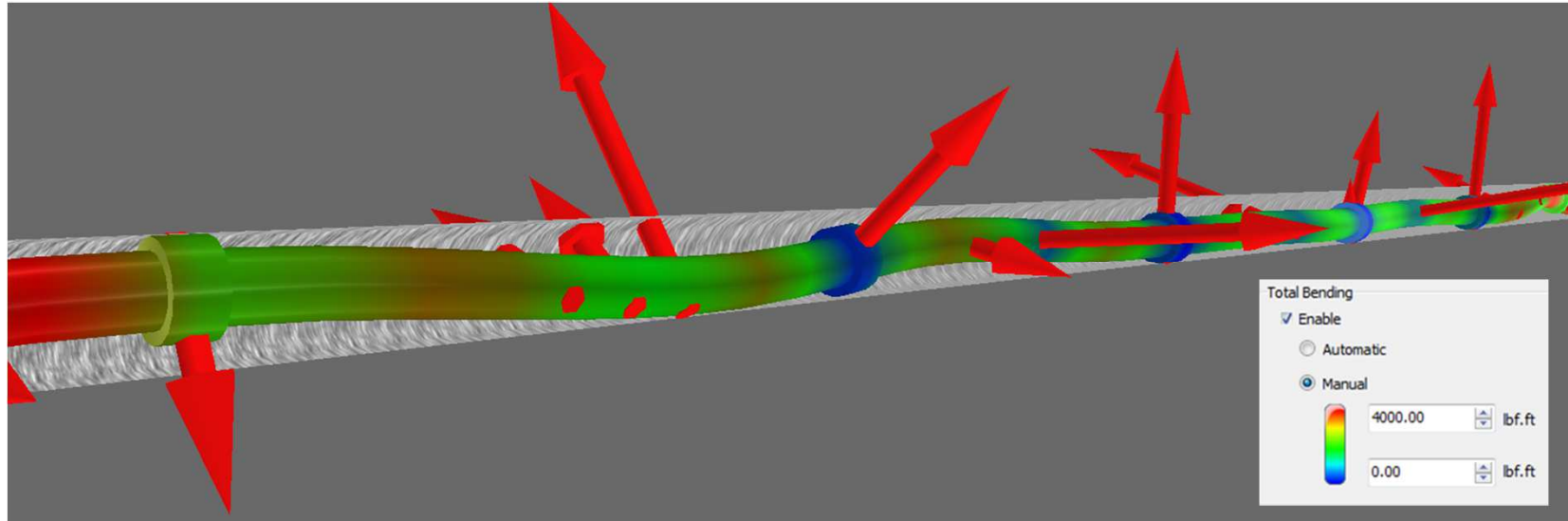
Soft-string model does not estimate properly contact side forces on the drill string. As contact is assumed to be regularly distributed on every joints, this can lead to an under or over-estimation of the contact side force depending on the well trajectory, and especially the dog legs. An under-estimation may be dangerous, as risk of casing wear is greater when contact side force exceeds 2000 lbs (API recommendation).

Inability of the Soft-string model to predict buckling



Soft-string does not predict buckling onset, that can lead to a risk of failure or lock-up. This plot shows the tension/compression curve all along the drill string, from the bit to the surface, for a run in hole operation in a highly deviated well. As soft-string solution starts to be inaccurate as compression increases, this plot shows that stiff-string model predict a higher compression in the drill string that can lead to helical buckling. According to the soft-string model, there is no risk of helical buckling. Stiff-string analysis shows that there is a risk of helical buckling, that can lead to a risk of failure or drill pipe stuck in the hole.

Soft-string cannot monitor drill string mechanical integrity



Soft-string cannot monitor drill string mechanical integrity, that can lead to a risk of tubular failure. As soft-string model ignores pipe stiffness, one cannot estimate the true load on drill string elements. Bending moments are often responsible of failure due to fatigue phenomena. This plot shows a stiff-string simulation highlighting the contact side force (red arrows) and bending moments on the drill pipes. Monitoring these loads enables to avoid premature drill pipe failures.

Other comments...

- **Stiff string model accurately simulates drill string torque and tension in actual bore hole conditions** whereas soft string model artificially increases friction factors to fit the actual field data to compensate for neglecting stiffness and clearance effects and miscalculating contact side forces.
- Soft-string model is as accurate as stiff-string model in terms of pick-up weight estimation only in the following case: the drill string is in tension inside a very smooth well bore (dog legs less than 1 deg./30 m)
- **Soft-string model starts to be inaccurate when dog legs are greater than 3 deg. / 30 m or when clearance is low.** Casing (low clearance) running in hole simulation with soft-string model can lead to improper hook-load estimation, and thus can lead to an unexpected lock-up
- **Soft-string and Stiff-string models use rigorously the same input parameters:** well bore geometry and trajectory survey, drill string characteristics, mud weight and operating parameters. No extra parameters are required for the stiff-string model
- **Stiff-string model computation time is greater than for the soft-string model.** As the stiff-string model includes a complex algorithm that estimates the accurate contact point locations and side forces, the time required to make a calculation is logically higher, as modeling and science are more complex. However, our stiff-string solution uses a new numerical methodology that makes it very much faster compared to the finite element analysis, without a lack of accuracy and robustness.

Literature

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