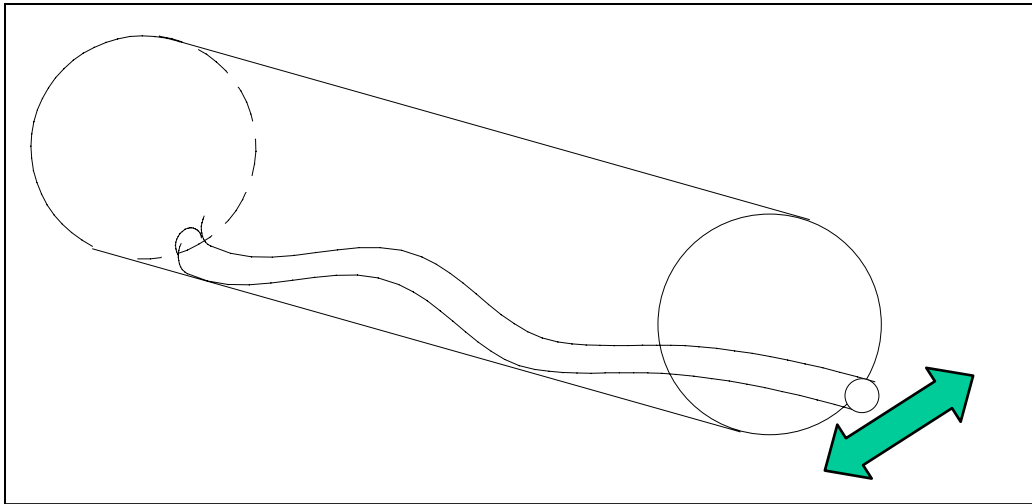
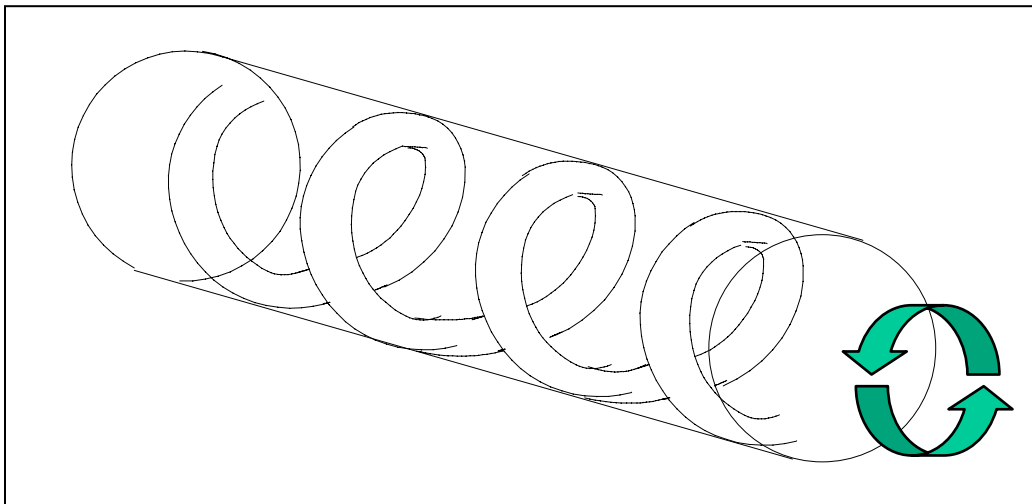


Attachment B: Sinusoidal Buckling and Countermeasures

Source: K&M Technology Group, *Drilling Design and Implementation for Extended Reach and Complex Wells – 3rd Edition*, 2003, p. 126-131.



Sinusoidal Buckling



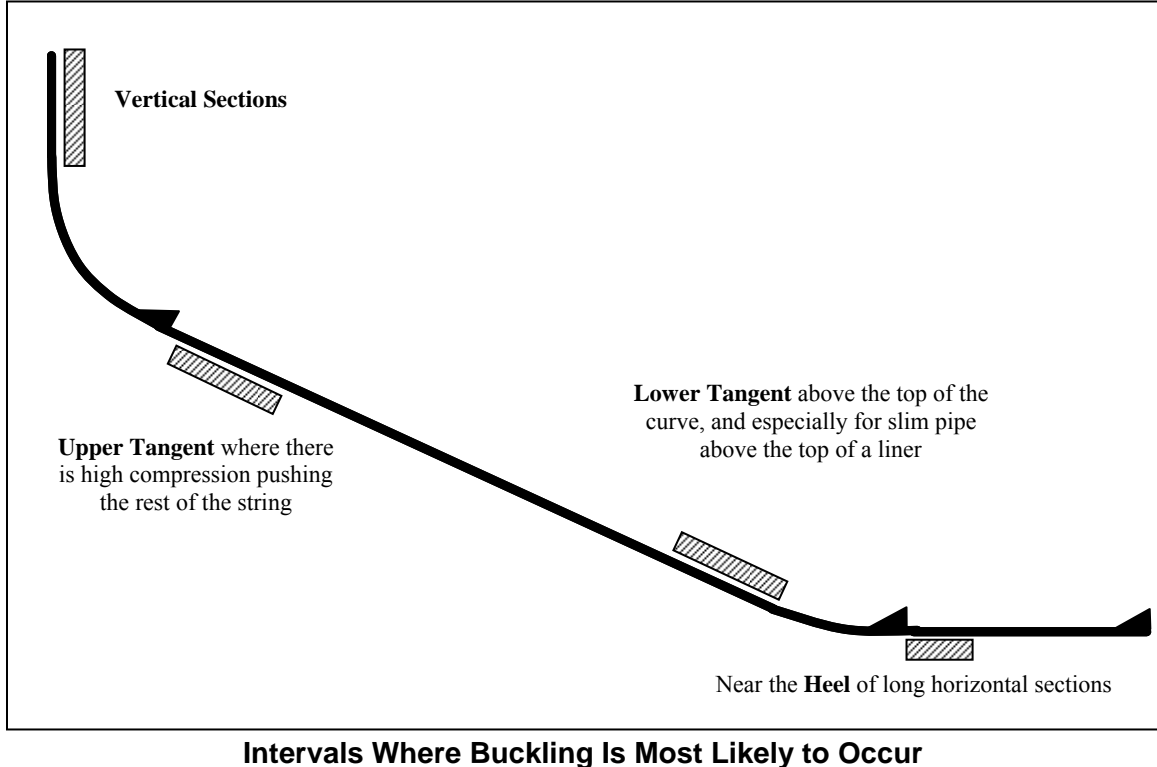
Helical Buckling

Is buckling bad for the drillpipe? For both sinusoidal and helical, the buckling itself is not harmful to the drillstring if there is no pipe rotation. The buckling stresses are usually well below the yield strength of the pipe. The one exception would be relatively small pipe in big hole. However, *it is important that you do not commence rotation of the drillpipe until all of the pipe buckling has been worked out of the string.* Buckled pipe will quickly be fatigued if rotated (i.e. cyclic stresses).

- This can be a significant issue for very long ERD wells, where the pipe stretch is considerable. After making a connection, it is good drilling practice to pick-up the string off-bottom and get all of the compression out of the pipe prior to going back to bottom and drilling ahead. If the pipe stretch is excessive, the compression in the pipe may not be able to be released, as the string cannot be picked up high enough. As a result, drillstring fatigue will be increased and premature failures may result.

Attachment B: Sinusoidal Buckling and Countermeasures

Source: K&M Technology Group, *Drilling Design and Implementation for Extended Reach and Complex Wells – 3rd Edition*, 2003, p. 126-131.



Options to Prevent or Reduce Buckling

There are numerous design options to prevent or reduce buckling problems. Some of the most common methods are described below.

Wellpath Design

The wellpath is a compilation of many differing objectives (i.e. collision avoidance, wellbore stability, target alignment, etc.). However, there may be scope to reduce buckling problems by designing the wellpath with buckling in mind. Options include different build or turn rates in the lower build section for a horizontal well, or varying the casing points or liner tops.

Drillpipe Size and Stiffness

The most common method of managing buckling is to place HWDP at strategically located intervals in the drillstring. This method was originally developed for use in conventional horizontal wells. While still quite effective in ERD wells, there are distinct disadvantages of relying on these methods for ERD applications. On a conventional vertical-to-horizontal well, the HWDP does not contribute significantly to increased torque and drag. Furthermore, hydraulics are not usually a limitation on vertical wells. Because of this, HWDP can be used quite easily to prevent buckling (see Figure 26). However, on an ERD well, the HWDP will

Attachment B: Sinusoidal Buckling and Countermeasures

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be placed in a high angle section of the well, and therefore results in significantly more torque and drag, while also increasing surface pump pressures. As such, the use of HWDP is less appropriate on ERD wells if there are torque, drag or surface pressure limitations. It is preferable to keep the drillstring as stiff as possible without increasing its weight significantly.

This can often be accomplished by increasing the size of the pipe that is being used. The use of 5½”, 5⅞” and 6⅝” drill pipe for improved hydraulics and buckling performance is common in ERD applications. The use of Non-rotating Drillpipe Protectors is also a common practice to prevent buckling by stiffening the existing drill string at strategic locations.

Increasing the diameter of the tubular improves buckling performance because the pipe stiffness is a function of the radius to the power of four. That is, $\text{Stiffness} = I^4 (R^4 - r^4)$. This explains why 4” drillpipe is significantly better for buckling compared to 3½” drillpipe, and why 6⅝” drillpipe and casing are basically immune to buckling.

The use of larger pipe, to avoid buckling, needs to consider the possible increase in ECD’s. This is especially important on very shallow ERD wells.

Special Downhole Tools to Improve Drillpipe Stiffness

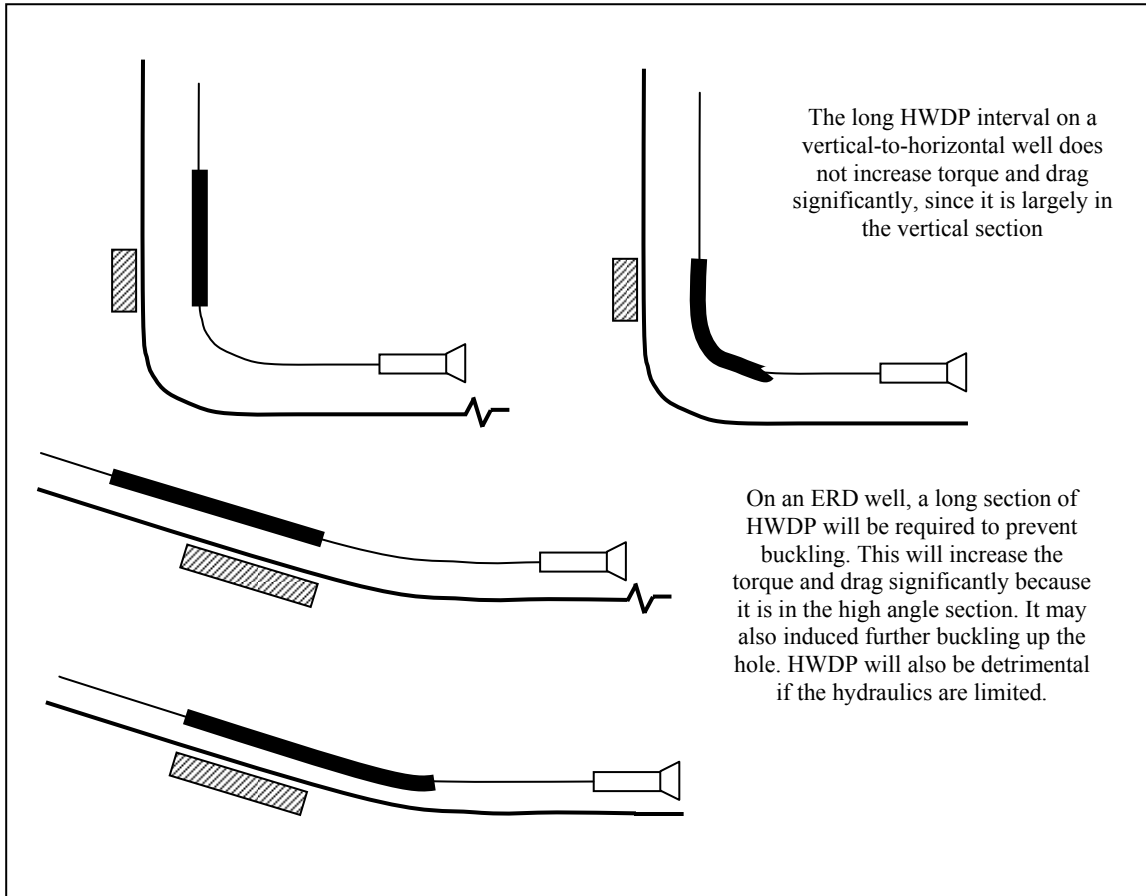
There are several specialized downhole tools that can stiffen drillpipe. Most of these items require some planning since they are relatively expensive and usually must be ordered in advance. There are also drillstring management issues, and in some cases there are also other risks that must be considered.

Bladed Drillpipe - Integral bladed-drillpipe (or spiraled drillpipe) will improve pipe stiffness without significantly increasing weight. This drillpipe will also aid hole cleaning, while being more resistant to buckling.

Non-Rotating Drillpipe Protectors / Roller Bearing Subs - Non Rotating Drillpipe Protectors (NRDPP’s) or Roller Bearing Subs (RBS) can be used to stiffen the drillpipe without increasing drag, (drag will increase while running through build section only) while also reducing torque. While effective at preventing buckling, there are obvious cost and drillstring management issues involved with these tools. Further, there is some risk of losing at least some of these downhole if *improperly* applied. In general, these tools have been found to be quite sturdy and reliable, but experience has shown that you cannot afford to take shortcuts with the quantity or type of tools required. The side-load forces must be modeled and sufficient quantities of these tools applied. ***Do not use these tools if you are not willing to run the required amount, as you are then likely to lose them downhole.*** Ensure that the side-load modeling assumes a backreaming scenario as well.

Attachment B: Sinusoidal Buckling and Countermeasures

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Use of Heavy Weight Drill Pipe (HWDP) to Prevent Buckling

The increased ECD's that will result from the application of these tools must also be considered.

Roller Centralizers for Casing and Completions - "Roller" centralizers can be added to a casing or completion string if buckling is a problem. These minimize buckling by reducing the overall drag on the string (effectively reducing the slack-off friction factor as well as stiffening the string). These centralizers can be used on casing, conventional jointed tubing or coiled tubing.

K&M's experience with these tools suggests that they are very effective in cased hole, especially if the hole is 'clean'. Openhole experience is limited, but they will most likely do some good as long as the hole is consolidated.

Attachment B: Sinusoidal Buckling and Countermeasures

Source: K&M Technology Group, *Drilling Design and Implementation for Extended Reach and Complex Wells – 3rd Edition*, 2003, p. 126-131.

Rotation and Flotation

The best defense against pipe buckling is to preserve the ability to rotate. This applies to drilling as well as running of liners and casing (floated). This cannot, generally, be applied to coiled tubing or conventional completion programs.

Rotary Steerable tools (RST's) are helping to overcome many of the drilling problems seen with buckling when using steerable motors.

When running liners, premium high torque connections are available that allow rotation while running in the hole and during cementing operations. Roller centralizers can also be used that allow significant reduction of both torque and drag.

Another option to limit buckling with casing and liners is flotation. By floating the string, the weight is significantly reduced, which results in much lower drag. However, under the right conditions, flotation may also result in increased buckling, as the casing will have less buckling resistance when its weight is lower. ***Where possible, the ability to rotate should always be designed in as a contingency on a difficult casing run.***