# Stick-Slip Behavior in Coil Tubing

Juan Montero

NCS Multistage

ICoTA Calgary Round Table

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# Outline

- Why study this subject?
- Introduction to coil tubing behavior
  - Physics in the well
  - Stick-Slip phenomenon
- LiveSim
- Case study - Software predictions versus real data
- How extreme the stick-slip can be?
- Problems with stick-slip and coil tubing
- Conclusions

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# Why did we look into this subject?

- Some challenges noticed while locating frac sleeves, including not having a locate signature and having confusion with surface charts
- A need to understand what the problem really is and why does it happen
- One method of validating LiveSim – a new company software / tool

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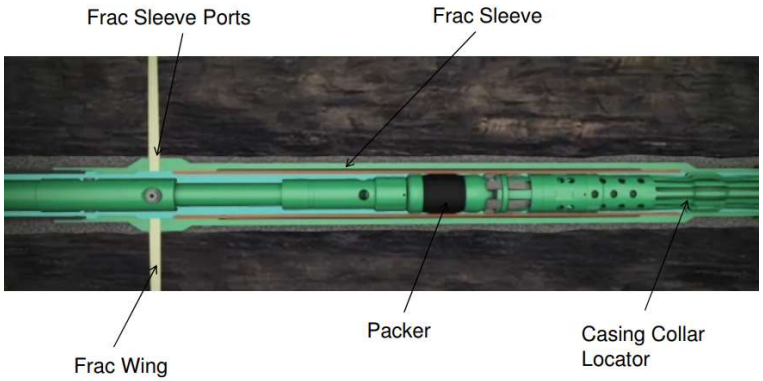
# An example of BHA position incorrectly in the sleeve




Break down of the zone was not achieved on Sleeve 7 after numerous attempts, this would indicate that the BHA was indeed set high and the packer element would have been placed across the frac ports when the sleeve shifted open. The shift pressure of the sleeve was also 4MPa higher than any of the previous.

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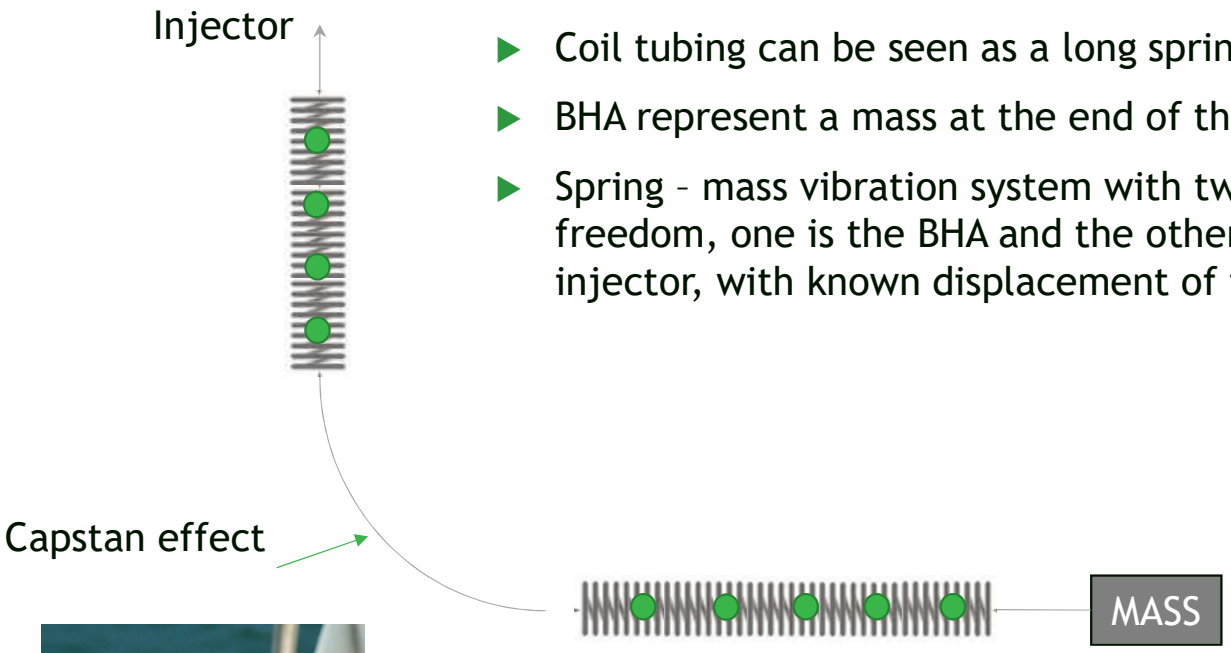
# Physics in the Well




- Coil tubing can be seen as a long spring
- BHA represent a mass at the end of the string
- Spring – mass vibration system with two degrees of freedom, one is the BHA and the other one the injector, with known displacement of the latter.

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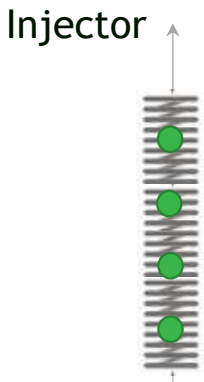
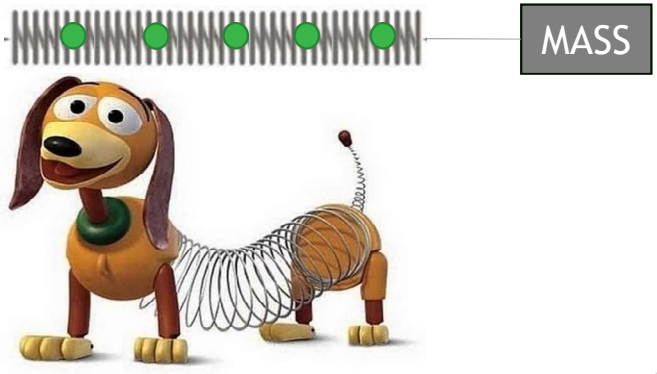
# Physics in the Well




- Capstan effect means pull force in the vertical translates into a reduced force in the horizontal around the build
- BHA movement is a delayed reaction to the pull force. Coil has to stretch and even get lifted up in the horizontal before the BHA feels the force.
- Behaves like a slinky!

Capstan effect

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# Factors affecting BHA behavior

The BHA movement inside the well is quite a complex phenomenon. It is affected by many simultaneously participating variables:

- Coil tubing size
- Well geometry
- POOH speed
- POOH start up acceleration
- Friction factor (constant and changing). Presence of sand
- Disruptions: casing joints, different IDs at the connections, overtorqued connections, eccentricity… and where these disruptions are placed in the well
- Fluid dampening effect
- BHA slack, mass & stick and slip
- BHA performance
- How the BHA is moved into the well: switching between POOH and RIH, POOH speed fluctuations, etc.

**Everything matters and affects the coil tubing behavior**

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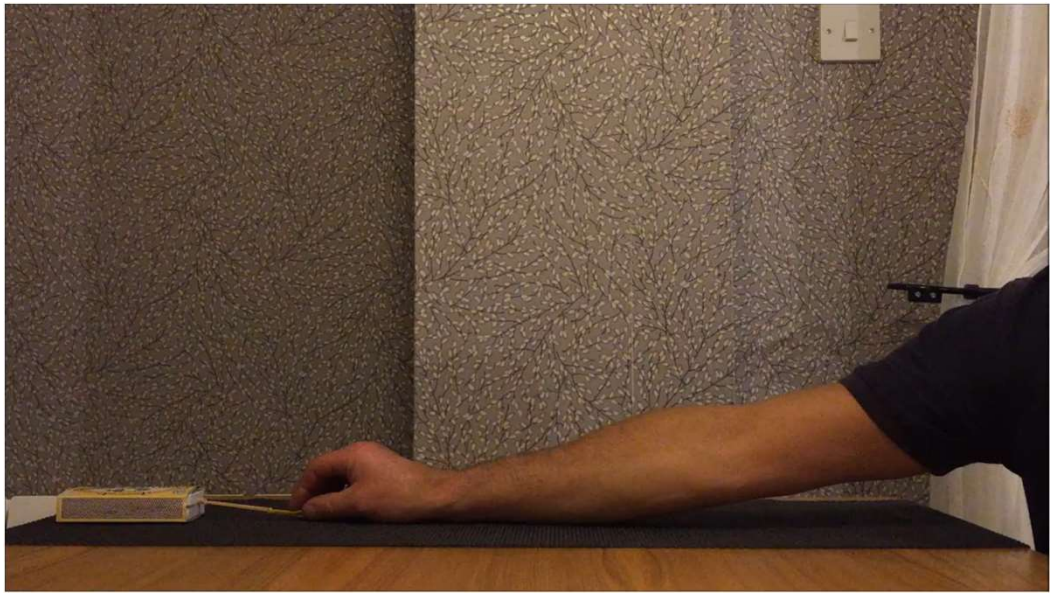
# Stick-Slip

- Stick-slip can be described as surfaces alternating between sticking to each other and sliding over each other, with a corresponding change in the force of friction.
- If an applied force is large enough to overcome the static friction, then the reduction of the friction to the kinetic friction can cause a sudden jump in the velocity of the movement



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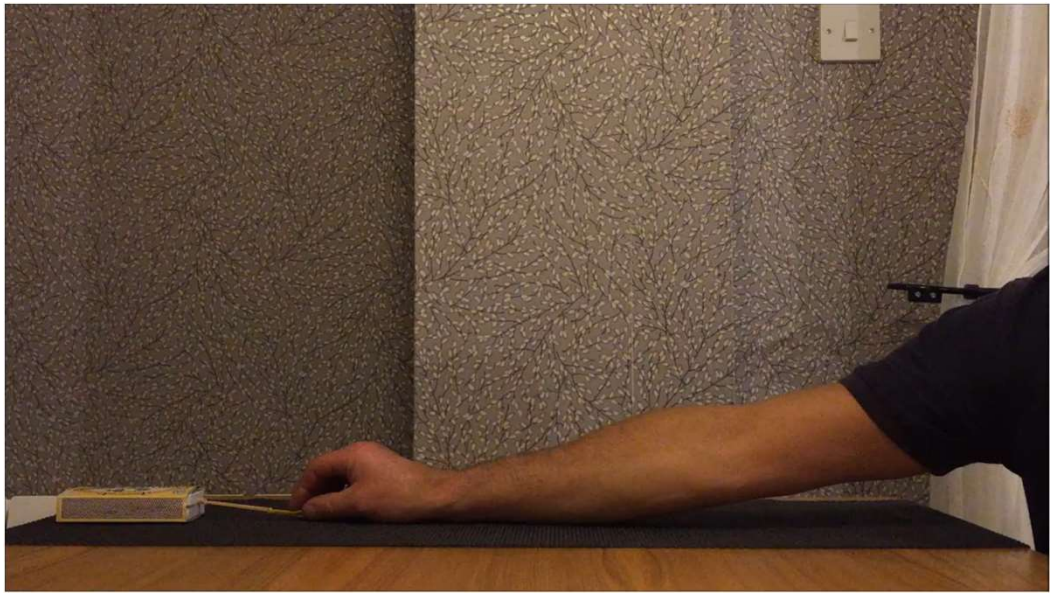
# Stick-Slip

- Coil tubing (rubber band) stretches
- Once sufficient force has been built, the BHA (matches box) moves, creating a sudden jump in velocity.
- Coil tubing recovers part its original length, making the available downhole force less than the dynamic friction force.
- BHA stops and cycle starts again



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# Stick-Slip

EV's Optis HD memory camera combined with pressure and temperature sensors is a cost effective means to identify water entry into a horizontal shale gas well. Deployed on coil tubing the video and log combination accurately identifies the water entry point and allows the customer to undertake a water shut-off intervention. There is a growing track record of operators in the US using this technique to re-establish gas production from watered out wells delivering an excellent return on investment

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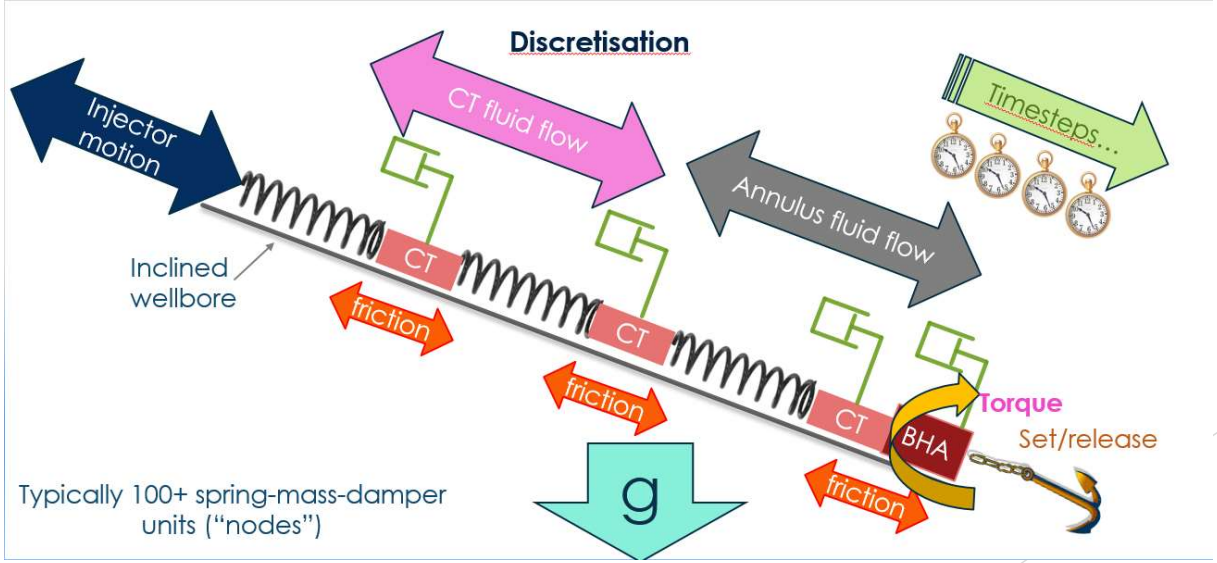
# How do we integrate all of this information to understand what is happening? LiveSim

- It is VBA code with an Excel interface that utilizes a spring-mass vibration system with two degrees of freedom
- It uses a finite-difference as the numerical method to solve the motion differential equations in typically 100+ spring-mass-damper nodes
- The model includes but is not limited to: BHA drag, locates, well geometry, friction at the build (Capstan effect), gravity and coil helical buckling.

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# Case study – LiveSim predictions

- Casing:  4.5” 11.6# L80
- 2-5/8” x .188” wall coil tubing
- Customer: Crescent Point Energy Corp
- Area:  Viewfield, SK
- TVD = 1725 m , MD = 3087 m
- Issues:  none

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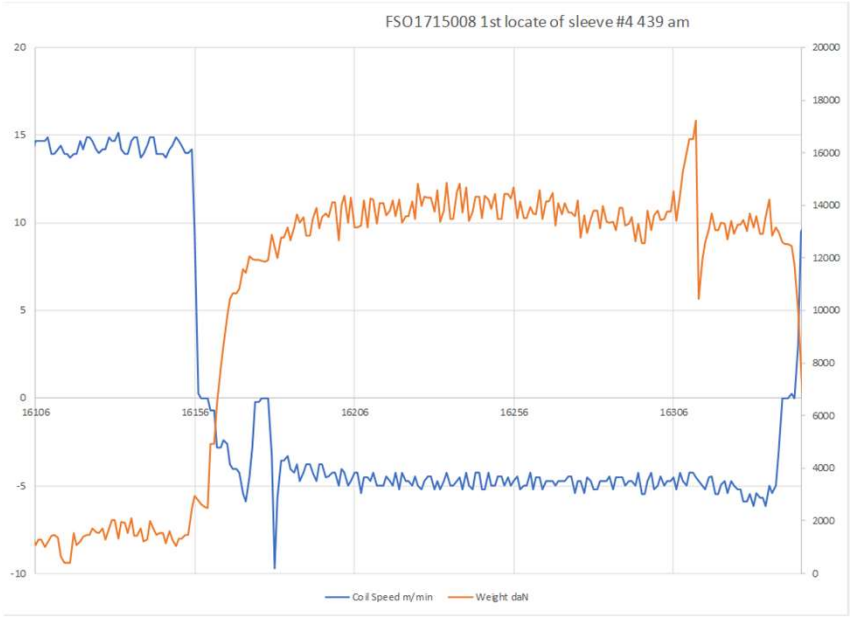
# Case study – LiveSim predictions

Real surface:




Points of interest:

1. POOH at -5 m/min
2. 13500 daN approaching locate
3. Peak force 17220 daN ; rise = 3720
4. 6 to 8 sec to reach peak
5. Slingshot weight 10,400 daN; drop = 6820

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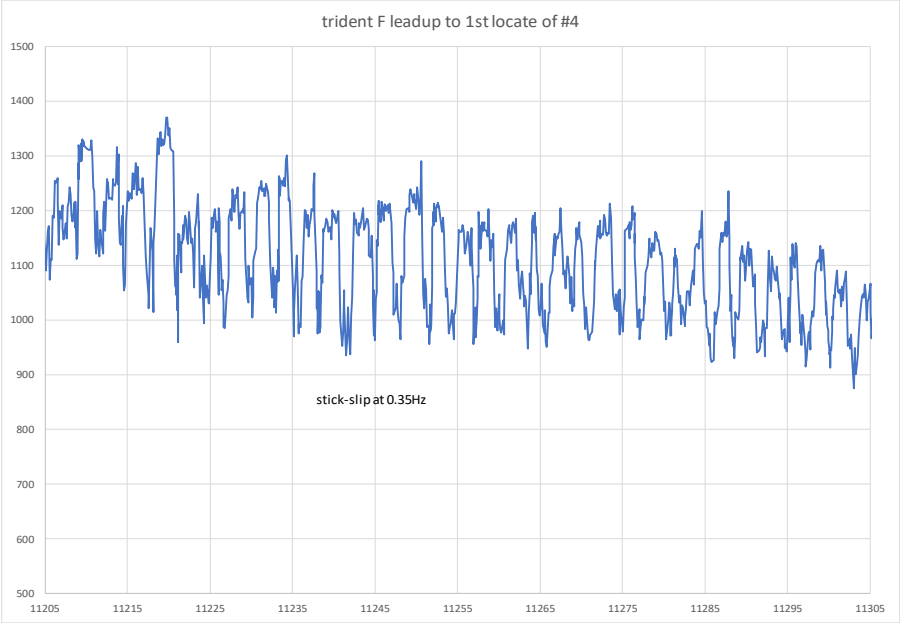
# Case study – LiveSim predictions

Real downhole data:




Sticks-slip at .35 Hz

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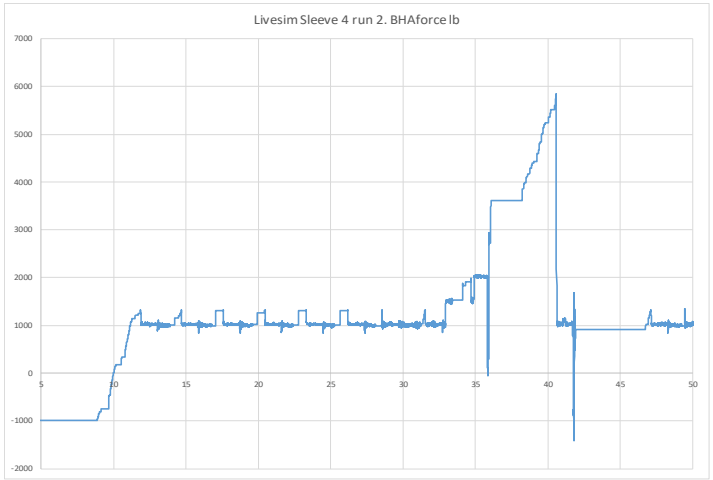
# Case study – LiveSim predictions

## LiveSim downhole:

Points of interest in Livesim BHA data

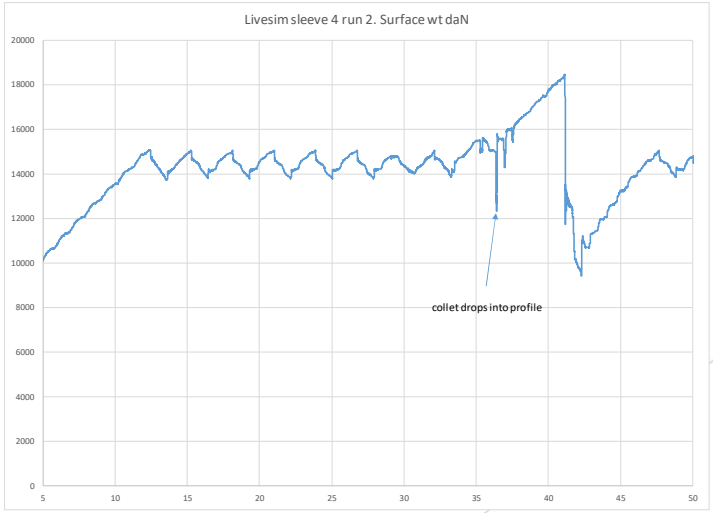
1. Approx. 1000 lb approaching locate
2. During approach the force oscillates 25-30% above base level at frequency 0.35 Hz although it is not as distinct as the Trident data.
3. Plateau to approx. 2000lb, 2.5 sec duration
4. Drop to 128lb, 0.25 sec duration
5. Staircase climb to 3815, 4634 then peak 5282 lb in 4.5 sec
6. Drop to -1220 lb with 1 oscillation in 1.2 sec.




## LiveSim surface:

Points of interest:

1. POOH at -5 m/min
2. 14400 daN approaching locate (CT field 13500)
3. Peak force 18450 daN ; rise = 4050 (field 3720)
4. 7 sec to reach peak from first contact; 4.8 from profile to release (field 6 to 8 total)
5. Slingshot weight 9450 daN; drop = 9000 (field 6820)




The match between Livesim and field data & downhole gauge is close and offers confidence in the model.

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# How light or extreme can the stick-slip be?

- An insight of the coil tubing behavior changing BHA drag, weight, coil tubing size and depth
- Initial condition: injector is at rest after moving in the chosen direction (in or out of the well).
- Run starts with the injector accelerating to target speed in 2 or 10 sec.

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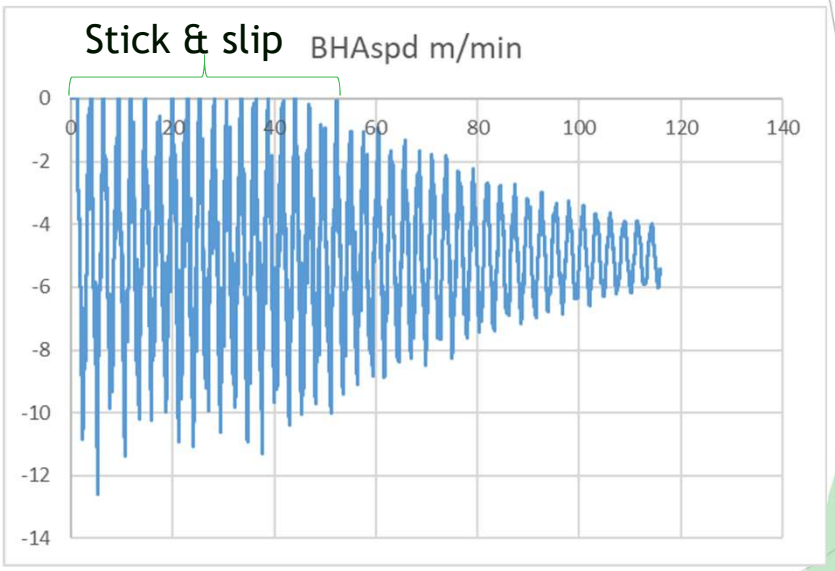
# How light or extreme can the stick-slip be?

- Example at the toe of the well
  - Casing:  4.5” 11.6# L80
  - 2-5/8” x .188” wall coil tubing
  - Depth: 2903 m
  - BHA drag: 980 lbf
  - BHA weight: 265 lbf
  - Speed: 5 m/min POOH




- Stick-slip behavior during ~45 sec, then BHA oscillates
- Desired speed is -5 m/min, but reaches a peak of ~-13 m/min
- Length of stick and slip is 4.3m, with .23m in each jump
- Oscillations damp out after 10m, or ~ 2 minutes of BHA movement

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# How light or extreme can the stick-slip be?

- Example at the toe of the well
  - Casing:  4.5” 11.6# L80
  - 2-5/8” x .188” wall coil tubing
  - Depth: 2903 m
  - BHA drag: 980 lbf
  - BHA weight: 265 lbf
  - Speed: 5 m/min RIH

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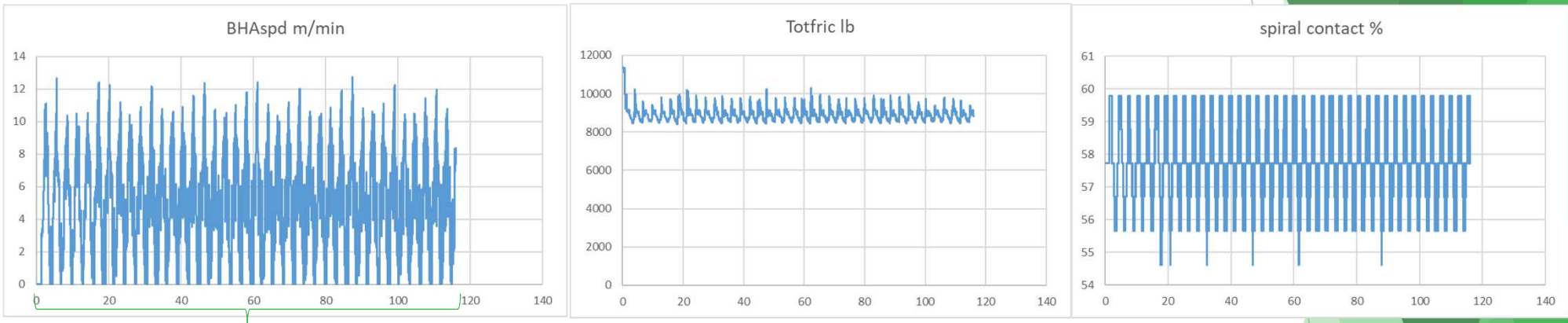
# How light or extreme can the stick and slip be?

- Example at the toe of the well




Stick & slip

- Stick-slip behavior during all time of the study (>10m)
- Similar jump between each stick-slip (0.24m)
- Total friction and spiral contact charts reveals extra built in the coil tubing along the well, which explains the long lasting sticking and slipping.

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# How light or extreme can the stick and slip be?

## Summary

**Depth = 1750 m, acceleration time = 2 sec**

| | | Length | Jump | | Length | Jump | | Length | Jump | | Length | Jump |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT dims (in) | 2.625 x .188 | 0.48 m | .12 m | 2.625 x .188 | 0 | 0 | 2.625 x .188 | >10 m | 0.13 m | 2.625 x .188 | 0 | 0 |
| Drag (lbf) | 980 | | | 490 | | | 980 | | | 490 | | |
| BHA weight (lbf) | 265 | | | 265 | | | 265 | | | 265 | | |
| Speed (m/min) | -5 | | | -5 | | | 5 | | | 5 | | |

**Depth = 2903 m, acceleration time = 2 sec**

| | | Length | Jump | | Length | Jump | | Length | Jump | | Length | Jump |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT dims (in) | 2.625 x .188 | 4.3 m | .23 m | 2.625 x .188 | 1.56 m | .22 m | 2.625 x .188 | 0 | 0 | 2.625 x .188 | >10 m | .24 m |
| Drag (lbf) | 980 | | | 490 | | | 0 | | | 1470 | | |
| BHA weight (lbf) | 265 | | | 265 | | | 0 | | | 265 | | |
| Speed (m/min) | -5 | | | -5 | | | -5 | | | -5 | | |

**Depth = 2903 m, acceleration time = 2 sec** Acceleration time = 10 sec

| | | Length | Jump | | Length | Jump | | Length | Jump | | Length | Jump |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT dims (in) | 2.625 x .188 | >10m | .24m | 2.625 x .188 | 1.25m | .23m | 2.625 x .188 | 0 | 0 | 2.625 x .188 | >10 m | .25m |
| Drag (lbf) | 980 | | | 490 | | | 980 | | | 980 | | |
| BHA weight (lbf) | 265 | | | 265 | | | 265 | | | 265 | | |
| Speed (m/min) | 5 | | | 5 | | | -5 | | | 5 | | |

**Depth = 2903 m, acceleration time = 2 sec** Depth = 2828m

| | | Length | Jump | | Length | Jump | | Length | Jump | | Length | Jump |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CT dims (in) | 2 x .156 | >10m | .24m | 2 x .156 | >10 | 1.17m | 2 x .156 | >10m | .35m | 2 x .156 | >10 m | .61m |
| Drag (lbf) | 980 | | | 980 | | | 490 | | | 980 | | |
| BHA weight (lbf) | 265 | | | 265 | | | 265 | | | 265 | | |
| Speed (m/min) | -5 | | | 5 | | | 5 | | | 5 | | |

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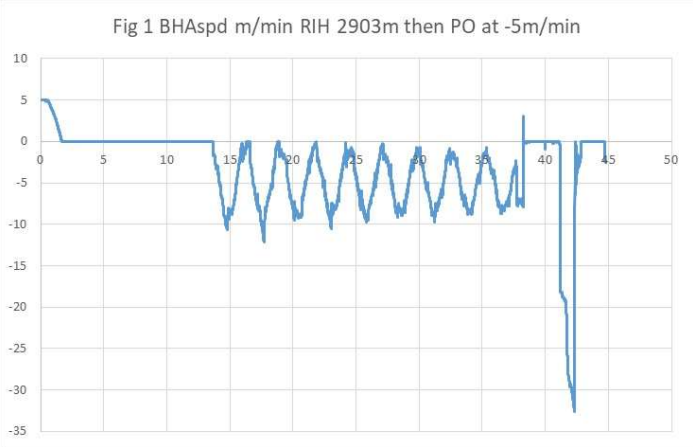
# Potential problems with locating a sleeve

- Same study case shown before.
- BHA mass is 120 Kg, locator drag is 700 lb dynamic, 910 lb static
- Low-end locator, collet type.




Stick & slip behavior under these conditions

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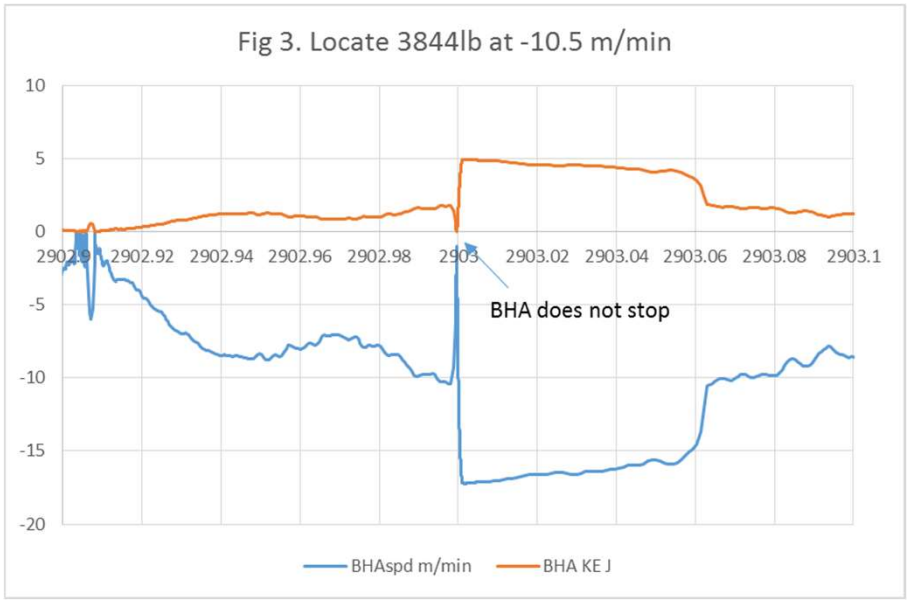
# Potential problems with locating a sleeve

Can the stick and slip be serious enough to make a locator fail?

- Very sensitive to wellbore “disruptions”
- Pop Thrus (with and without surface indication)

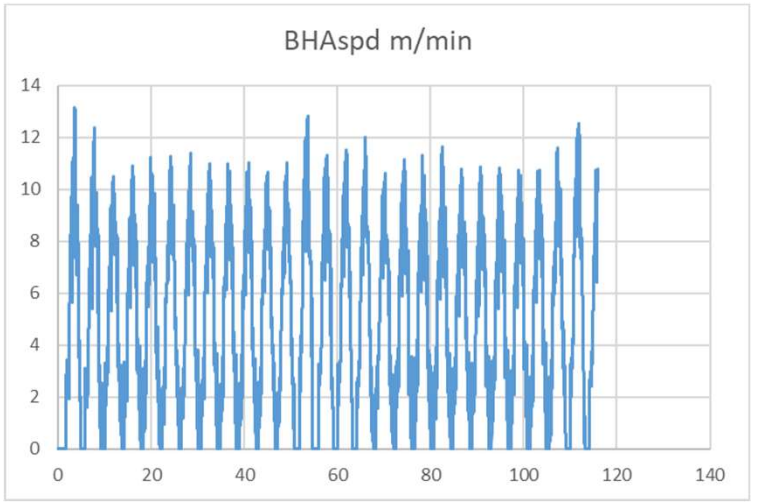



Pops thru

# Potential problems with BHA autocycling

- Coil tubing frac BHA changes modes as movement direction changes
- Sudden velocity increase due to stick and slip can make the BHA to cycle inadvertently

- In this example with 2” CT, injector is moving at 5 m/min RIH. Speed bounces up to ~13 m/min.
- Can create a localized tension effect in the BHA, making it to autocycle.
- Could stop RIH operation in CT and, at worst, could accidentally shift a sleeve open

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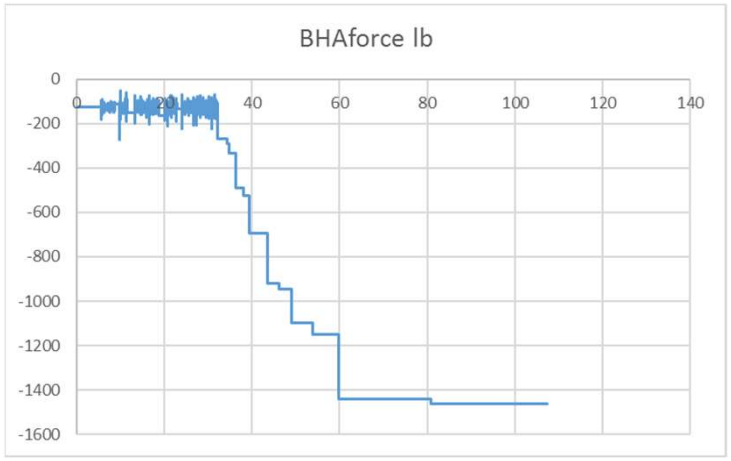
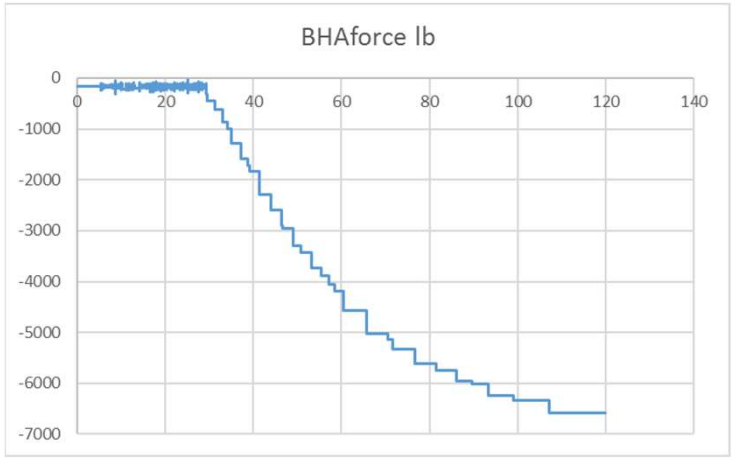
# Downhole force deployment

- Stick and slip causes the erratic behavior in downhole force.
- Creates challenges in obtaining desired set down force




2” CT




2-5/8” CT

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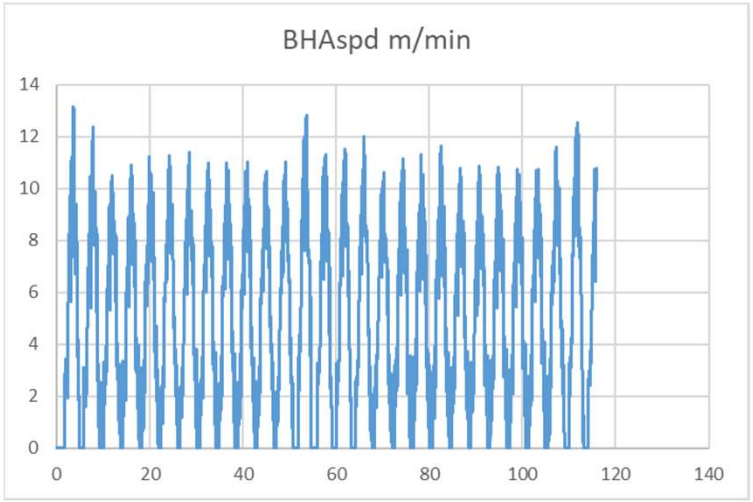
# Other potential problems

- Difficulty maintaining a constant downhole speed
- Almost impossible to position BHA at precise depth
- Depth correlation challenges

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# Conclusions

- LiveSim validation on stick-slip and locating events.  Software can be trusted.
- Stick-slip is a real phenomenon.  More pronounced at the toe with smaller CT while running in hole.
- It makes the BHA movement erratic and unpredictable
- A source for inefficiency in coil tubing operations, including:
  - Sleeve locating.  Solution is on the locator technology
  - Cleanouts
  - Camera runs
  - Logging jobs

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# Acknowledgments


- Special thanks to Rob Standen and John Ravensbergen from NCS Multistage
- Thanks to SPE/Icota for the opportunity to present today


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# Questions?