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Slugging in Pipelines: What You NEED to Know

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Outline

• Why Worry?
• Hydrodynamic Slugs
• Terrain Induced Slugs
• Turn Up Slugs
• Pigging Slugs
• Slug Modelling: Where Are We?
• Areas Currently Being Researched
• Conclusions
Why Worry?

- Damage to facilities
- Separators flooding
- Increased corrosion
- Starving compressors
- High back pressures
Hydrodynamic Slugs

Slugs can be created by just flowing

...and there might be lots of them ...

Steady state mechanistic models will account for hydrodynamic slugging (OLGAS, XIAO models)
Hydrodynamic Slugs

![Graph showing liquid inventory and inlet pressure over time](image)

- **Liquid Inventory (m³):**
  - 25
  - 26
  - 27
  - 28

- **Inlet Pressure (kPa):**
  - 6300
  - 6400
  - 6500
  - 6600
  - 6700

- **Time (hours):**
  - 0.0
  - 0.5
  - 1.0
Avoiding Hydrodynamic Slugs

Superficial Gas Velocity (ft/sec)
Superficial Liquid Velocity (ft/sec)

Bubble
Slug
Wave
Terrain Induced Slugs

A Slug can be created by liquid trapped in the pipeline at low spots

...... Irregular ......
Terrain Induced Slug - Severe

Severe Slugging

Stage 1

Gas blockage can occur in downward sloped flow line at riser base

A liquid slug begins to form in the riser
Terrain Induced Slug - Severe

Severe Slugging Stage 2

Riser fills, and liquid begins to unload into the separator

Gas pressure builds up behind slug!!!
Terrain Induced Slug - Severe

Severe Slugging
Stage 3

Gas penetrates into the riser

Liquid begins to unload rapidly
Severe Slugging
Stage 4

Liquid blows through with residual fallback

Gas blockage occurs, and cycle begins again
Terrain Induced Slug

Steady State Multiphase Software:

- Severe slugging: Fuchs and Pots correlations give contradictory results but Pots can give indication of potential severe slugging
- Cannot predict other terrain induced slugging
- Check for high liquid holdup in low spots and low liquid velocities
Terrain Induced Slug

Use a Transient Multiphase Model to Determine:

- Whether terrain induced slugging will occur
- Length and size of slug
- Transit time of slug
- Frequency of slug
- Separator size required to handle the slug
Severe Slugging Liquid Flow Rate

Outlet Liquid Rate m³/d vs. Inlet Pressure kPa over time (hours).

- Outflow peaks at 7000 m³/d.
- Inflow peaks at 7500 kPa.

Graph shows the cyclical slugging behavior.
Avoiding Terrain Induced Slugs

In Onshore Pipelines:
• Increase gas flow rates
• Decrease diameter

In Offshore Risers:
• Add riser base gas injection
• Increase backpressure
A Slug can be created by a Flow Rate change

...... but only when it increases .......

Slug volume = difference between liquid holdup at 2 flow rates

Use transient model to rigorously model
Pigging Slugs

Slugs can be created by Pigging

.. but typically just one......

Slug volume = total liquid in pipe minus volume dumped into the separator during pig transit

Use transient multiphase model to accurately model pigging slug size and transit time
Pig Position and Pig Velocity

- Pig Position km vs. Time hours
- Pig Velocity m/s vs. Time hours

Graph shows changes in pig position and velocity over time.
Liquid Inventory from Pigging

![Graph showing liquid inventory over time]
Slug Modelling: Where are We?
Slug Modelling: Where are We?
Slug Modelling: Where are We?

Mechanistic Models Use the “Unit Cell Model”

- Developed by Taitel in 1980’s
- Liquid picked up from liquid film = liquid shed
- In mechanistic models now (OLGAS, XIAO)
- Accurate pressure gradients and holdup in fully developed slugs
Areas Currently Being Researched

• Flow pattern transition to / from slug flow in steady state

• More robust models for
  • Liquid holdup in liquid slug (gas entrainment)
  • Gas velocity in liquid slug (turbulence within the liquid slug)
  • Liquid holdup in elongated bubble
  • Liquid slug translational velocity
Conclusions

• Define what you mean by “slugging”
  - hydrodynamic
  - terrain induced
  - turn up
  - pigging
• Transient modelling provides additional information
• Mechanistic modelling of slug flow understood but still actively being researched and improved
Acknowledgements

• Dr. Garry Gregory and Dr. Khalid Aziz
  • For creating the multiphase video at the University of Calgary
  • For the images for severe slugging and slug flow
• Pablo Adames, Schlumberger
  • For updates on the current state of slug research and parsing the multiphase video
• Schlumberger for sponsoring
  • My time, visas, inoculations and hotels
Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation at http://www.spe.org/dl/
Slugging in Pipelines: What You NEED to Know

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Hydrodynamic Slugging: Steady State
Hydrodynamic Slugging: Transient

Dynamic Study

- Name: Hydrodynamic
- Date: 31/03/2010
- Title: Hydrodynamic slugging
- Subtitle:
- Notes:

Study Type: Hydrodynamic Slugging

- Initialization Time: 1 [hours]
- Analysis Time: 2 [hours]
- Number of Profiles: 10
- Low Drain Rate: 100 [sm³/d]
- High Drain Rate: 500 [sm³/d]
Hydrodynamic Slugging: Transient
Terrain Induced Slugging
Terrain Induced Slugging

Elevation Profile Editor - Seafloor pipe

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<tr>
<th>Distance (m)</th>
<th>Elevation (m)</th>
<th>Cumulative Distance (m)</th>
<th>True Length (m)</th>
<th>Surroundings Temperature (°C)</th>
<th>Description</th>
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Distance Along Pipe vs. Elevation

Elevation Profile

View All
Complete Flyby
Segment Angles
Surroundings Temperature
Filter Profile
Print Graph
Data Import
Cancel
Save & Close
Turn Up
### Turn Up: Elevation Profile

#### Elevation Profile Editor - Tie-In Line

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#### Distance Along Pipe vs. Elevation

- Snap To Dist: 1
- Elev: 1
- Sum of Uphill Rises: 240.000
- Distance: Elevation

![Elevation Profile Graph](image)

- View All
- Elevation Profile
- Segment Angles
- Coord Flyby
- Surroundings Temperature
- Filter Profile
- Print Graph
- Data Import
- Cancel
- Save & Close
Pigging