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

Liquid Inventory m³

Inlet Pressure kPa

Time hours

0.0 0.5 1.0

6300 6400 6500 6600 6700

25 26 27 28
Avoiding Hydrodynamic Slugs

Superficial Liquid Velocity (ft/sec)

Superficial Gas Velocity (ft/sec)

Bubble

Slug

Wave
Terrain Induced Slugs

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

...... Irregular ......
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!!!
Severe Slugging Stage 3

Gas penetrates into the riser

Liquid begins to unload rapidly
Terrain Induced Slug - Severe

Severe Slugging
Stage 4

Gas
Liquid

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

![Graph showing outlet liquid rate and inlet pressure over time](image-url)

- **Outlet Liquid Rate**: m³/d
- **Inlet Pressure**: kPa
Avoiding Terrain Induced Slugs

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

In Offshore Risers:
• Add riser base gas injection
• Increase backpressure
Turn Up Slugs

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
Turn Up Slugs

Outlet Liquid Rate m3/d

Inlet Pressure kPa

Time hours
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

![Graph showing Pig Position (km) and Pig Velocity (m/s) over Time (hours).]
Liquid Inventory from Pigging

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

- **Liquid Inventory (m³)**
  - 6400
  - 6450
  - 6500
  - 6550
  - 6600
  - 6650
  - 6700

- **Inlet Pressure (kPaa)**
  - 6400
  - 6450
  - 6500
  - 6550
  - 6600
  - 6650
  - 6700

**Time hours**
- 0
- 2
- 4
- 6
- 8
- 10
Slug Modelling: Where are We?
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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
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