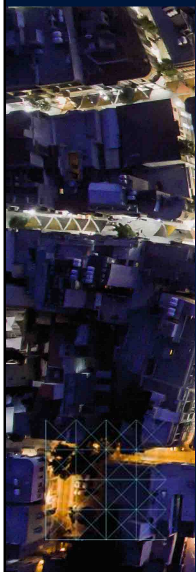

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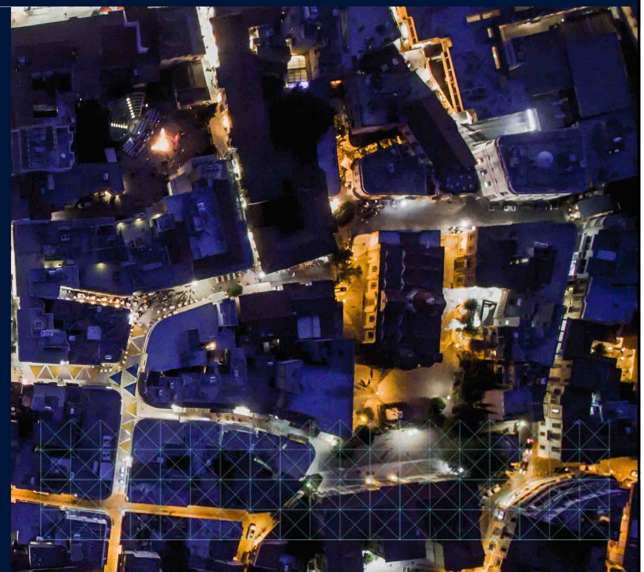
SPE FTS SEMINAR

Wax Deposition and Hydrate Transport Modeling for Flow Assurance and its Application in Field Design

26/09/2019

Neeraj Zambare, Product Director



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Introduction

- Long distance multiphase flow transport presents *well known challenges* which are not *well understood*:
  - Wax formation and deposition:
    - Occurs below WAT
    - Better understanding helps to determine the optimum pigging frequency
  - Hydrate formation and transportation:
    - Clathrates or crystalline solids
    - Occurs under low temperature and high pressure
    - Innovative solution: transport hydrates in suspension safely – use of LDHI-AA
- *New LedaFlow™ modules* provide better understanding of wax deposition and hydrate transport challenges for application in real fields

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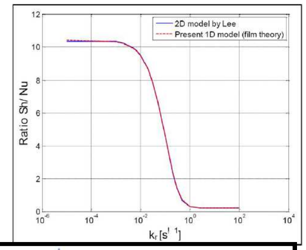
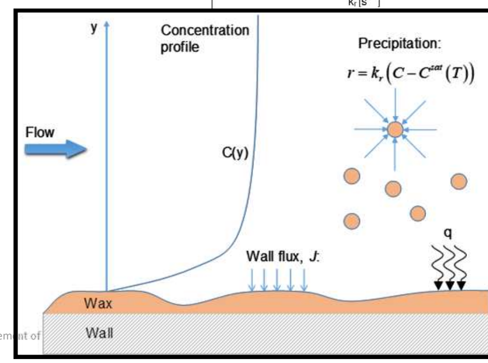
Wax deposition model



- Methodology in the modeling software:
  - Uses Lee's model (2008-University of Michigan)
  - Uses custom fluid framework
  - Important parameters for wax deposition
    - Wax precipitation curve
    - Diffusion coefficient
    - Wall surface area wetted by oil
    - Temperature gradient
  - Wax deposition reactions are fully reversible



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Wax deposition model

...contd.

- General Concepts:
  - When temperature drops below WAT
  - The wax-in-oil slurry is non-Newtonian
    - Newtonian fluid, Thomas model
    - Non-Newtonian fluid, Pedersen or SoFA
  - Wax diffuses towards the pipe wall
  - Pigging is necessary for removing wax
- Main objectives:
  - Determine pigging frequency
  - Assess the impact of wax on oil viscosity
  - Estimate the pressure drop along the pipeline

Thomas

$$\frac{\mu}{\mu_0} = 1 + 2.5\,\alpha_{wax} + C\alpha_{wax}^2 + A(\exp(B\alpha_{wax}) - 1)$$

Pedersen

$$\frac{\mu}{\mu_0} = \exp(18.12D\alpha_{wax}) + \frac{405.1E\alpha_{wax}}{\sqrt{\frac{du}{dy}}} + \frac{7.88\ 10^6 F\alpha_{wax}^4}{\frac{du}{dy}}$$

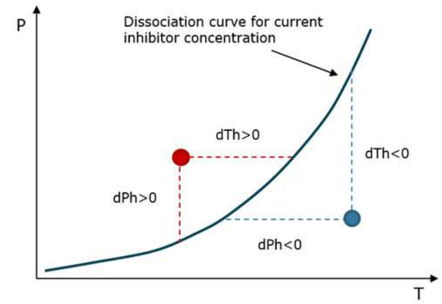
Suspension of Fractal Aggregates (SoFA)

$$\frac{\mu}{\mu_0} = \frac{1 - A\alpha_{wax}\tau^{-X}}{(1 - \frac{A\alpha_{wax}\tau^{-X}}{\alpha_{wax,max}})^2}\ , with\ \tau_0 = \left(\frac{A\alpha_{wax}}{\alpha_{wax,\,max}}\right)^{1/X}$$

Hydrate transportation model

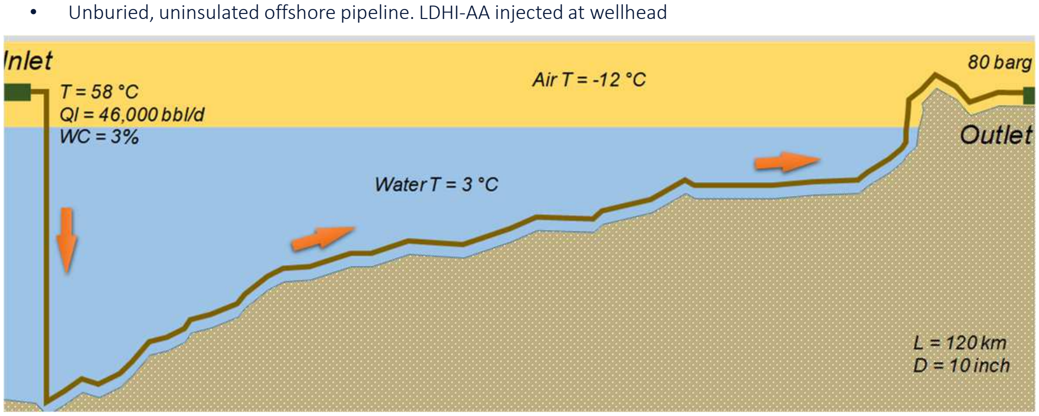
- General Concepts:
  - Potential for pipeline blockage
  - May form under favorable P and T conditions
  - There must be water and light hydrocarbons and/or CO_2/H_2S
  - Traditional approach is to avoid the hydrate formation region
- The hydrate transport module:
  - Developed by SINTEF based on a kinetic expression
  - Predicts hydrate formation and particle transportation in oil and/or water phases
  - Main assumptions:
    - Hydrate agglomeration is accounted by the liquid viscosity models
    - Hydrate particles do not stick to the wall

$$1 \text{ hydrate former} + \gamma \text{ water} \rightleftarrows (\gamma+1) \text{ hydrate} \qquad \text{[mole]}$$



Study Case

- Case data:
  - Unburied, uninsulated offshore pipeline. LDHI-AA injected at wellhead



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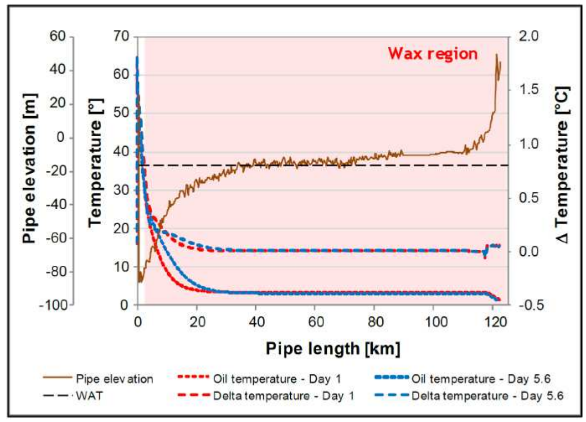
Study Case

Wax Deposition

- Objectives:
  - Determine the wax deposition rate and the wax layer thickness to estimate pigging frequency
  - Determine the oil viscosity
  - Estimate the pressure drop along the pipeline
- Wax deposition simulation inputs:
  - Heat of reaction
  - Wax precipitation curve
  - Viscosity slurry model
    - Newtonian fluid, Thomas model
    - Non-Newtonian fluid, Pedersen or SoFA



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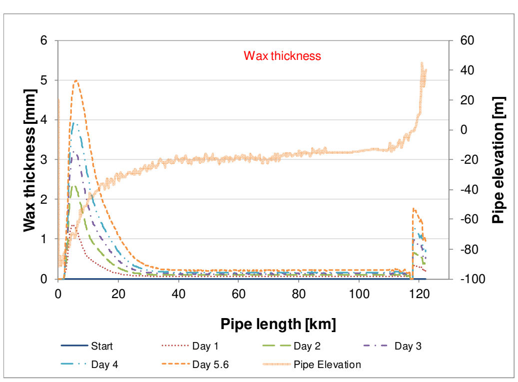
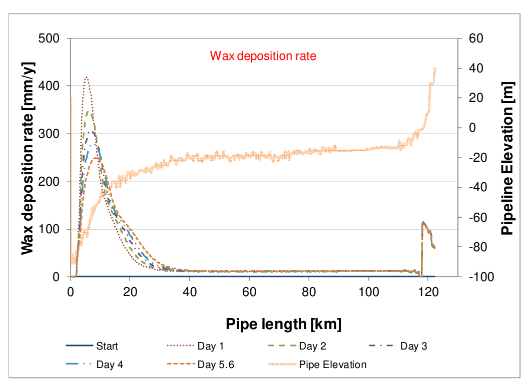
Wax Deposition

Results





- *Maximum allowed thickness, 5 mm, reached at 5.9 km after 5.6 days*

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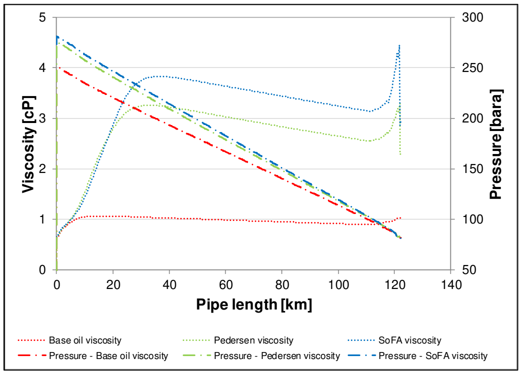
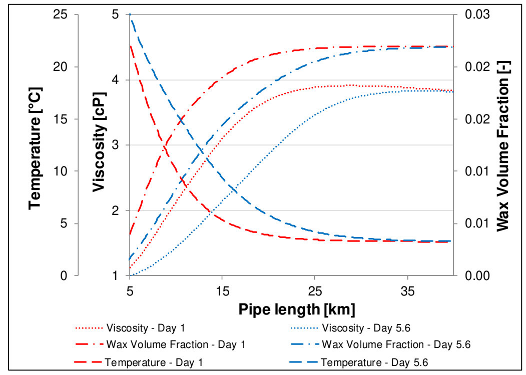
Wax Deposition

Results



Viscosity and pressure after 5.6 days



SoFA model at 1 and 5.6 days

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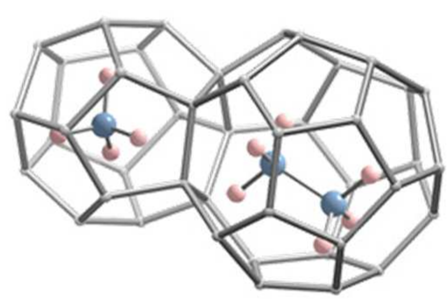
Study Case

Hydrate Transportation

- Objectives:
  - Determine the oil viscosity along the pipeline
  - Determine the effect on pipeline pressure drop
- Hydrate transportation simulation inputs:
  - Hydrate curve
  - Hydrate former phase
  - Minimum velocity
  - Stoichiometric coefficient
  - Sauter mean diameter of hydrate particles
  - Viscosity slurry model:
    - Non-Newtonian fluid, SoFA



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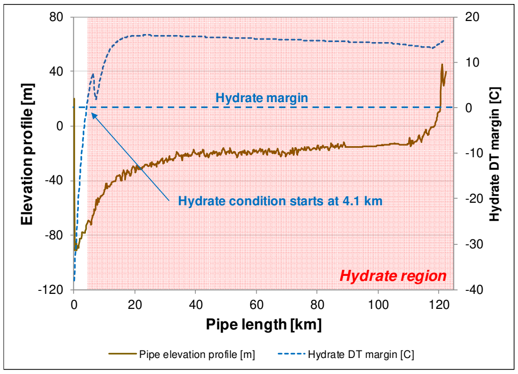
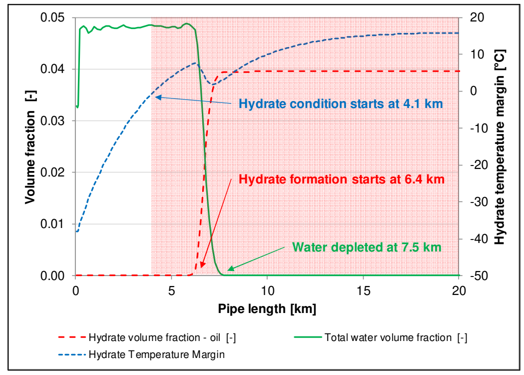
Hydrate Transportation

Results





Hydrate margin

Hydrate and water fractions

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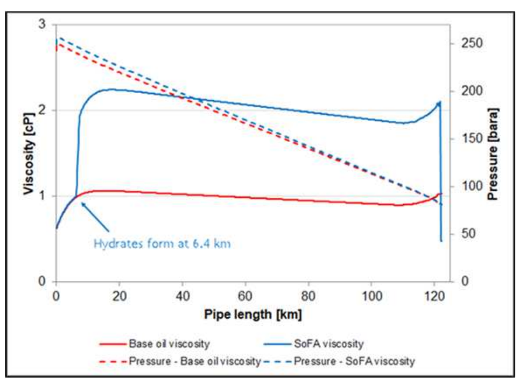
Hydrate Transportation

Results



Viscosity and pressure comparison

Conclusions

- New modules for wax deposition and hydrate transport demonstrated their robustness to simulate more realistic conditions in offshore pipelines
- These modules allow the user to input information from lab analysis, or use the default inputs for early design work
- Simulation results allow a deeper understanding of the wax deposition and hydrate transport process; help to improve the design and operation of long subsea pipelines
- Implementation of the presented wax deposition and hydrate transport models in a dynamic multiphase flow framework like LedaFlow allows practical application and analysis valuable for field design

Thank you

Acknowledgements

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Questions?

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