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FloWax: Wax Deposition Modelling

Wax deposition in pipeline is normally the result of a temperature drop. As the temperature drops below the WAT (Wax Appearance Temperature), waxes may precipitate from the fluid as a separate solid phase. However, for waxes to form a deposit in the pipeline, the appearance of a wax phase may not be sufficient. Wax will deposit along the pipeline, and subsequently may present a problem to flow assurance and production, if the flow conditions allow for such a deposit to form.

The prediction of wax deposition in the pipeline results from a combination of two main factors:

- Thermodynamic wax precipitation model
- Fluid flow model, with wax deposition mechanism in pipeline

FloWax™ is a powerful modelling tool to estimate the deposition of waxes along pipe branches for multi- or single-phase flows in flow assurance and production applications. Based on the thermo-hydraulics modelling capabilities of Maximus™ and the accurate wax thermodynamics modelling capabilities of Multiflash™, FloWax provides Flow Assurance and Production Engineers with:-

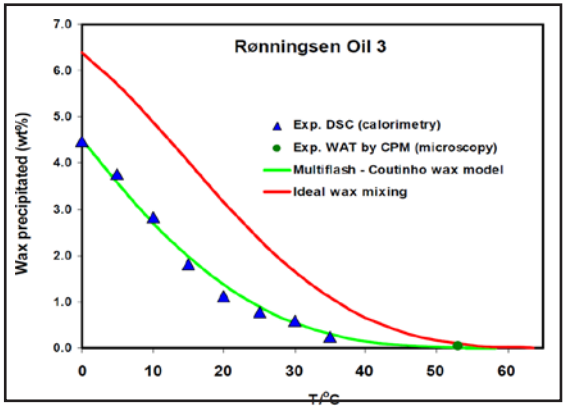
- Accurate estimates of wax deposition location, thickness and volume along the pipeline
- Pressure and temperature of the bulk fluid
- Physical properties (density, speed, molecular weight, viscosity, holdup) of the gas, hydrocarbon liquid and aqueous phase
- Velocity profile evolution and pigging frequency

In addition to the wide range of native flow correlations, FloWax has the possibility to also use advanced and standard models such as OLGAS® (by Schlumberger) and LedaPM® (by Kongsberg).

Thermodynamic model

The thermodynamic wax model is the Coutinho solid solution model as implemented in Multiflash. The model is used to derive reliable values of the thermodynamic driving force in the wax deposition model. FloWax describes the wax with a distribution of n-paraffins of differing molecular weights. The rigorous modelling of non-ideal interactions between waxes results in a more realistic prediction of the amount of wax phase precipitating from the fluid.

The retention of a sufficiently detailed representation of the fluid results, whilst not affecting the overall pipeline simulation, will provide a more accurate prediction of the wax deposit.



Shear removal

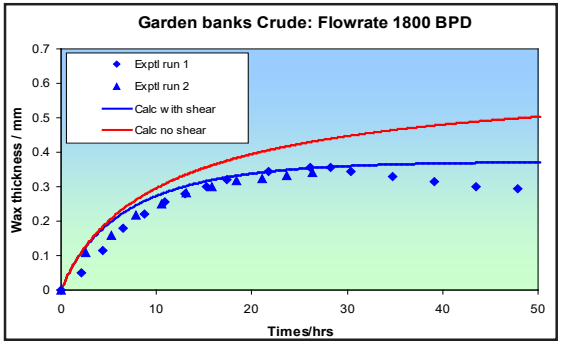
In highly turbulent flow, the observed deposition rate decreases with increased flow as wax is mechanically sheared off the deposits on the pipeline walls. FloWax includes a shear removal term that gives the correct trend.

Fluid Flow

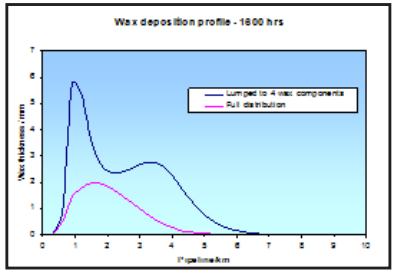
The multiphase fluid flow model can be selected from an extensive list of standard flow correlations as well as the option of using advanced correlations such as OLGAS® (by Schlumberger) and LedaPM® (by Kongsberg). This defines the flow patterns and calculates all the hydrodynamic parameters. All of the physical properties of the fluid are determined by Multiflash.

Heat and mass transfer

FloWax is based upon the rigorous heat and mass transfer model of Maximus coupled with the multiphase thermodynamic model. Adjustments can be made to standard correlations to match observations for a particular oil or to import flow profile data from experimental or simulated data.



Fluid properties



The fluid is characterised either loaded directly through the use of a Multiflash model file or using the built-in PVT (Pressure, Volume, Temperature) dialogue powered by Multiflash. This also allows for matching of fluid properties such as bubble or dew point, volume, viscosity and WAT.

Pipeline description

The pipeline dialogues allow the user to describe the pipeline topography in terms of sections of horizontal distance and elevation with corresponding ambient temperature, internal diameter, wall thickness, roughness and heat transfer definitions. The thermal conductivity of the pipeline wall can be specified as an overall heat transfer coefficient or defined by layers of material with thicknesses and corresponding thermal conductivity values.

Properties of deposited wax

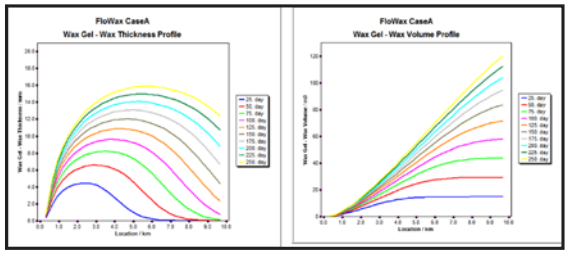
FloWax allows the user to modify certain properties of the deposited wax layer. In practice, this layer is not made up solely of wax crystals but is a gel of wax crystals and trapped oil. The amount of oil trapped in the wax layer, often known as the porosity, can be adjusted. Similarly there are adjustment factors for the gel strength, which affects the shear removal, the thermal conductivity of the wax layer and the contribution of the deposited layer to the roughness of the pipeline wall. The viscosity of the oil phase will be modified by the appearance of entrained wax crystals which do not deposit. This effect can be reproduced by use of a multiplying factor or by matching to measured values.

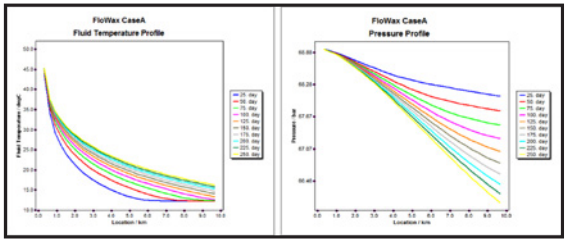
Sensitivity studies

The user specifies inlet or outlet pressure and flowrates and inlet temperature, as well as the simulation time and time step. Sensitivity studies can also be set up to run a sequence of variants of the original case, with modified pipeline, inlet/outlet parameters, or wax deposit properties.

Results

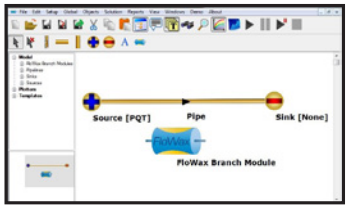
The simulation results displayed within the FloWax solution are in tabular and graphical form as functions of time and position. Properties reported include the thickness of the wax layer, the amount of trapped oil, the fluid temperature and pressure, the inside wall temperature and the amount of each phase present. Results may be exported to Microsoft Excel.





Pigging

FloWax will calculate the pigging frequency required to meet various criteria such as maximum wax thickness, wax volume or pressure drop.



References

Our thermodynamic and deposition models are described in the following publications:
Energy & Fuels, vol. 22, 729-741 (2008)
Energy & Fuels, vol. 20, 1081-1088 (2006)

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