

INFOCHEM

COMPUTER SERVICES LTD



Wax Deposition

Introduction

There are two types of wax model: thermodynamic and deposition. Thermodynamic models predict the WAT and amount of wax that comes out of solution. As the temperature cools below the WAT, thermodynamic models predict that increasing amounts of wax will precipitate. Deposition models predict whether the precipitated wax will deposit on a surface, such as a pipeline wall, and common outputs are the location and rate of wax build up. Deposition models can also be used to assess prevention and remediation strategies, such as insulation effectiveness and pigging frequency.

The FloWax software developed by Infochem has five main features:

- Thermodynamic wax model
- Compositional wax model
- Heat and mass transfer
- Shear removal
- Fluid flow model

that allow the user to model wax deposition in pipelines.

The software handles both single phase and multiphase flow. The phases present are determined by the fluid composition and the operating conditions. The fluid phases considered are hydrocarbon gas and liquid and water.

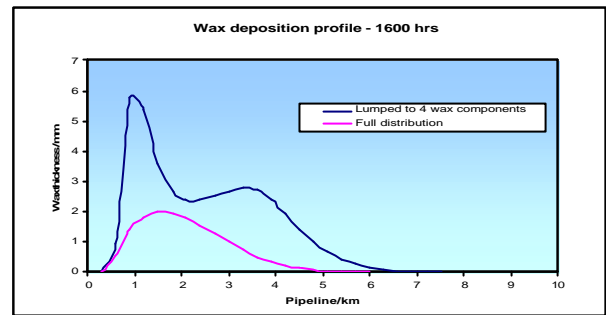
Thermodynamic model

The thermodynamic model is Coutinho's solid solution model. The advantages of the model are:

- It is based on high quality thermodynamic data for wax and oil phases. It has been validated against data for a wide variety of crude oils, diesel and jet fuels.
- It uses the measured n-paraffin distribution when available but has estimation methods if it is not.
- It is designed to predict not only the WAT but also the amount of wax precipitated as a function of temperature.
- It is predictive.

The Coutinho model is used to derive reliable values of the thermodynamic driving force in the wax deposition model. FloWax describes the wax with a group of pseudocomponents of differing molecular weights (as is needed to model the thermodynamic properties). The resulting deposition profiles

are different from and more physically realistic than if a lumped composition is used.

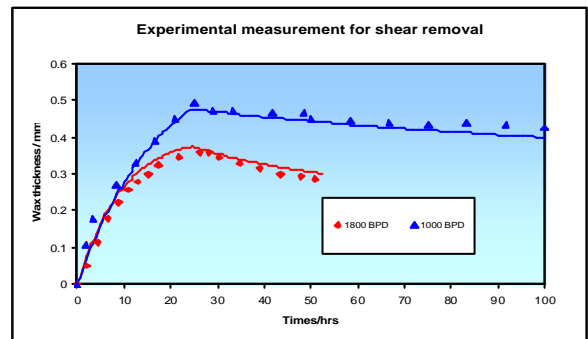


Heat and mass transfer

The Nusselt and Sherwood numbers are used to describe the heat and mass transfer. Adjustments can be made to these numbers to match observations for a particular oil. In FloWax the dominant mechanism in the wax deposition is molecular diffusion. The effects of shear dispersion rate, Brownian diffusion and gravity settling are not considered.

Shear removal

At high rates of 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.

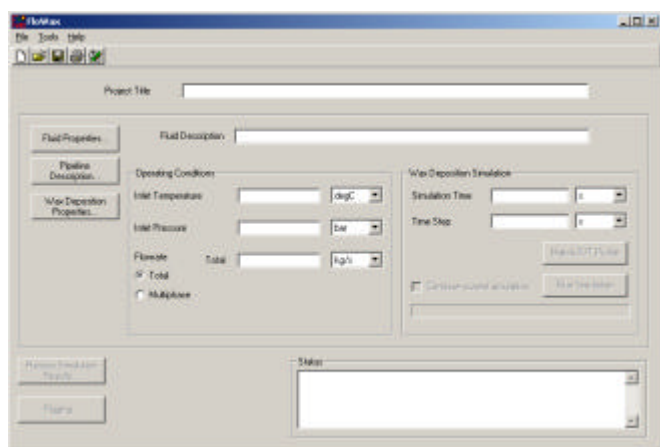


Fluid Flow

The multiphase fluid flow model is based on the Beggs and Brill method, which defines the flow patterns and calculates all the hydrodynamic parameters; all the physical properties of the fluid are determined by Multiflash.

FloWax

The FloWax software is a Windows program to calculate pressure drop and the thickness of the wax layer as a function of pipeline location and time.



The input comprises:

Fluid properties

The fluid is characterised using the Multiflash PVT Analysis which also allows for matching of fluid properties such as bubble or dew point, volume, viscosity and wax appearance temperature. The Multiflash GUI is launched automatically.

Pipeline description

This allows the user to describe the pipeline topography in terms of length, sections and inclination as well as internal diameter, thickness and roughness. The thermal conductivity of the pipeline material is specified as is the overall heat transfer coefficient which effectively allows for pipeline insulation and the temperature of the external environment.

Wax deposition properties

This section 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—the effect of this can be reproduced by use of a multiplying factor or by matching to measured values.

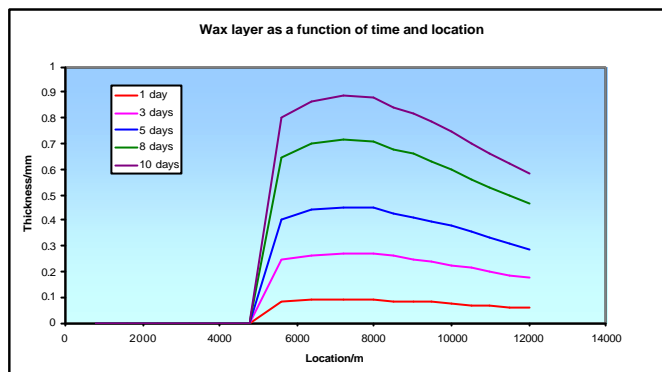
Operational properties

The user specifies inlet temperature, pressure and flowrate as well as the simulation time and time step.

Results

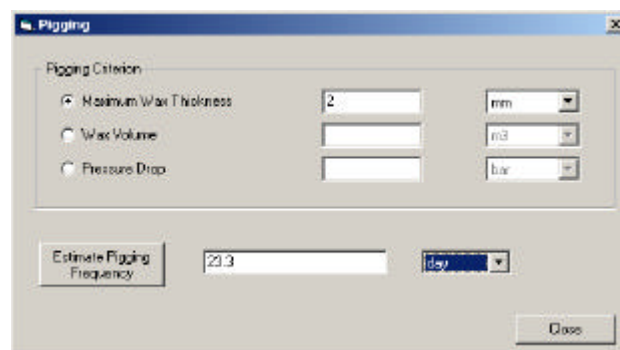
The results of the simulation can be displayed as a table or used to determine pigging frequency according to set criteria. The table provides, for each segment and time step, properties of the pipeline, wax layer and fluid phases present. For the pipeline the data are the temperature, pressure and inside wall temperature. For the wax the thickness, MW and % trapped oil and for the oil, gas and aqueous phases the speed, hold-up, density, viscosity and molecular weight are reported.

The tabular data may be plotted within FloWax or written to Excel and plotted.



Pigging

The pigging criteria may be set in terms of maximum wax thickness, wax volume or pressure drop. FloWax will then calculate the pigging frequency required to meet the criteria.



Matching P,T profiles

FloWax calculates the P,T profile along the pipeline but provision has also been made for matching pipeline P,T profiles generated by third party applications.

Possibilities for future developments include automatic matching of laboratory measurements, e.g. flow loop data, and additional output such as phase compositions at specified locations, but developments will be user driven. The software will also be tested for waxy gas condensates.

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