

The FluidFlow3 Slurry Module is divided into two parts: **non-Newtonian/non-settling liquids** and **settling slurries**.

Non-Newtonian/non-settling liquids can be simulated using four different correlations, viz:

- Bingham plastic
- Power law
- Herschel-Bulkley
- Casson

Settling slurries can be simulated using one of three different simulations:

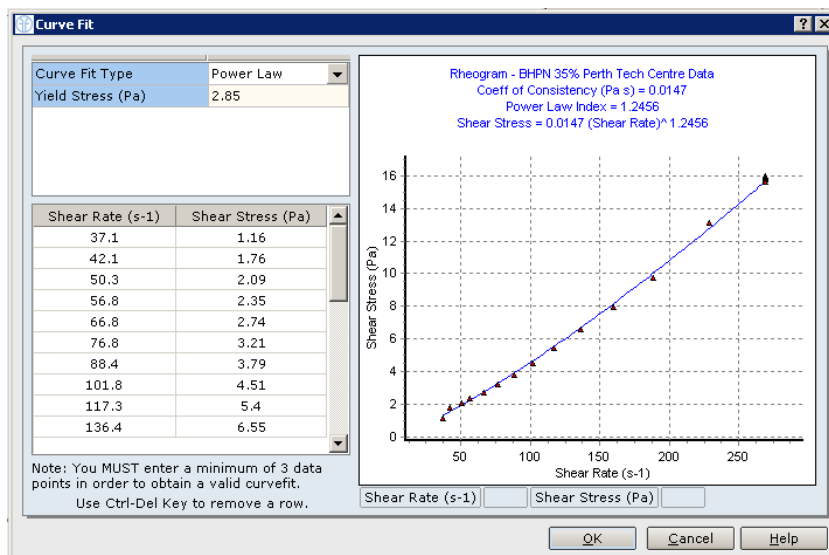
- Durand
- WASP
- Wilson-Addie-Selgren-Clift

Non-Newtonian/non-settling Liquids

Liquid properties are entered into the database by one of two methods...

- Equation coefficients (depending on selected correlation), for example yield stress and coefficient of rigidity.
- Direct entry of shear stress versus shear rate test data – with the user selecting the correlation or curve fit to the data from the four options described above.

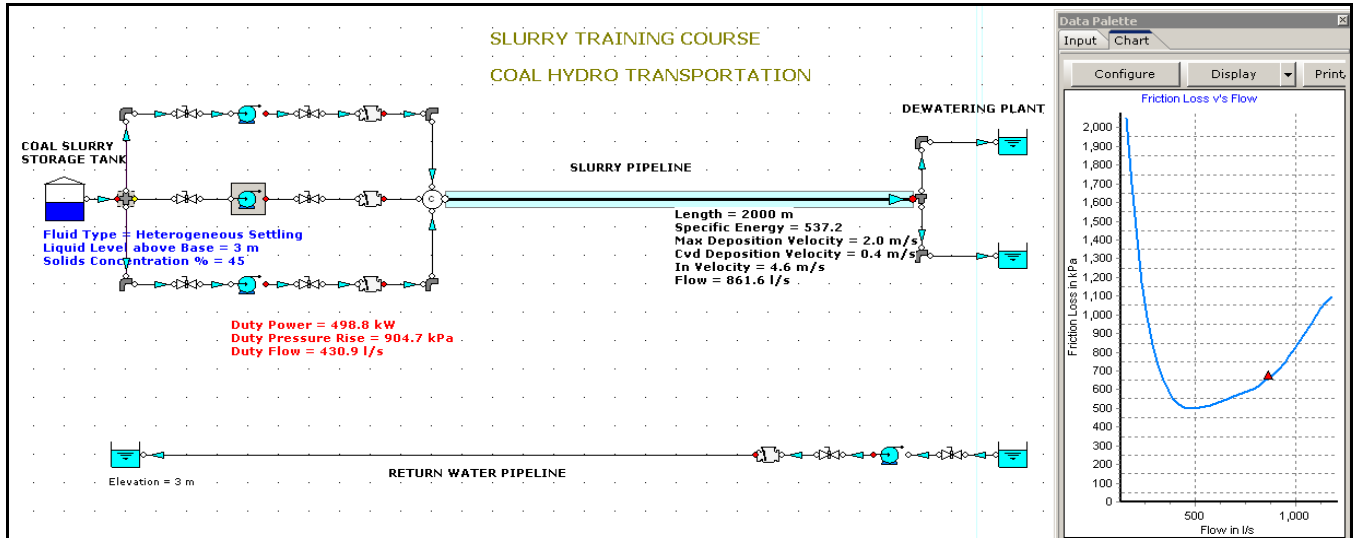
The Input Inspector is then used to define the liquid at the network boundary of the model and the apparent viscosity is then determined for each pipe in the system depending on the calculated shear rate.



Data entry – Non-Newtonian/non-settling test data.

Settling Slurries

An additional database is provided for bulk solids properties. The Input Inspector is used to select the carrier fluid from the fluids database and to define the % solids content and particle size characteristics. The pipe pressure drop is then calculated based on the selected correlation. Pump performance can be modified due to solids content. Settling velocity is calculated.



Settling slurry calculation showing friction loss versus flowrate for main pipeline

Bayer Liquors

The flow of fluids within the alumina process can be simulated with FluidFlow3. Friction loss of Newtonian fluids such as water, steam and sodium hydroxide solution are calculated using the normal Darcy equation/Moody diagram method. (The compressible flow calculation is particularly sophisticated taking into account the expansion of the gas and associated temperature and physical property changes. Sonic conditions are also handled. For predicting all physical properties of water FluidFlow3 uses the IFC-97 formulations developed by the International Association for the Properties of Water and Steam).

FluidFlow3's heat transfer capabilities would be useful here, say for calculating heat change across heat exchangers.

Pure Bayer liquors – green/pregnant liquor or spent liquor – are also Newtonian fluids but with varying physical properties depending on their make-up, for instance, total alkali content etc. The viscosity, density, vapour pressure and thermal properties would have to be determined separately, but once this was done, the values can be entered into the FluidFlow3 fluids database for use in a model.

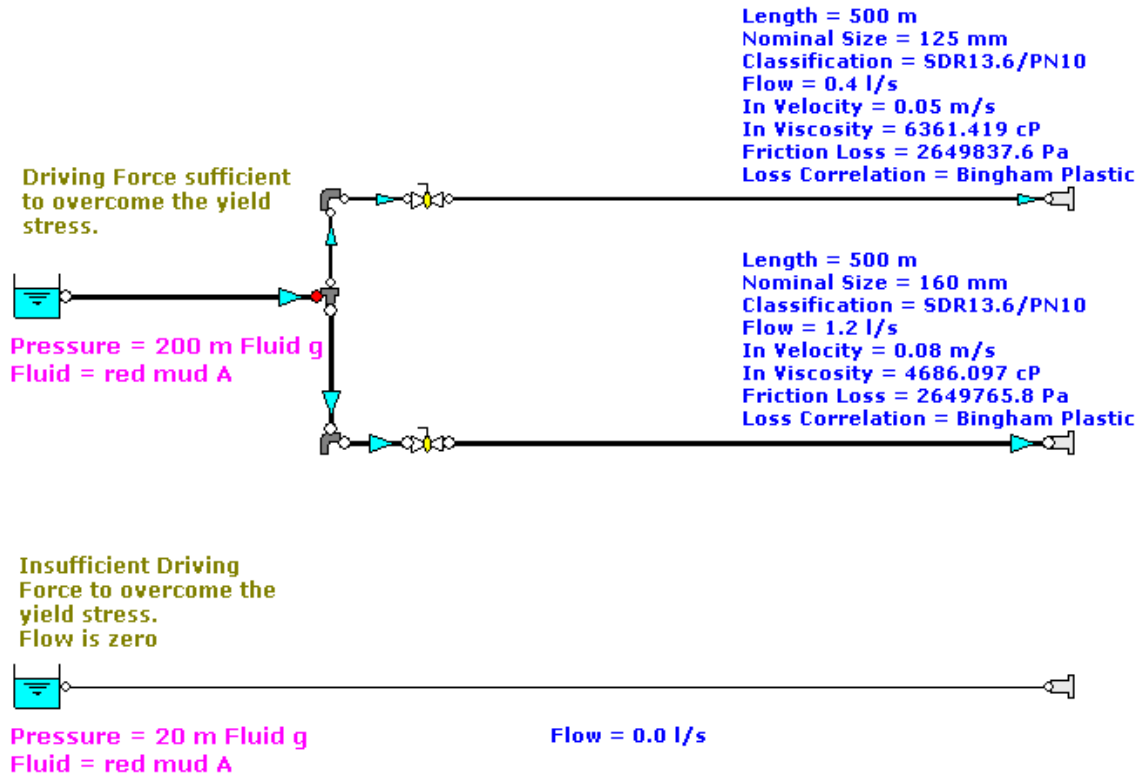
These fluids can also be used as the carrier fluids for suspensions in the Bayer process, say when the hydrates are precipitated. These would be regarded as settling slurries and simulated as described above, using an appropriate correlation such as Wilson-Addie-Selgren-Clift.

At the very end of the Bayer process we are dealing with a non-Newtonian/non-settling slurry, the “red mud”. The image below shows this type of fluid simulated as a Bingham plastic. In the upper image the pipes are of different diameter. Consequently the shear rate is different and therefore the calculated apparent viscosity is different for each pipe.

The example also illustrates the concept of yield stress – in the lower pipe the driving force is insufficient to overcome the yield stress of the fluid and so no flow takes place.

The properties of the red mud were entered into the fluids database, where its correlation was specified as a Bingham plastic.

PIPE FLOW OF RED MUD MODELLED AS A BINGHAM PLASTIC



Slurry flow design methods are highly empirical. *“Slurry Transport Using Centrifugal Pumps”*, by KC Wilson, GR Addie, A Sellgren and R Clift provides the best reference for settling slurries, with a synthesis of the authors’ many papers. *“Introduction to Practical Fluid Flow”* by RP King provides a useful summary of the Wilson-Addie-Sellgren-Clift method plus a comprehensive chapter on non-Newtonian slurries. *“Chemical Engineering Fluid Mechanics”*, by Ron Darby provides a very useful introduction to all types of flow.

These three references provided the basis for the FluidFlow3 Slurry module.

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