SWORD – Fast Reservoir and IOR evaluation

Sword is a unique software package for rapid reservoir and prospect evaluations. The potential of key Improved Oil Recovery (IOR) methods can be quickly evaluated by help of various implemented techniques which are based on multi-criterion models, proven analytical solutions, the existing industry experience and expert knowledge in IOR applications. The tool has been developed in close co-operation between research and the oil industry supported by Norwegian SPOR and RUTH programs.

Sword helps reservoir engineers in planning reservoir exploitation strategy and making decisions on IOR applications. It is especially useful when quick evaluations are needed and in situations with limited available reservoir information and large uncertainties in reservoir description, as often the case at initial evaluation stages. The tool is also helpful for training of young reservoir engineers and students of the petroleum science.

Sword modules

Applicability screening allows for a fast first-order screening (ranking) of the applicability of key IOR methods like waterflooding, gas, thermal and chemical injection at specific reservoir conditions. The applicability assessment is based on applicability ranges for critical reservoir parameters, using a multi-criterion model. The underlaying expert system is based on the existing industry experience and expert knowledge in IOR applications. The tool is user-friendly and available in the standard or in the advanced dynamic mode, which offers full flexibility in modifying the underlaying expert system.

Recovery factor estimation is a tool for rapid assessment of suitability of main IOR methods at given conditions. It allows to determine the likelihood of deployment success of a given injection method. Results can be ranked by the estimated recovery factor. The module presents statistical data from projects carried out world wide.

Performance prediction is a unique "pre-simulation" tool for rapid quantitative predictions. It allows a convenient evaluation and comparison of the potential of recovery methods such as Depletion, Waterflooding, Polymer, Surfactant and Polymer/Surfactant flooding, Immiscible and Miscible Gas (CO2, N2, HC) flooding, Steamflooding and Water Alternative Gas (WAG) injection. Displacement results are available for stratified reservoirs in 2D cross-section and an approximate 3D geometry (5-spot pattern). Predictions are based on proven analytical solutions, f.e. Dykstra-Parsons method and a vertical equilibrium approximation (gravity-dominated). A wide range of reservoir parameters and computed results enables the user to perform a rapid but comprehensive reservoir analysis as well as sensitivity studies. A unique feature is its capability to handle a series of cases in only one single run. In addition, a Production decline curve is integrated for the prediction of expected production rates.

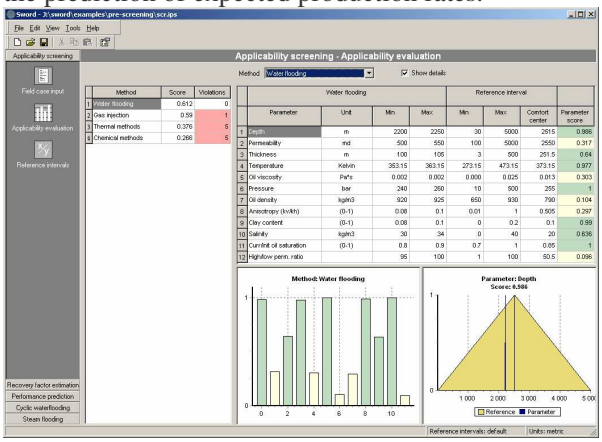

Figure 1. Applicability screening is useful in situations with limited available reservoir information, e.g. at early-stage field planning.

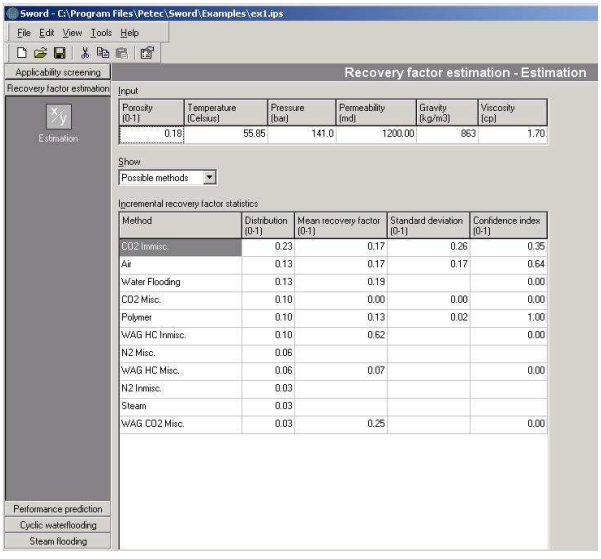

Figure 2. Recovery factor estimation presents statistical data from projects carried out world-wide to simplify the task of determining the likelihood of success of deployment of a given method.

Cyclic waterflooding is a module for fast evaluation of the effect of cyclic injection on the efficiency of water flooding in layered reservoirs. The effect of pulsing injection is evaluated by introducing a correction to the original Dykstra-Parsons model to take into account the fluid exchange (cross-flow) between the layers in the reservoir. This is neglected in the original Dykstra-Parsons model. The cross-flow includes physical mechanisms of gravity, capillary forces and the compressibility-related effects of the pulsing injection conditions.

Steam flooding is a module based on the Jones model allowing to account for three main stages of the steam flooding process: reservoir heat-up, oil recovery and tail production. The steam flooding module is based on the proven performance prediction module. The results of the module are verified over a leading thermal reservoir simulator

WAG module allows to estimate increased oil recovery as a result of immiscible 3-phase flow in the layered reservoir. The module is using Stone II 3-phase model and estimates residual oil saturation for the reservoir in general and for each individual layer based on user specified two phase relative permeabilities and WAG injection schedule.

Software features

- Modern user-friendly interface;
- Flexible unit conversion system including default systems (e.g., SI, metric, field, lab);
- Context-sensitive help;
- Extensive graphic output;
- Advanced reporting functionality for input and output documentation for all modules;
- Easy interaction with other windows applications;
- Copy/paste function to export results to reports and presentations;
- Full plot configuration and print preview;
- Export charts to most common formats.

Applications

- Planning of reservoir exploitation strategy and help in making decisions for the application of IOR methods;
- First-order IOR screening and simulations;
- Rapid reservoir evaluation and sensitivity studies;
- In situations with limited available reservoir information or uncertainty in reservoir description, e.g., at initial evaluation stage.
- Often used prior or while using numerical simulators to avoid high costs for modelling/simulation;

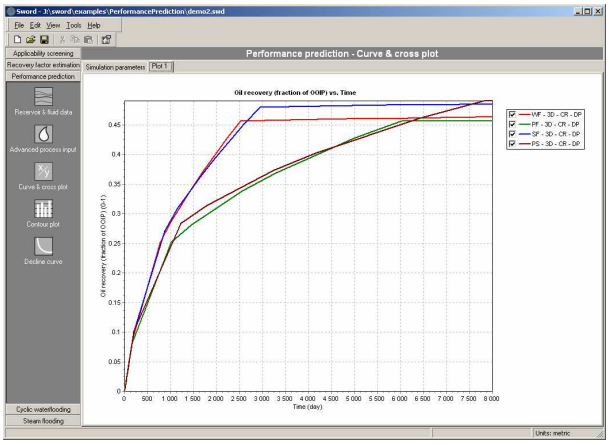

Figure 3. Performance prediction computes a wide range of results and is perfect to quickly compare the potential of different IOR methods. Use it also for sensitivity studies.

Technical features

Applicability screening module:

- Multi-criterion model using interval approach and distribution functions for input;
- Expert system for fast and convenient evaluations of IOR applicability;
- Involves existing industry experience and expert knowledge in IOR applications.

Recovery factor estimation

- Processing kernel based on world-wide field case database;
- Multi-dimensional projections and machine learning algorithms.

Performance prediction module:

- Displacement results in 2D cross-section and approximated 3D (5-spot) geometry;
- Based on proven analytical solutions, e.g.
  - Dykstra-Parsons (no cross-flow estimation),
  - Vertical equilibrium approximation (max. cross-flow estimation, gravity dominated);
- Production decline curves (based on exponential or hyperbolic decline);
- Critical rates for viscous channeling and gravity tonguing.

Software development sponsors

The development was sponsored by ConocoPhillips (before Conoco), PDVSA, OMV, StatoilHydro (before Statoil) and Total (before Elf), BG, GdF.

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