COMPUTER MODELLING GROUP LTD.

What's New in IMEX

IMEX

Black Oil & Unconventional Simulator

Version 2021.10

cmgl.ca

#FutureOfSimulation

Simulator Changes

IMEX + Python

*OUTBOARD provides a generic data passing interface for any outboard (third-party) software to update IMEX's recurrent data. A standardized Python class (***ob_cmg.py***) is formulated illustrating the basic data exchange protocol between the Outboard and the simulator. The new well management template, *mxwwm087.dat*, is paired with an exemplary Python script (***ob_cmg_test.py*** which imports ***ob_cmg.py***) in order for a desired well control. The user is encouraged to implement one's own recurrent control workflows using Python script as an alternative to complex TRIGGERs. Please find the Python scripts at the release directory \CMG\IMEX\2021.10\TPL\, and refer to the manual page of *OUTBOARD *OUTLIST for output information available from IMEX.

Reformulation of Salt Modelling

The original seawater injection option has been reformulated into a more general salt modelling. The injection aqueous salt concentration can be specified by *SEAWATCON in conjunction with the relative salt concentration of each water injector using *INCOMP (or *INCOMPWL). The initial formation salt distribution can be specified using the region-dependent *RESWATCON or the new block-based array assignment *SALTCONC. Each aquifer may have a different influx salt concentration using the newly introduced keyword *AQSALT. The new formulation is backward compatible in the sense of maintaining the phase fluid behavior. However, the previous keyword *SEAWATFRC (initial seawater volume fraction) is obsolete and is replaced by *SALTCONC.

The Scale Buildup/Well Damage model allows scale buildup and well damage to be a function of the relative salt concentration with respect to the reference taken as the maximum concentration of all three sources (injection, reservoir brine and/or aquifers).

Brine injection recycling is also available under the group control. The relative salt concentrations of water injectors, when setting to a negative value by the user, will be dynamically calculated by averaging the total salt and water produced under the same group. *Please refer to the revised manual pages for keywords *INCOMP and *INCOMPWL.*

Rock Modelling with Mean Total Stress (Formal Release)

The conventional full geomechanics model is computationally expensive in field applications although it is necessary to determine accurately the mechanical behavior of reservoir for anisotropic and poroplastic situations. Alternatively, a simplified model for reservoirs with isotropic linear elastic behavior has been formulated in IMEX, in which all geomechanics stress/strain equations are consolidated into a single equation with mean total stress as the primary variable. It is solved with fluid flow equations under proper definition of the boundary conditions. The obtained mean total stress for grid blocks is then used to modify porosity and permeability applying the rock-compaction infrastructure that is already available in IMEX. *Please refer to new manual pages *CROCKTABS, *MTS-ELASTMOD et al. and the new templates mxsmo092, 093 and 095.dat.*

Continual *AUTOTUNE Improvement

The following elements have been included in *AUTOTUNE which improves IMEX overall numerical performance noticeably:

Internal pressure norm adjustment;

Automated 1D - 2D solver partitioning fitting;

Dynamic solver convergence control on material balance;

Automatic combinative switch based on logical workloads.

New Imbibition Capillary Pressure Scaling Options

In addition to the existing full-range saturation scaling method for reading the boundary imbibition curve in capillary pressure hysteresis, two new methods are implemented for the oil-water and liquid-gas imbibition capillary pressure, respectively. The new options provide great flexibility in controlling the curvature of formed scanning curves.

*Please refer to the manual pages of keywords *PCOWI_SCALE and *PCOGI_SCALE for technical details, and the new template mxsmo094.dat.*

Enhanced Tracer Functionality

A negative value of -1.0 can now be specified to any type of tracers so as to direct the simulator to internally assign the tracer concentration equal to the in-situ reference phase density. By doing so, the reported vapor or liquid tracer volume correlates to the produced volume of the tagged phase, leading to a direct derivation of well allocations.

Global Backward Compatibility

This option (*BACKTO) was newly designed to retain collectively the previous physical results from IMEX simulations, wherever it is feasible, from noticeable deviations due to major bug fixes, default changes, or evolution of reservoir simulation theories and practices. The restoration does not include the numerical drifts attributed to the enhancement of numerical algorithms or compiler updates. The equivalent command-line option is '*-backto*'.

Supporting Zero-Porosity Blocks

IMEX now fully supports zero-porosity blocks in the coupled GEOMECH or Mean Total Stress modelling. No need to assign small artificial porosities to those blocks as recommended in previous releases.

New RPT Sets Interpolant

A new relative permeability table set interpolant, *WFLXMULT, has been implemented under the keyword *INTCOMP to allow the rock-fluid properties be function of the ratio of the cumulative water flux to block pore volume. *Please refer to the revised manual page of *INTCOMP and the new template mxspr027.dat.*

Minimum Wellbore Pressure

A new wellbore control keyword, *PWELMIN, has been introduced to regulate the wellbore pressure so that it will not drop below a user-given threshold pressure. *Please refer to the new template mxwwm086.dat.*

Half-Life Time for Polymer Degradation

The half-life time for polymer degradation can now be specified directly (*POLY-DEGR-HL) as an alternative to the specification of reaction order and frequency factor (*POLY-DEGR). Please refer to the manual page of *POLY-DEGR-HL for the correlation between these two input methods.

Improvement for Overburden Pressure

Improvement for overburden pressure in compaction-dilation modelling by allowing *COVB-STRESS without the accompanying overburden table (*COVBTAB). This feature is equivalent to the *DEPLETION option but in the effective overburden pressure input sequence (opposite to the effective fluid pressure input sequence).

Also, keyword *REFCUR, used to update the reference values at the time when compaction-dilation models are switched, is now made *CROCKTYPE based. In order for backward compatibility, If *REFCURR is specified for the first rock type, it will be applied to all rock types, otherwise, it will be only applied to subsequent rock types that have the keyword explicitly specified.

Default PVT Extrapolation at 1 ATM

The internal extrapolation scheme for PVT tables toward 1 ATM (if user did not provide the entries) has been revised to satisfy the compressibility checking.

*OUTSRF *SPECIAL *MBERROR

Added special histories for material balance errors of valid phases.

*AIMSET in Planer Fracture Templates

Allow setting implicit *FZ blocks within *PLNRFRAC_TEMPLATE.

Solver Changes

Automatic Combinative Preconditioning

The switch between the two combinative two-stage preconditioners (ILU and AMG) has been made automatic by dynamically comparing the average solver iterations and projected workload from each preconditioner. Embedded in the improved *AUTOTUNE already, this feature can also be activated by command-line switch *"-combinative auto'.* Note that *"-combinative ilu_auto*" and *"-combinative amg_auto*" are also available since the previous release.

1D Partitioning along Forced Direction

The PARASOL class partitioning along a selected/forced direction can be specified using the keyword *PPATTERN *AUTOP2D (*I / *J / *K) *n* or its equivalent command-line option "-autop2d (i/j/k)*n*", without having to indicate the second direction which has only 1 slot. Also note that command-line "-autop2d" triggers the command-line "-parasol" automatically in IMEX.

Geomechanics Changes

Water Weakening

The water saturation is used in the geomechanics to change rock properties such as Young's modulus, cohesion etc. A lookup table is used for each rock type to obtain new values of properties at every time step. *Please refer to the new template mxgmc101.dat.*

Besides the water saturation, oil saturation and gas saturation can also be used to change the rock properties. The water saturation can make the rock weaker; therefore, rock properties can be changed with time according to the amount of water contained in it. The change of rock properties will also lead to effects of its stresses and deformation.

Enhanced Non-linear Elastic 2

The nonlinear elastic constitutive model was modified to handle discontinuous loads. With the existing explicit method, rock properties related to the constitutive model were updated at the end of each time step. This approach should not cause much deficiency for continuous loads, but might lead to an incorrect result when the load is discontinuous (such as external loads). To remedy this situation, an implicit method has been implemented where the rock properties are updated instantly when a load is applied.

Modified Cam Clay Model

The Cam Clay (MCC) model has been revised to solve the Mandel-Cryer phenomenon for an undrained problem. Keyword *MICSIM has been introduced for backward compatibility. *Please refer to the new template mxgmc100.dat.*

Grid Changes

Wildcard for Block Group Names

*BLOCKGROUP or *SBLOCKGROUP names can now be referenced with the wildcards '*' and '?' in the similar fashion as the wildcards used for well names, where '*' replaces any number of characters at the end of a block group name or can be used on its own to represent all block groups. '?' replaces any single character anywhere in the block group names. Wildcarded name must appear in quotes.

HFs Pass through Inactive Blocks

The new keyword *HF_IN_NULL *ON enables hydraulic fractures pass through null / zero-porosity / zero-net gross blocks. Several properties can be specified for the fracture zone created in those blocks. See new sub-keywords *POR_NULL, *PERMI_NULL, *PERMJ_NULL, *PERMK_NULL, *NETGROSS_NULL in Planar Fracture Template.

Bi-directional Permeability Gradients

A set of new keywords in Planar Fracture Template allows the users to specify bi-directional permeability gradients. Keyword *KH_TYPE/*KV_TYPE *EXPONENTIAL | *LINEAR gives a decline option in the horizontal/vertical direction. Either a center-tip value (*K_CENT, *KH_TIP / *KV_TIP) or a center-rate value (*K_CENT, *KH_DECLINE / *KV_DECLINE) can be defined to produce a permeability gradient along the horizontal / vertical direction based on the decline type. Keyword *ELLIPTICAL_DISTRIBUTION *ON can transform the permeability gradient into an elliptical-shaped distribution. The old keyword *K1INT is now a subset of the new keywords and should not be present if the new keywords are used.

HFs in LGR Blocks

The origin of a planar hydraulic fracture (*PLNRFRAC / *PLNR_REFINE), previously must be a member of the fundamental grid, can now be assigned to a one-level LGR grid. In the latter scenario, the hydraulic fracture is restricted to be created within a referenced region where the fundamental blocks should be statically refined in the Reservoir Description section. The referenced region must be pre-defined with the refined blocks using a structured block group (*SBLOCKGROUP), and be associated to the fracture using the newly introduced sub-keyword *USE_SBG. *Please refer to the new template mxfrr030.dat.*

Mixed *MINC and *DUALPERM in Reservoirs

New sub-keywords (region specifier) *IJK/*ALL following *MINC and *DUALPERM are available now in IMEX for specifying regions with the desired grid types. Previously, only one of the natural fracture grid types can specified in the same model. This flexibility allows the user to use MINC (higher matrix resolution) in the area of interest and the rest with DUALPERM (relatively lower matrix resolution). Note that this option currently does not support combinations of other grid types. *Please refer to the new template mxfrr031.dat.*

Separate Matrix and Fracture Pinch Out

The pinch out array *PINCHOUTARRAY now supports the vertical pinch out of matrix and fracture blocks, separately. For the *DUALPOR and *DUALPERM natural fracture models, if none of the *MATRIX or *FRACTURE qualifier is specified, the *PINCHOUTARRAY will be applied to both matrix and fracture blocks, which had been the only available action in the earlier releases.

Pore Volume Cut-off for Refined Grids

New grid-section keywords, *PVCUTRG and *PVCUTRG-FR, control the threshold level at which a refined matrix or fracture cell's pore volume is small enough to be considered zero. Such a block will be systematically removed from the fluid flow simulation either through nulling or pinch out. Note that the corresponding keywords for fundamental blocks are *PVCUTOFF and *PVCUTFR, respectively.

Property Distribution Data input

New grid-section keyword, *PDD, allows direct import of hydraulic fracture property data from third party fracturing software (e.g. GOHFER), and meanwhile defines a conductivity distribution template. This property distribution template can be assigned through the new reading option *PDD_DATA after grid-array keywords (*PERMI etc.), in either the Reservoir Description section or Well and Recurrent Data section.

DFN by General Polygons

DFN input capability has been enhanced in order to process the discrete fracture networks generated in planar polygons with vertices less than 20, including tessellated (triangulated) surfaces.

Grid Offset, Orientation and Direction

*XOFFSET, *YOFFSET, *ROTATION, *AXES-DIRECTIONS can now be specified in grid building procedure. This is particularly useful when DFN or independent well data are read in with particular offset, orientation, and axes direction. The combination of the keywords can be used together to match reservoir grid to DFN or well trajectories.

Well Management Changes

Multilateral Well Trajectories

A new Well Management keyword, *WBRANCH, has been introduced to define the multi-lateral well trajectories using spatial coordinates and measured depths. The well main branch and subordinate branches can be conveniently relocated using keyword *WBSHIFT and *WBROTATE. Well perforations and associated index parameters can be specified in terms of the measured depth intervals (*PERF-MD) rather than the traditional block address. There is no need to redefine the perforations in case of a recurrent grid change since the well layers (i.e. intersections with grid blocks) will be automatically reconstructed based on the given well branches and measured depth intervals.

Any existing layer control option (e.g. *LAYER-CTRL and *KRPERF) takes the new syntax with the branch names and measured depth intervals.

Please refer to the relevant manual pages for syntax details and the new templates mxwwm088.dat and mxwwm089.dat.

New Hydraulic Table Lookup Methods

Two new table lookup methods (*PTUBE-FIXFRAC *NEWTON | *TIMESTEP) have been implemented to provide more flexible controls on handling the implicit WHP well constraint, especially when it is close to a lift failure. These options sometime are able to avoid the frequent lift failures by effectively lowering the enforced WHP from the specified values.

Hydraulic Table Generation

New keyword *PTUBE-GEN can be used to specify the controlling parameters in order to re-represent the applied wellbore pressure drop correlation (*PWELLBORE / *IWELLBORE *MODEL) or multiple linked pressure drop correlations or hydraulic tables in iSegWells (*WB-PDMETHOD) into a single tabular form in *PTUBE1 / *ITUBE1.

The generated hydraulic table will be written to a portable include file ("fname_ptube.inc") after the base data file name ("fname.dat").

Please refer to the new pair of templates mxsgw028.dat and mxsgw029.dat.

iSegWell Enhancements

New keyword *TE-EXTEND can be used to extend the end of an existing tubing string to avoid redefinition of the tubing string under new name as iSegWell requires unique name for each iSegWell entities in the entire data set.

New keyword *RELOCATE can be used to set new locations for iSegWell entities on tubing string and/or wellbores. This avoids redefining them under a new name.

Please refer to the new template mxsgw027.dat.