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What's New in STARS

STARS

Thermal & Advanced Processes Simulator

Version 2021.10

Simulator Changes

Numerical Control

New and improved features have been added to keyword *AUTOTUNE, including adaptive timestep size selection, under-relaxation, adaptive material balance error control, and variable overshoot control. Numerical settings have been chosen from the analysis of complex and highly nonlinear problems to ensure optimal performance. New sub-keyword *IGNORE_EXISTING provides flexibility by allowing the alteration of individual settings at different stages of the simulation. *See template "stsmo084.dat".*

New *MATBALTOL sub-keyword *MAT_MONITOR allows the monitoring of material balance error during the run. Error tolerance will be adjusted adaptively, if material balance error exceeds the maximum allowed value. *See template "stsmo084.dat".*

New *DT_ADJUST sub-keywords *NRSTEP, *SC_ADJ and *NC_ADJ provide more options for optimizing the adaptive timestep size selection, by taking into account the number of Newton cycles and solver iterations for the previous timesteps. *See template "stsmo084.dat".*

New keyword *VARI_URF and associated sub-keywords provide more flexible control of variable under-relaxation by defining separate variable change targets for pressure, saturation, temperature, and mole fractions. *See template "stsmo084.dat".*

Flexible Wellbore

New keyword *FW-COUPLING (available for all *SEGREGATION options) provides extra control for the accuracy of coupled wellbore-reservoir solution, thereby enhancing the stability, convergence and run time for difficult models. Sub-keywords *PER-WELL and *PER-LAYER allow the user to define error tolerance, minimum volumetric rates, and maximum number of Newton cycles for optimal performance. New section "Improving Numerical Performance - Flexible Wellbore" provides guidelines for the usage of *FW-COUPLING and other numerical options. *See template "stwwm159.dat".*

New sub-keyword *END-PACKER specifies a packer for preventing the fluid flow between the toe of a tube and its outer tube or outer casing. This type of packer cannot be placed at any location other than a tube toe. For example, in order to circulate a fluid between shorter inner tube and longer outer tube, this type of packer can be placed at the toe of the longer tube.

Tracer Options

Passive tracers can now be modelled by associating each tracer with an existing component. The associated component's movement will be tracked by inheriting the component's fluxes at the end of each timestep. Each reservoir component can be associated with more than one tracer. Tracers can be injected through a well which also injects its associated component, thus identifying the injected component's path through the reservoir. The feature is useful in EOR applications for studying injected polymer or surfactant components movement between different regions and towards the producers. Regional tracers can be defined per grid block to track the movement of the components of interest. Tracers associated with aquifer can be used to identify the aquifers most active in providing pressure support to the reservoir.

The following keywords are available:

*NTRCR	number of tracers
*TRCRNAME	Tracer's name
*TRCR-ASSOC	tracer-component association
*MW-TRCR	molecular weights of tracers
*TRGLOBALC	initial tracer concentrations in grid blocks
*TRCR-AQUIFER	initial tracer concentrations in aquifers
*TRCR-INJCONC	tracer concentration in an injector well
*TRCR-SOLVE	solution method (explicit or implicit) for tracers
*TRCR-CFL	CFL condition type for sub timestep size calculation (explicit method)

The explicit solution method is particularly useful for models with many tracers and with moderate heterogeneity where CFL criterion is readily satisfied. Two methods based after Sagen (1996) and Palagi (1992) are available.

Tracers can be added to models with various options, including dispersion/diffusion, adsorption, dual permeability, dual porosity, and flux boundaries. *See templates "sttrc001.dat" through "sttrc017.dat".*

Steam-Solvent Injection

New keyword *RAMPCTRL and associated sub-keywords allow the user to implement various steam and solvent co-injection schemes in order to maintain the well bottom-hole pressure. For example, it's possible to specify the target steam rate which will be reached gradually over the specified period. Alternatively, a multistage control period can be defined, with injection rate of either steam or solvent specified for each stage. The injection rate for the other stream will be automatically adjusted to maintain the total injection rate necessary for the target bottom-hole pressure. *See template "stwwm160.dat".*

Component Mobility Factor

New keyword *MOBCFAC allows the user to adjust the mobility of individual components in water phase without ignoring the contribution of all components to the phase saturation. This option is useful when a component that is supposed to be immobile at a certain saturation has become mobile with the phase. New keyword *SWCONM makes the mobility of the specified component dependent on connate water saturation. New keyword *SCWIPV specifies that water volume of the specified component contributes to the total inaccessible volume. *See template "stflu077.dat".*

Viscosity Nonlinear Mixing

*VISOLOGLOG sub-keyword *MASSWT (available only for linear mixing in previous releases) can now be used with nonlinear mixing enabled by *VSMIXFUNC. When *MASSWT is present, weighting is done by mass fractions even if *MASSBASIS isn't used.

*VSMIXGROUP was limited to water phase components in previous releases but now can be used for the components in oil phase.

Geochemistry

- New keyword *TREF_GCH specifies the reference temperature for temperature-dependent geochemical reactions.
- New *SLD_KIN sub-keywords are available for improved solid species kinetics:

*TST:	Precipitated solid will form a stationary solid and approach equilibrium at a specified rate using Transition State Theory.
*EQLTRAP:	Precipitated solid will form a flowing solid in equilibrium with the aqueous and ion exchange species. Flowing solid will then become mechanically trapped according to a rate-dependent process.

- New keywords for solid species reactions:

*RENTH_GCH	solid precipitation/dissolution reaction enthalpy
*ACTIVATION-ENERGY	activation energy for transitional state theory rate parameter
*REACTIVE-SURFACE-AREA	initial reactive surface area of mineral per pore volume
*MIN-REACT-SURFACE-AREA	minimum reactive surface area of mineral per pore volume
*SUPER-SATURATION-INDEX	super-saturation index for delaying the precipitation of minerals
*LOG-TST-RATE-CONSTANT	rate control for *TST option
*TST-DAMP	dampening factor on *TST rate
*LOG-TRAP-RATE-CONSTANT	tapping rate constant

See templates "stgch021.dat" through "stgch026.dat".

Output Enhancements

*OUTSRF *SPECIAL *SIMPERF will activate the output of following simulation performance indicators:

*ELTSCUM	elapsed time (seconds)
*ELTSRATE	elapsed time per simulation day
*TSTEPCUM	elapsed time per simulation day
*NCYCCUM	cumulative number of Newton cycles
*SOLITCUM	cumulative number of solver iterations
*TSCUTCUM	cumulative number of timestep cuts
* DELTIME	timestep size (days)

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* NCYCPTS	number of Newton cycles per timestep
*SOLITPN	number of solver iterations per Newton cyclev
*MBERROR	material balance error (%)
*AVGIMPL	average implicitness (%)
*MEMUSAGE	memory usage (MB)

The output is also available for each indicator separately, e.g. *OUTSRF *SPECIAL *ELTSCUM.

*OUTSRF *GRID FLUXCON is used by Results to generate streamlines of each phase at reservoir conditions. *STRMLN is still accepted but will generate the same output as FLUXCON.

Special history for DFN grid blocks can now be outputted via keyword *OUTSRF <property> UBA *DF | *DU | *DS *ifr* for a discrete fracture unit or segment's intersection with the grid block.

Solver Changes

Cut Direction Specification for Parallel Solver

The syntax of *PPATTERN *AUTOPSLAB is modified to include optional cut direction via sub-keywords (*I | *J | *K).

Geomechanics Changes

Saturation-Dependent Properties

New keywords *GRWATAB, *GROILTAB and *GRGASTAB define the dependence of geomechanical properties (Young's modulus, Poisson's ratio, Biot's coefficient, etc.) on water, oil, and gas saturation, respectively. A user-specified lookup table is used for each rock type to obtain new values of properties at every timestep. The increase of water saturation can make the rock weaker, affecting rock mechanical properties, stresses and deformation. *See template "stgeo100.dat".*

Nonlinear Elastic Constitutive Model 2

The nonlinear elastic constitutive model has been modified for better handling of discontinuous loads. With the already existing explicit method, rock properties related to the constitutive model are updated at the end of each timestep. This approach is sufficient for continuous loads but might lead to incorrect results when the load is discontinuous (such as external loads). As a remedy, an implicit method has been implemented so that 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. New keyword *MICSIM is introduced to use a simplified form of the Cam Clay model. New keyword *MCHARDF allows the user to choose between two pre-consolidated functions described in the manual.

Grid Changes

Bi-Directional Permeability Distribution for Hydraulic Fractures

A permeability distribution within a fracture can now be defined in horizontal and vertical directions, such that the horizontal or vertical permeability away from the fracture origin could dissipate linearly or exponentially with distance.

New keywords *KH_TYPE, *KV_TYPE, *K_CENT, *KH_TIP, *KV_TIP, *KH_DECLINE, *KV_DECLINE and *ELLIPTICAL_DISTRIBUTION are introduced in the Planar Fracture Template to control the distribution, with the latter transforming the fracture permeability distribution from the usual rectangular shape to an ellipse-like shape following the fracture geometry inputs.

Hydraulic Fracture in Inactive Blocks

Hydraulic fractures can now go through inactive grid blocks, such as blocks with zero-porosity, zero-net-gross null blocks. The option, invoked by new keyword *HF_IN_NULL, creates active fracture zone within the blocks. The properties of fracture zone can be defined through newly introduced keywords *POR_NULL, *NETGROSS_NULL, *PERMI_NULL, *PERMJ_NULL and *PERMK_NULL.

Hydraulic Fracture in LGR Blocks

The origin of a planar hydraulic fracture (*PLNRFRAC, *PLNR_REFINE) can now be assigned to a one-level LGR grid. For this scenario, hydraulic fracture's creation is restricted 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 new sub-keyword *USE_SBG. *See template "stgro095.dat".*

Property Distribution Data Template

New keyword *PDD allows the definition of a property distribution template that can be applied readily to planar fractures. The template may then be used via *PDD_DATA in both the Reservoir Description and Well and Recurrent Data sections by a fracture grid created with *PLNR_REFINE or *PLNR_FRAC.

Wildcards for Block Group Names

*BLOCKGROUP or *SBLOCKGROUP names can now be referenced with wildcards '*' and '?' in similar fashion as the wildcards 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. Wildcard '?' replaces any single character anywhere in the block group names. *See template "stgro071.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 *DUALPOR and *DUALPERM natural fracture models, if *MATRIX or *FRACTURE qualifier is not specified, the pinch out array will be applied, as before, to both matrix and fracture blocks.

Pore Volume Cut-Off for Refined Grids

New 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 removed from the fluid flow simulation either through nulling or pinching out. *See template "stgro096.dat".*

Grid Offset, Orientation and Direction

New keywords *XOFFSET, *YOFFSET, *ROTATION, and *AXES-DIRECTIONS can be used in grid building procedure. This is particularly useful when DFN or independent well data with offset, orientation, and Y axis direction different from reservoir grid are read. The keywords can be used together to match reservoir grid to DFN or well trajectories.

DFN

In addition to default quadrilateral shape, triangular and polygon shapes can now be used for the modeling of discrete fracture networks.

Electrical heating options (keywords *ELECHEAT, etc.) and mechanical dispersion options (keywords *MDSPI_WAT, etc.) are now applied to DFUs.

Well Management Changes

Grid-Independent Wells

New keyword *WBRANCH allows the definition of the multi-lateral well trajectories using spatial coordinates and measured depths. The well main branch and subordinate branches can be relocated using keyword *WBSHIFT and *WBROTATE without altering the original input coordinates of the well trajectory segments. Well perforations and associated index parameters can be specified as measured depth intervals (*PERF-MD) instead of 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. All existing layer control options (e.g. *LAYER-CTRL and *KRPERF) can be used with the new syntax for branch names and measured depth intervals. *See templates "stwwm161/162.dat".*

Hydraulic Table Lookup

New keyword *PTUBE-FIXFRAC provides more flexible controls for handling the implicit WHP well constraint, especially when it is close to a lift failure. This option is useful for avoiding frequent lift failures by effectively lowering the enforced WHP from the specified values.

Template Dataset Changes

New Template Datasets

stflu077.dat	Verify/Illustrate Component Mobility Factor *MOBCFAC
stgch021.dat	NaCO3 Flood in Core with *TST Solid
stgch022.dat	Water Chemistry with Exothermic Dissolution
stgch023.dat	Water Chemistry with Exothermic Dissolution and *TST
stgch024.dat	NaCO3 Flood in Core with Non-Geochem Solid

stgch025.dat	NaCO3 Flood in Core with *COMP-GEO Solid
stgch026.dat	NaCO3 Flood in Core with *EQLTRAP Solid
stgeo100.dat	Saturation-Dependent Geomechanical Properties with *GRWATAB
stgro095.dat	Hydraulic Fracture in LGR Blocks
stgro096.dat	*DUALPOR with *PVCUTRG-FR
sttrc001.dat	Polymer Injection with Tracer
sttrc002.dat	Polymer Injection with Tracer and Shut-in Well
sttrc003.dat	Water Flooding with Well Tracers
sttrc004.dat	Water Flooding with Regional Tracers
sttrc005.dat	Steam Injection with Tracer
sttrc006.dat	Test/Illustrate Aquifer Tracer
sttrc007.dat	Gas-Aquifer Drive with Tracer
sttrc008.dat	Flux Boundary with Well Tracer - Full-Field Run
sttrc009.dat	Flux Boundary with Well Tracer - Reduced Run
sttrc0010.dat	Flux Boundary with Well Tracer - Full-Field Run
sttrc0011.dat	Flux Boundary with Well Tracer - Reduced Run
sttrc0012.dat	Test/Illustrate Tracer with *DUALPERM
sttrc0013.dat	Test/Illustrate Tracer with Mechanical Dispersivity
sttrc0014.dat	Test/Illustrate Tracer with Molecular Diffusion
sttrc0015.dat	Test/Illustrate Tracer with Total Dispersion and LGR
sttrc0016.dat	Test/Illustrate Well Tracer with Adsorption
sttrc0017.dat	Test/Illustrate Well Tracer with *DUALPERM and *DYNAGRID
stwwm159.dat	Flexible Wellbore with *FW-COUPLING
stwwm160.dat	Steam-Solvent Injection with *RAMPCTRL
stwwm161.dat	Grid-Independent Well with *WBRANCH
stwwm162.dat	Grid-Independent Well with *WBRANCH and *DYNAGRID

Changed Template Datasets

stgch002.dat	Replace obsolete *SLD_KIN *FLW with *SLD_KIN *TST
stgch003.dat	Replace obsolete *SLD_KIN *FLW with *SLD_KIN *TST
stgch007.dat	Replace obsolete *SLD_KIN *FLW with *SLD_KIN *TST
stgch010.dat	Add *SLD_KIN *TST
stgch011.dat	Add *SLD_KIN *TST
stgch013.dat	Replace obsolete *SLD_KIN *FLW with *SLD_KIN *TST
stgro071.dat	Use wild card for block group names
stsmo084.dat	*AUTOTUNE with *MAT_MONITOR, *DT_ADJUST, *VARI_URF