New features and optimizations in the hygrothermal transport model DELPHIN 6

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Overview

• Physical model in DELPHIN 6
  ➢ Coupled heat and moisture transport model with detailed moisture transport and storage model
  ➢ Optional ice formation model
  ➢ Optional air flow model (forced flow/bouancy driven), fully coupled to heat and moisture transport model
  ➢ Optional salt transport model including transient phase transitions
  ➢ Many boundary condition models, contact resistances, source/sink models, special models (e.g. interior longwave radiation exchange)

  ➢ Mostly the same as in DELPHIN 5, but thoroughly reviewed and more efficient/stable (*routinely tested with automated benchmarks*)
  ➢ Support for 3D geometries (in solver, not in user interface)

• Optimization of the solver engine
  ➢ Iterative preconditioned Newton-Krylov-Methods significantly accelerate simulation of 2D details, enable 3D simulations
  ➢ Parallel solver
  ➢ Optimized memory layout for faster physics evaluation algorithms
The DELPHIN 6 Software

• Executables (Windows executables, on MacOSX and Linux similar naming)
   DELPHIN 6 User Interface (modelling environment)
    Delphin6.exe
   Console solver (command line argument controlled)
    DelphinSolver.exe
   Graphical (modern) solver, just as fast as the command line solver (except for parallel solver variants), yet with live preview of simulation results
    DelphinSolverUI.exe
   Command line discretizer (can be used to automatically perform grid sensitivity studies)
    CmdDiscretise.exe
   DSixOutputConverter utility (extracts data from output files, converts data into other formats, creates TECPLOT files)
    DSixOutputConverter.exe

• Databases (Climatic Data and Materials)

• Post-Processing
   Either DELPHIN 5 Post-Processing (can be installed alongside with DELPHIN 6)
   Or new POSTPROC 2 software (recommended for simulation analysis)
New User Interface

- New Icon and Splashscreen

*Picture taken from IBK-GWT project about improving construction detail for intersection of interior separation wall with inside-insulated historic brick wall*
New User Interface

- Multiple languages
  - Switch with menu option Edit → Languages...
  - Currently: English, German, French
  - Translation is simple → Translators are welcome!

- Software runs natively on Windows, MacOS and Linux

- On Mac OS X: Security → allow software from any sources
New User Interface

- Welcome page
  - Recently used projects (with preview)
  - Examples/Validation cases (with descriptions)
  - Current version, Update information, Web-content from Bauklimatik-Dresden.de
New User Interface

File Operations
New User Interface

Project, Geometry and Simulation Views
• 3 Views with project data
  ➢ Project properties, location and climate
  ➢ Construction/Geometry view (main modelling view)
  ➢ Simulation view (physical model settings, solver options, simulation start)
New User Interface

Geometry/Grid Editing
New User Interface

Dresden, 09/21 2017
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Language selection
Definition windows (freely arrangeable)
New Modeling View

- Zooming via mouse scroll wheel

- Equidistant view toggle mode
Consistent Coordinate System Definition

- Coordinates
- Assignment/range indexes

- Assignment order
  - Later assignments override earlier assignments (applies to all assignments)

<table>
<thead>
<tr>
<th>Row indexes</th>
<th>Column indexes</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
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<tr>
<td>0</td>
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</tr>
</tbody>
</table>

- Grid without materials assignments
- After assigning material to range 0 0 2 3
- After assigning VOID material to range 1 1 2 2
- After assigning another material to range 2 1 2 1
• Highlighting of edges/boundaries with assignments

Dash-dot line pattern for boundaries without interfaces, corresponds to symmetry conditions (adiabatic and moisture tight)

Thick solid lines indicate assigned interface
Modeling Improvements

- Highlighting of coordinate outputs (sensors)
• Highlighting of side assignments

Dashed lines show assigned contact conditions and flux outputs
Modeling Improvements

- Indication of used and unused definitions

Gray italic text indicates an unused/not assigned definition

- Assignment lists are located alongside definition window

(re-introduced from DELPHIN 4)
• No embedded material data
  ➢ Material files (*.m6) are always referenced
  ➢ Material list/definition window lists Material References

• Interfaces group several boundary conditions
  ➢ Instead of assigning individual boundary conditions to several sides, interfaces are defined (e.g. outside, inside, basement, …) and these are associated with boundary conditions
  ➢ Support for *Engineering Interface Models* (predefined sets of boundary conditions and related climatic conditions)
New Modeling Concepts

• Interfaces – Example

First floor (dashed because selected in definition view)

Outside

Basement

Boundary conditions associated with interface “Basement”
New Modeling Concepts

- Interfaces – Engineering Level
  - DIN indoor and outdoor climate
  - WTA model
  - Standard model
  - Boundary Conditions and Climate Conditions are created automatically during simulation setup
  - Engineering interface definitions can be converted to detailed model
Output handling

- Output file definitions
  - Filename
  - Physical Quantity
  - Grid reference
  - Time and spatial handling (averaging/integration)
  - Value unit

- Grids
  - Define intervals and output steps

- Global options (for all files)
  - Binary/ASCII Format
  - ASCII-Format precision (rarely needed, for example for energy density integrals to compute overall gains/losses)
  - Output time unit (same for all output files)
  - Over-hygroscopic moisture content limit (as relative humidity)
Output handling

- **Physical Quantities**
  - Quantity defines also default unit and type (flux or field quantity)
  - Anything calculated in DELPHIN is available as a quantity
  - Includes transport coefficients (which can be monitored in output files)
• Flux output sign conventions
  - Distinguish between boundary/surface fluxes and flux fields – *different sign conventions*
  - Fluxes are assigned to sides
  - One flux output (definition) can be assigned to several locations

• Rules
  - When flux outputs are assigned only to boundary sides
    Flux is *positive* when it flows *into* the construction
    i.e. a positive moisture flux increases the moisture content in the construction, a positive heat flux increases energy density (and temperature)

  - When flux is assigned to at least one internal side, flux is *positive* when it flows into *positive coordinate* direction
New Modeling Features

- Schedules
  - Replace time limits for boundary and field conditions, can be specified like output intervals

- Interface – BC indication
  - Color bars indicate types of BC associated with an interface

- Intelligent Auto-Discretization
  - Clusters grid only at boundaries where interfaces are assigned
  - Recognizes and keeps field assignments (outputs/sources)
Databases

- Material Data Base
  - set of m6 Material files (as in DELPHIN 5)
  - data files are read in separate thread – no longer delay when importing materials

- Climate Data
  - New format: c6b climate data container files for use in CCM (Climate Calculation Module)
  - Basically same content as EPW, but binary format (data protection), epw natively supported
  - Free Climate Data Editor (CCMEditor) tool available for editing/converting data

- Additional time series (climate data)
  - Still using ccd files as in DELPHIN 5
  - Now supporting csv files (tabulator separated data files):
    - first column time points, second column values, description and units in first row

  Example file:

<table>
<thead>
<tr>
<th>Time [d]</th>
<th>Temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>10.0</td>
</tr>
<tr>
<td>0.02083</td>
<td>9.0</td>
</tr>
<tr>
<td>0.04167</td>
<td>8.7</td>
</tr>
<tr>
<td>0.0625</td>
<td>7.4</td>
</tr>
</tbody>
</table>
First page: Model options

- Contains settings, that define physical model and naturally give different results
Second page: Solver options

- Tolerances control error test – to how many digits shall my conserved quantities be accurate
  
  Mind: there is a non-linear relationship between conserved quantities and analysed properties (e.g. relative humidity)

- Settings have an influence on model results

- Smaller tolerances slow down simulation but can help increase robustness!
### Third page: Performance options

- Numerical settings only influence simulation speed  
  (differences in order of rounding errors possible)
New Solvers / Performance Optimization

• Time integrators available
  - Explicit Euler (for debugging purposes)
  - Runge Kutta 47 (Dormand-Prince), explicit solver
  - Implicit Euler (for testing numerically tricky problems)
  - CVODE (default, as in DELPHIN 5)
  - Alternating-Direct-Implicit (ADI), good for certain 2D/3D problems, research code

• Linear equation system solvers (for use within implicit solvers)
  - Banded (general 1D simulations, small 2D simulations)
  - Block-Tridiagonal (VOC/Salt simulations in 1D)
  - Sparse direct (KLU solver, for thermal problems in 2D/3D)
  - GMRES and BiCGStab (for general 2D/3D cases) – Krylov-Subspace methods!

• Preconditioners (for Krylow-Subspace solvers)
  - Banded
  - ILU (incomplete LU factorization)
  - … others are research/test implementations

• Physical model evaluation done in parallel (OpenMP parallelization)

See presentation and workshop from BauSIM 2016 for details
New Solvers / Performance Optimization

• Example 1 – EN ISO 10211 – Case 2
  ➢ Energy balance only (thermal bridge problem)
  ➢ 36666 Elements, 189 half-bandwidth (rectangular 194 x 189 grid)

• Variants
  ➢ Band solver vs. KLU (in DELPHIN 6)
  ➢ Serial/parallel code (1 vs. 4 threads)
  ➢ Parameters for steady-state result (transient accuracy does not matter)
• Example 2 – Corner
  - Hygrothermal simulation
  - 10931 Elemente (21862 Unknowns)

• Variants
  - Serial banded solver in DELPHIN 5 (half-bandwidth 223)
  - Parallel GMRES solver in DELPHIN 6 (4 threads), ILU preconditioner, colored Jacobian (14 colors)

Simulation time [min], first 60 days of simulation
Remote Solver Server

- Send projects to remote (powerful) server and collect results

  - Project input files are collected and exported into project package (*.d6pp)
  - Project package is sent to server, scheduled in either fast or slow queue (fast jobs are automatically aborted after 30 minutes if not yet finished)
  - Once completed, results are archived as 7zip file and retrieved from server
  - Results are extracted in projects directory just as if simulated locally \( \rightarrow \) ready for PostProcessing
New License Model

• Only limited lifetime licenses
  ➢ Much reduced license costs
  ➢ Annual license duration with support and free updates/upgrades
  ➢ Activation provided for work and private computer (linked to person/company)
  ➢ Activation needs to be updated every year (license renewal)

• License/support renewal/extension:
  ➢ Always for 1 year after last license expired, includes free updates/upgrades and support
  ➢ Cannot skip renewal intervals, after approximately 4 years same price as new license

• Pricing:

  Commercial license: 800 € initial + 600 €/a
  Academic license: 600 €/a
  Student/teaching license: --- €/a

  all prices excluding VAT
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Thank You! Questions?