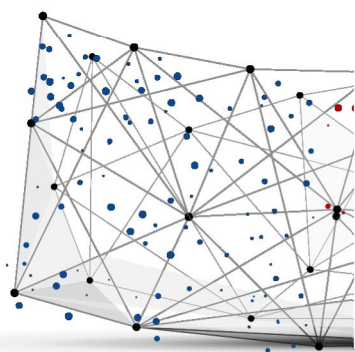


THESEUS-FE 9.0



- Automatic Multi-Airzone Modelling
- Support for FMI Co-Simulation
- Revision of Cabin & Comfort Tutorials
- Improvements for Abaqus input file converter
- E-Coating: Overset Mesh Method
- Oven: New Nozzle View Factor Method
- Oven: Method to prescribe a gradient for T_{circ}
- Extended OpenFOAM Support
- And many more ...

Automatic Multi-Airzone Modelling

From the early beginnings of THESEUS-FE, air-zones have been used to model the interior air of cabins representing fluid regions with averaged thermal conditions. Air-zones are fully implemented into the THESEUS-FE solver allowing for interaction with shell elements and manikins to derive the time-varying solutions for temperature and humidity. Ventilations enable easy and flexible modelling of sophisticated HVAC systems as well as the directed exchange of air between different air-zones. By now, cabin models usually rely on a small number of air-zones as the major challenge is the proper definition of these exchange rates.

THESEUS-FE 9.0 introduces the new Multi-Airzone GUI feature together with a completely revised internal air-zone solver. Pre-calculated CFD solutions are utilized to discretize the cabin volume by a higher number of air-zones and derive all exchange rates automatically (Fig. 1). This closes the huge gap between single-air-zone-models and computationally expensive fully-coupled simulations with CFD-solvers as data is based only on a few distinct steady-state CFD results providing information about the velocity field. While manual adaption to the special load-case are still possible, all convective boundary conditions and ventilations are generated automatically not requiring any further user interaction.

Due to a general revision of the physical modeling of air-zones, results may change compared to older releases of THESEUS-FE, but major improvements have been achieved concerning mass conservation and representing over-saturated conditions.

To improve compatibility with thermal manikins, convective boundary conditions can now be applied in a geometrically arbitrary manner on manikin surfaces (Fig. 2).

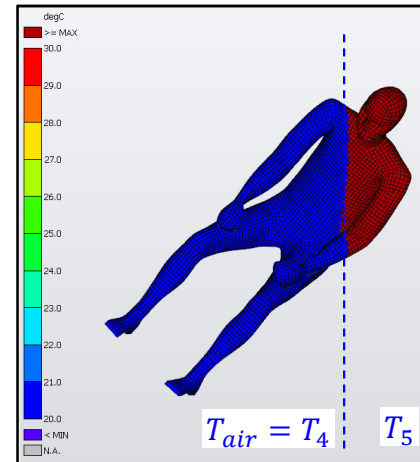


Fig. 2: Manikin boundaries

A new tutorial will explain this new feature for automated multi-zone modelling on a realistic cabin-comfort model including post-processing of the air-zone temperature distribution with the THESEUS-FE GUI (Fig. 3).

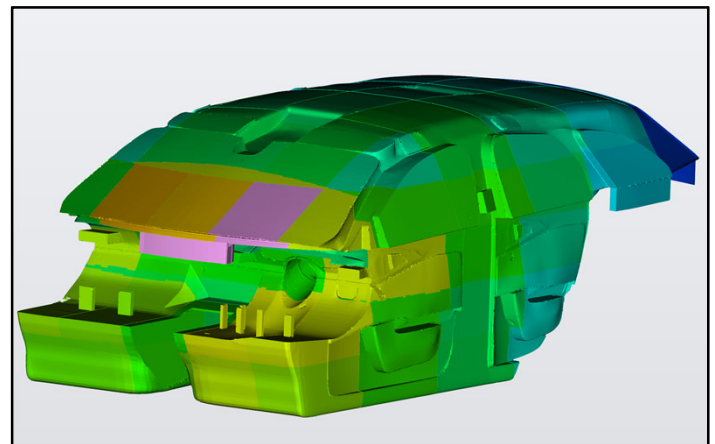


Fig. 3: Air-zone temperature distribution

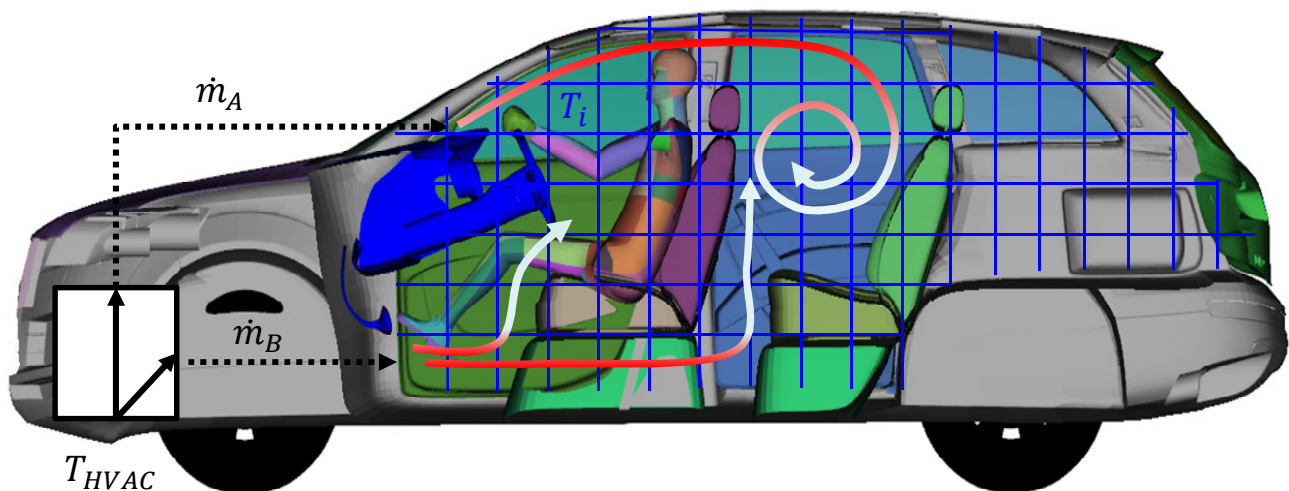
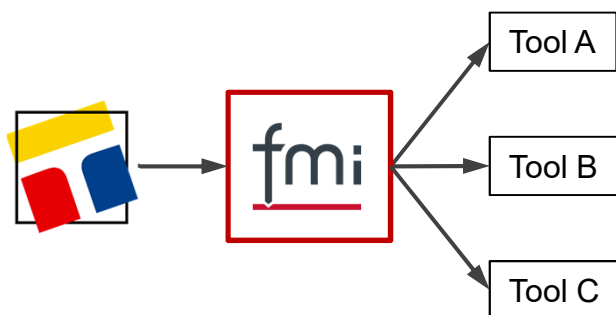


Fig. 1: Multi-Airzone approach for a thermal cabin simulation

Support for FMI Co-Simulation

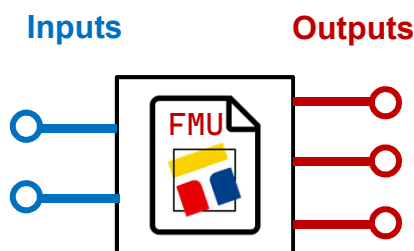
FMI⁽¹⁾ is a free standard that defines a container format and an interface for exchanging simulation models. A simulation model packaged into such a container is called a FMU⁽²⁾. The idea behind such FMU models is that, once created, they are exchangeable between different simulation programs supporting the FMI standard without any need for adaption on either side.



Cases exported as FMU models can be used by any tool that supports FMI

THESEUS-FE 9.0 adds support for exporting cases as FMU models. By default, both the case (tfe file and its dependant files like include files or datafiles etc.) and the solver are bundled into the FMU file. That way, the FMU will work as long as it runs on a machine using the same general type of operating system (Windows or Linux) and the THESEUS-FE license server can be contacted at runtime. There exist also the options to exclude case and/or solver which also have their use cases. For example, one can more easily get hold of the HDF results written for the case itself if it is not bundled into the FMU model file.

Under the hood, a FMU model is a ZIP file which has very specific content. It contains the model description in a XML file adhering to the FMI standard. It also comes with program code or binaries which implement the functionality needed so that a third-party tool can integrate and run the FMU model. In the case of THESEUS-FE it may also contain the case files and solver as mentioned beforehand.

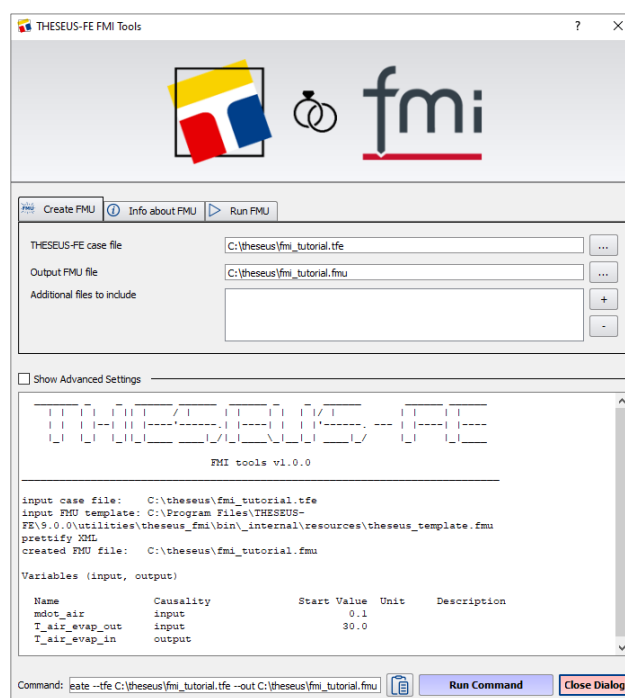


FMU models have ports for input and output signals

For the end user it is generally enough to think about the FMU model as a “black box” which has some ports to which input signals are connected and which provides some output signals. The most common use case of a FMU is to integrate a THESEUS-FE simulation into some 1D network of some kind of larger simulation, for example a full vehicle thermal management simulation.

The THESEUS-FE installation comes with a command-line utility called “theseus_fmi”. This can be used to create FMU models for specific cases, to inspect their contents or to drive them with some example data to test that they are basically functioning in isolation. This is an advisable practice before integrating them into some larger 1D network as components.

The most common tasks to perform on FMU models are conveniently available in the THESEUS-FE GUI:



Actions to create, inspect and test run FMU models in dialogs

Overall, the support for the FMI standard raises the co-simulation capabilities of THESEUS-FE to a whole new level. THESEUS-FE cases can now with ease be integrated into every other software program which supports importing FMU models. The number of such software programs is steadily increasing and can be checked on the FMI Tools page⁽³⁾.

Check out the brand-new tutorial in the Co-Simulation manual dedicated to exporting a THESEUS-FE case as a FMU model!

(1) FMI, Functional Mock-up Interface, <https://fmi-standard.org>

(2) FMU, Functional Mock-up Unit

(3) Tools supporting the FMI standard: <https://fmi-standard.org/tools/>

Revision of Cabin & Comfort Tutorial

At the THESEUS-FE Shanghai User Conference in April 2023, an outlook on new functions of version 9.0 was presented for the first time. The cabin and comfort models shown there use realistic geometries, materials and boundary conditions. As new tutorials (No. 7-10), these realistic models are now available to all THESEUS-FE users within the installation package of version 9.0 and are extensively documented:

- Tutorial 7: Soak cycle - simplified cabin model
- Tutorial 8: Cooling cycle - simplified cabin model
- Tutorial 9: CarGenerator - draft cabin model with manikin
- Tutorial 10: Cabin heating - detailed model with manikin

The tutorial cabin models are derived from the same detailed 3D data of the identical car geometry but with simplifications at different levels.

A standard database for layer and material definitions is delivered within the installation package for general use. The initial and boundary conditions employed for the tutorial cases correspond to the typical summer- and winter-load-case test cycles prescribed in the German standard DIN 1946-3 for air conditioning in automobiles.

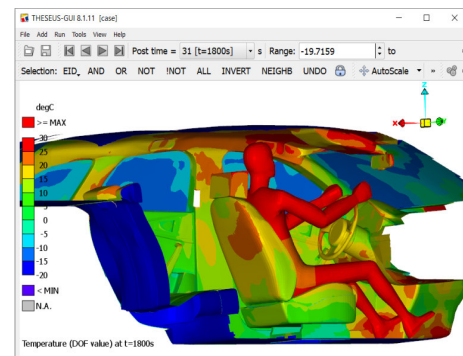
Therefore, these tutorials can serve as valuable references for realistic development processes. The flexible utilization of glass properties, air-zones, ventilations and thermal comfort manikins are explained thoroughly.

It is worth noting that the newly revised Extended CarGenerator tool is introduced in Tutorial 9. This parameterized approach can significantly reduce the model complexity and computational costs. Therefore, it is perfect for rapid analysis in the prototyping process. Compared to the old CarGenerator tool, the new approach is more automated and can reflect more details of the original cabin geometry, and hence improves the simulation accuracy.

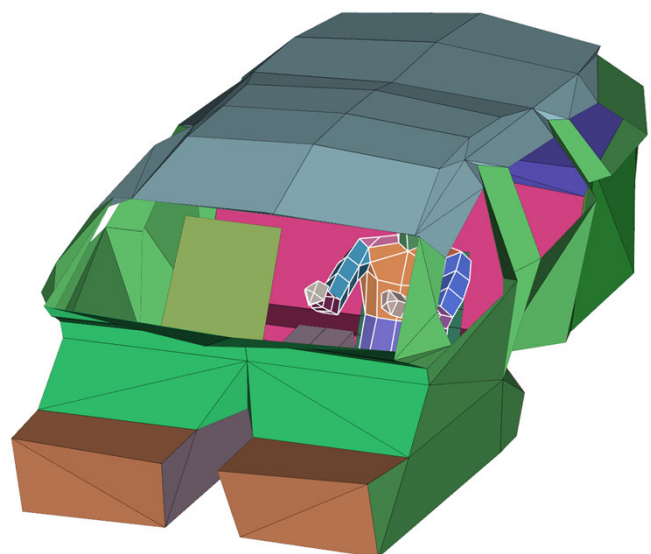
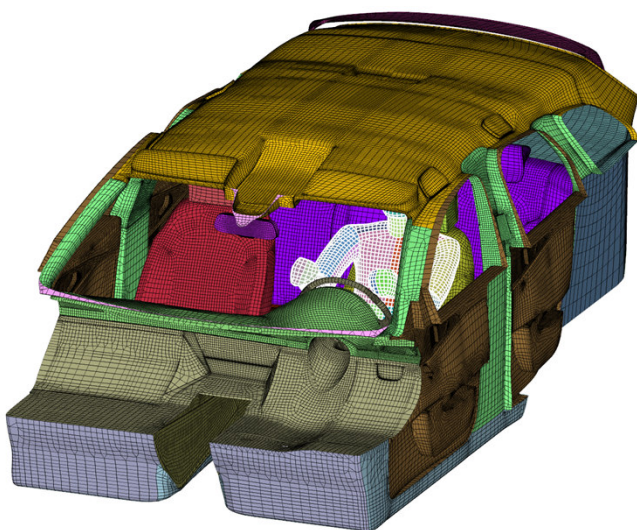
This new tutorial package also includes totally revised coupled cabin models that are delivered together with full 3D CFD models explained in the CoSimulation Manual:

- Cabin heat-up – coupled with Star-CCM+ (revised)
- Cabin heat-up – coupled with OpenFOAM (added)

The cabin models for the THESEUS-FE model are kept identical to that used in Tutorial 10 for a good comparability. The THESEUS-FE coupler settings and the execution of the co-simulation runs are described in detail.



Results of a realistic winter load case test cycle

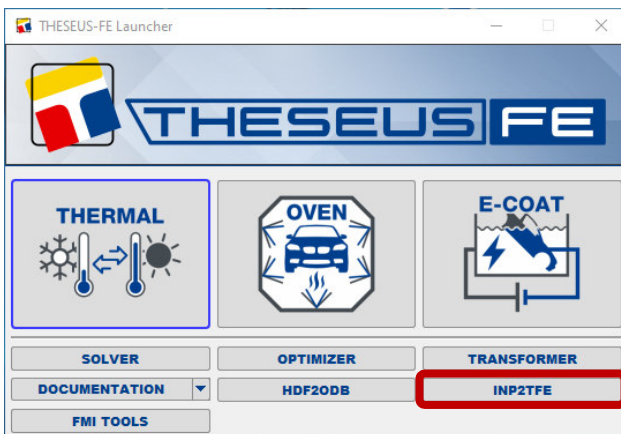


Interior cabin model (Left: Detailed model. Right: Extended CarGenerator model.)

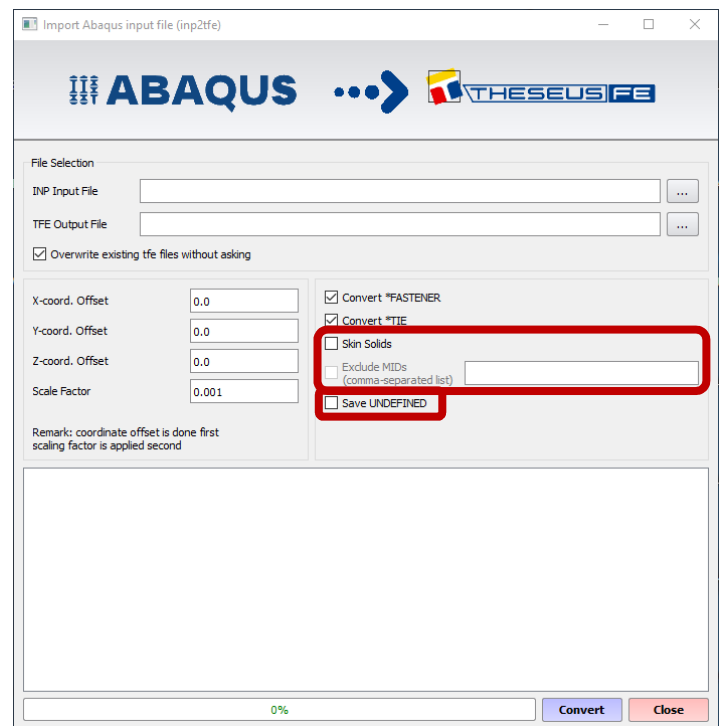


Improvements of the Abaqus input file converter

- The Abaqus input file converter (in GUI: File > Import > Abaqus) is now also directly available on the THESEUS-FE Launcher panel via the "INP2TFE" button.
- The new automatic generation of shell elements on free surfaces of solid element meshes makes the conversion of Abaqus models more convenient.
- The handling of missing property and material cards in the input file has been improved so that you can now decide whether undefined cards will be automatically generated or omitted from the converted THESEUS-FE model. This makes life easier when working with models consisting of multiple include files.
- Abaqus *FASTENER and *TIE connections referring to surfaces defined on solid element meshes are now also supported.
- Support for additional fastener attachment methods has been added (EDGETOFACE, FACETOEDGE, EDGETOEDGE).
- Improvements have been implemented to increase the robustness of flange detection for Abaqus fasteners.
- Connector elements are now generally converted to bar elements in THESEUS-FE in addition to the support of Abaqus connector elements that are part of fastener definitions.
- Abaqus membrane elements M3Dx are now supported. They are converted to shell elements in THESEUS-FE.



Abaqus input file converter is now available in launcher



New options in Abaqus input file converter

E-Coating: The New Overset Technology

E-Coating module: Before version 9.0, the vehicle geometry was permanently connected to the fluid paint mesh with fixed anode positions as a quasi-static approach. Since version 9.0, the vehicle geometry can be moved during the coating process relative to the anodes. This corresponds to a more realistic representation of the actual e-coating process in the automobile production. This new technology is referred to as “overset mesh method”. The related new keywords are called OVERSET and TRNSFRM. The idea is to move the oversight mesh (Fig. 1) through the tank mesh (Fig. 2) with a user-defined kinematic (black curve) and with adaptive contact relations between the oversight surface and the tank elements.

Compared to the quasi-static approach, the new oversight technology enables higher accuracy, especially when the anodes are switched on during the dipping process. However, the computing time is about 3 times higher compared to the quasi-static approach.

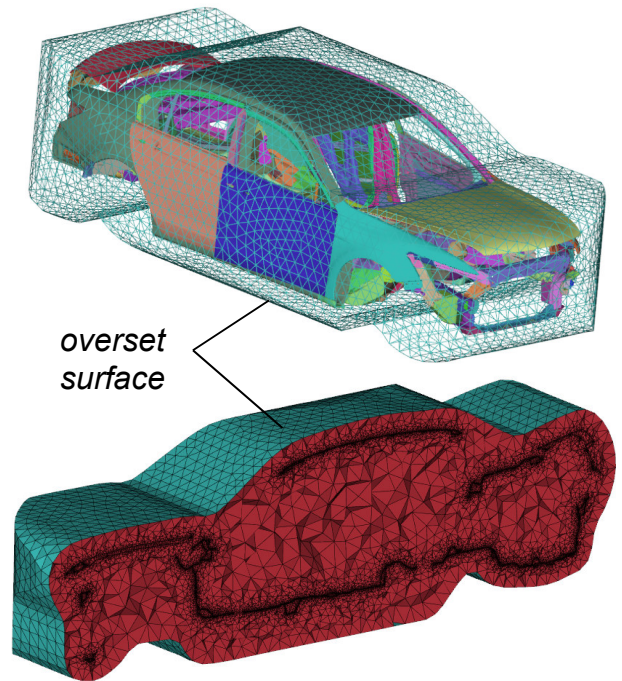


Fig. 1: Oversight mesh

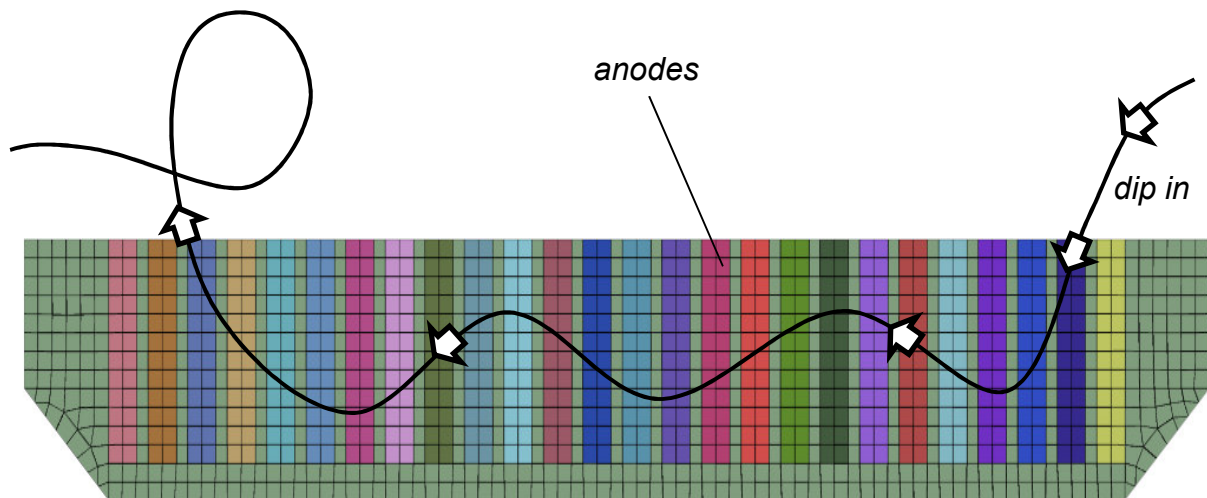
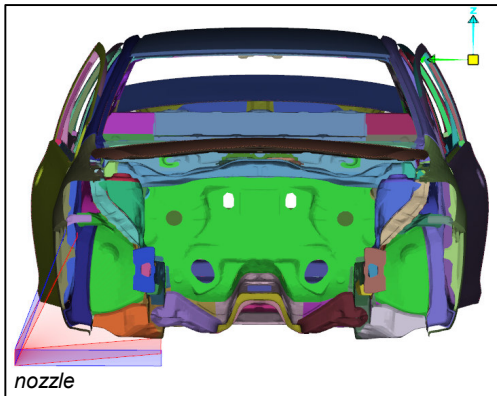


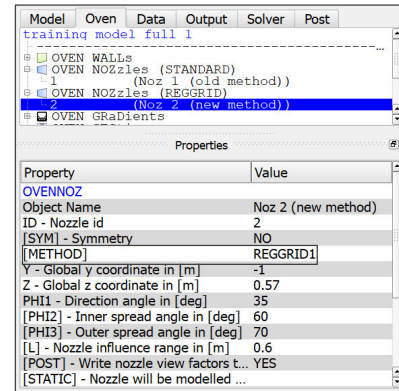
Fig. 2: Tank mesh

Oven: New Methods for Nozzle View Factor

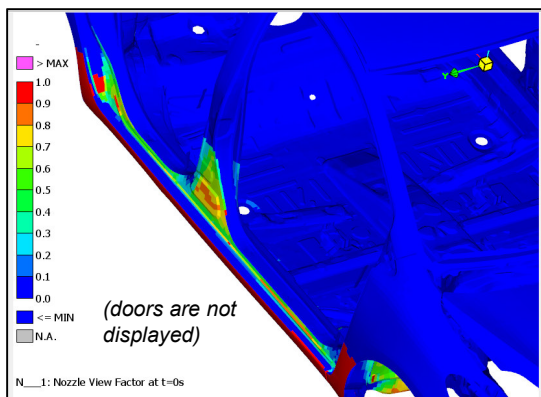
In the Oven module, convective boundary conditions in areas with nozzle influence are identified using so-called nozzle view factors. In the past there was only one method available for the internal calculation of those “view factors”: based on ray-tracing techniques. However, this method has the disadvantage that the nozzle air flow is unable to penetrate through gaps and holes into the interior of the vehicle. Starting with version 9.0 there is a new method that deals with these deficiencies. The new REGGRID method is a useful alternative especially for sill nozzles. Results of the new and old methods are compared in the figures below.



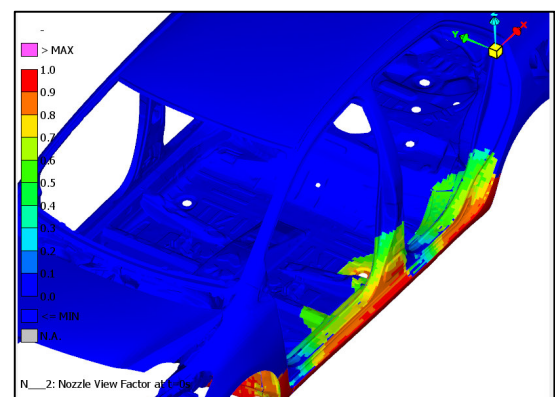
Sill nozzle



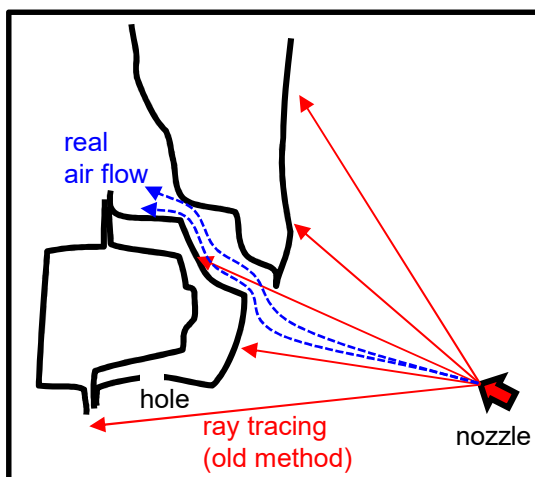
How to select the new method



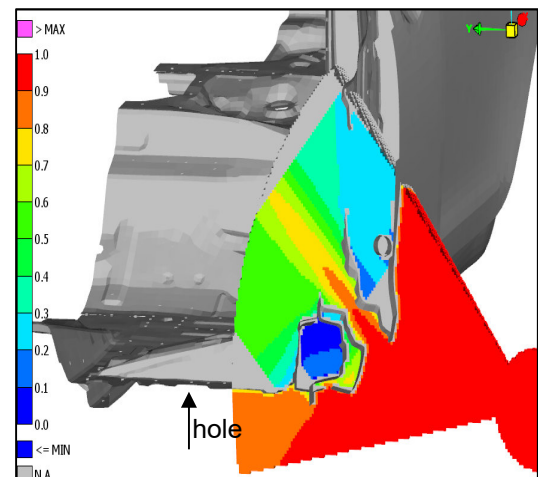
Nozzle view factor (old method)



Nozzle view factor (new method)



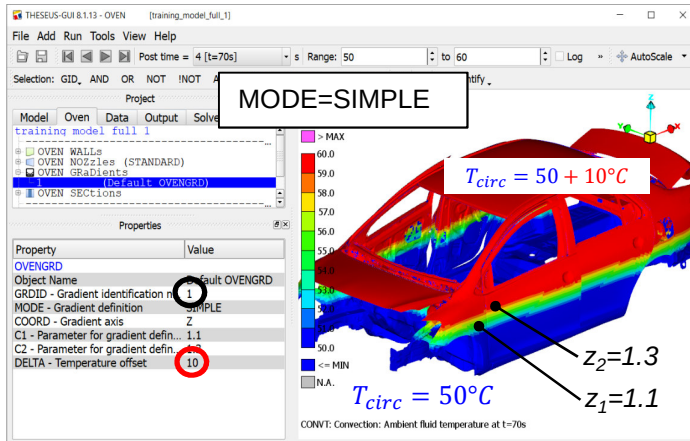
Nozzle view factor (old method)



Nozzle view factor (new method)

Oven: New Gradient for T_{circ}

The circulating air temperature defined in keyword OVENSEC was previously a uniform value for the entire model (variable only over time). Since version 9.0 it is now also possible that T_{circ} depends on the position (coordinates X/Y/Z). For this we use the new keyword OVENGRD, as shown in the figures below. Typically, the new T_{circ} option is used to represent variability of the air temperature across the Z axis.



New OVENGRD with $\Delta = 10^{\circ}\text{C}$

Model	Oven	Data	Output	Solver	Post
training model full 1					
OVEN WALLS (STANDARD)					
OVEN NOZZLES (STANDARD)					
OVEN GRADIENTS (Default OVENGRD)					
OVEN SECTIONS					
1 (Init)					
2 (Heating 1)					
OVEN settings					
Properties					
Property Value					
OVENSEC					
Object Name	Init				
TIME - Sector duration time in [s]	70				
Sector Starting Time in [s]	0				
[DT] - Fixed time step in [s]					
T_CIRC - Circulating air temperature in [K]	50				
H_CIRC - Circulating air HTC in [W/(m2K)]	8				
H_GAP - Gap HTC in [W/(m2K)]	5				
[T_CIRC_EXP] - Exponent in nonlinear f...					
[RID] - Rule ID					
[GRDID] - Gradient ID	1				

New OVENSEC

In addition to the option shown above (MODE=SIMPLE), there are other options. E.g. with MODE=TABULAR you can distribute two or three measured air temperature curves of T_{circ} over the vehicle height. Documentation on this can be found in the updated Keyword Manual.

Additional Oven News

- OVENREAD: Nozzle view factors can be read from CSV file so that pre-calculated values from external CFD methods can be used.
- POSTDAT: Advanced weighting functions WGHT_POS and WGHT_NEG are available. With these a distinction can be made between positive and negative differences of the simulated temperature curves and the measured ones.
- OVEN: New option DMXFLAG to use one common gap factor for both T_{gap} and h_{gap} .
- OVENSEC: Can conveniently use default values for wall and nozzle parameters from previous sector with T_{F0} and T_{W0} .
- OVENSEC: Added new offset temperature T_{OFF} . With this the temperature values of all sector heat sources can be raised or lowered by a fixed amount – including T_{circ} at the end.
- New oven calibration training material is available. Ask the THESEUS-FE support team to get access to it.

Additional News for Advanced Solver

- New post-processing field variables EMISS and ABSRB are available for quick checks of the radiation properties of the model.
- New shell type PSHELL2 for two-dimensional heat conduction, especially useful for thin metal sheets to reduce simulation times and memory requirements.
- New keyword RADPROP replaces keyword PRAD. It comes with subtypes OPAQUE, CONST, SINGLE, and TABULAR to model different surface property types in a more understandable way. The GUI will convert models containing PRAD keywords automatically. The new keyword with its various subtypes distinguishes thematically between different models for translucent and opaque materials.
- The default parameters of BC-FC and BC-MFC have changed. Use option LEGACY to use the old values. The new default parameters are especially adapted to the conditions inside car cabins and on manikins.
- Support added for temperature-dependent heat generation for materials (MAT4/MAT5).
- Convergence behavior and parallel efficiency has generally been improved in all solver modules.



Coupler News

The Adapter now supports Buoyant Boussinesq Solvers of the following OpenFOAM versions:

- ESI versions up to v2112 (incl. dynamic-mesh-capabilities)
- Foundation versions up to 6

Moreover, OpenFOAM coupler routines for data exchange have been improved and are significantly faster for simulations utilizing a high number of OpenFOAM MPI tasks.

Manikin News

- The default Berkeley comfort model revision is now 2014.
- The model borders for ISO comfort index can be customized now.
- New defaults for more realistic radiation parameters for unclothed skin surfaces.
- New documentation about manikin clothing (Theory Manual).
- The clothing area factor f_{cl} is now considered for equivalent temperature calculation.
- New SENDFILE option COMFORT.

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Upgrade of FlexNet Licensing to 11.19.4.1

THESEUS-FE 9.0 uses the recent version 11.19.4.1 of FlexNet Publisher for licensing. It will be necessary to upgrade existing installations of the license server "lmgrd", maintenance tools like "lmutil" and our vendor daemon "puzld" to run this new version of THESEUS-FE. Suitable versions of all programs are included in the installation packages and can be downloaded from our website separately as well. Be sure to stop a running license server first, especially on Windows systems such that existing files can be overridden during the installation.

Operation System Support

THESEUS-FE 9.0 officially supports:

- Windows 10 and 11
- RHEL 7-9, CentOS 7-9 and Rocky Linux 8-9

We want to give early notice that version 9 will be the last major version of THESEUS-FE that supports RHEL/CentOS 7. Those are reaching the end of their regular maintenance life-cycle on 2024/06/30 and support for them will be dropped in the next major release of THESEUS-FE.