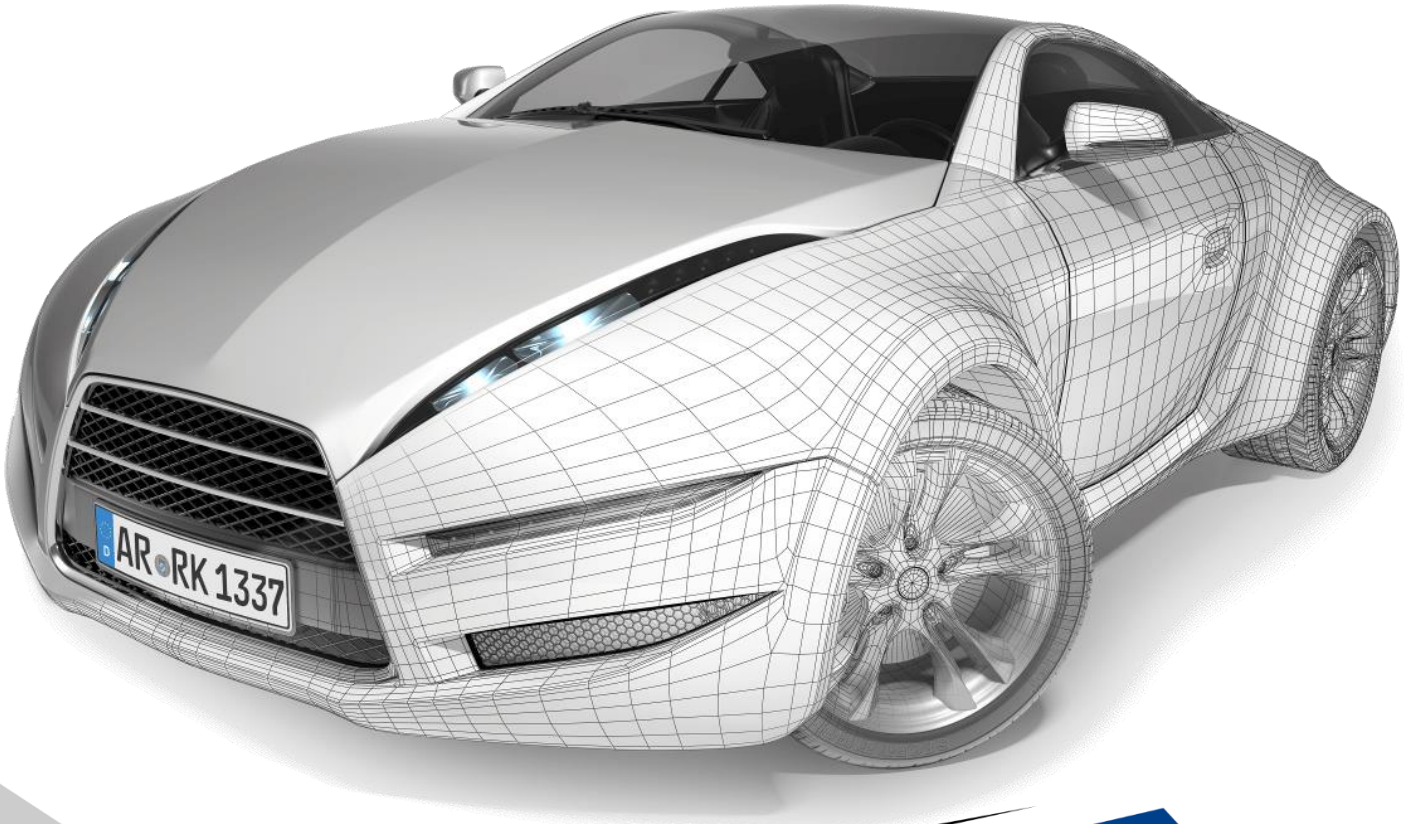
NEWSLETTER
2018 / May

THESEUS-FE 7.0

Major version 7.0 released in May 2018 ships with several improvements on board

To just name a few important ones:

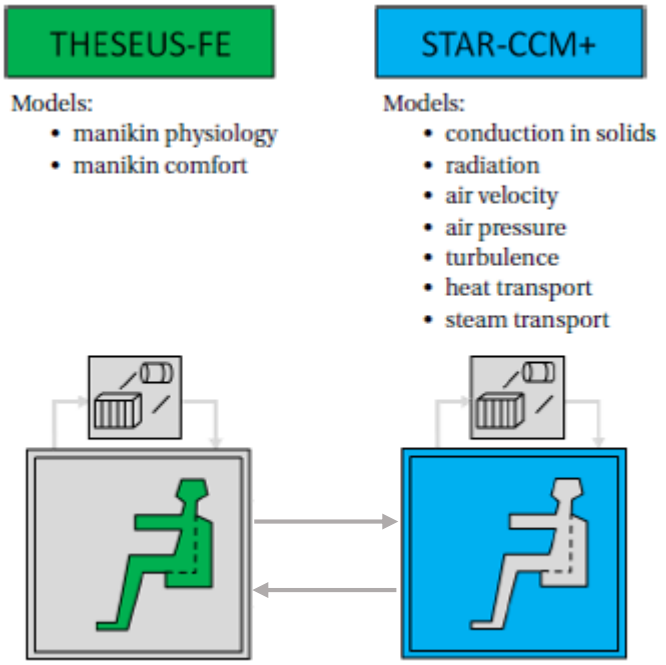
- Improved manikin coupling for STAR-CCM+
- Many enhanced thermal manikin features
- Significant improvements for the E-Coating module
- Advanced screenshot tool and animation recording functionality in the GUI
- Generalized concept for user-defined variables



READFF Manikin Coupling for STAR-CCM+

Since 2013 we are working on a special coupling tool for Linux OS which allows the direct coupling of StarCCM+ models with the THESEUS-FE thermoregulatory model FIALA2.

Compared to the previous coupling methods there is no need for a finite-element mesh representation in the THESEUS-FE model. Only the thermoregulatory part including clothing is defined in the deck. This leads to a minimal data transfer between the THESEUS-FE body elements and the corresponding STAR-CCM+ boundaries.

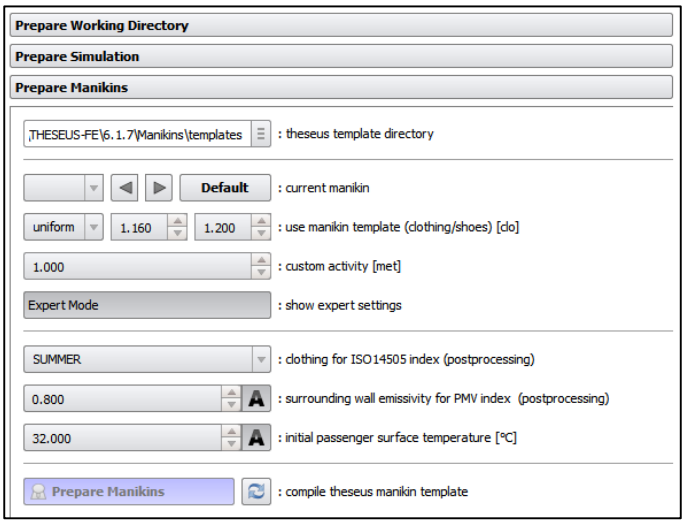


STAR-CCM+ calculates the conductive, radiative and convective heat flows as well as the ambient air velocities, temperatures and humidity and transfers them to THESEUS-FE. It receives surface (skin) temperatures, steam mass flux and local comfort indices in return.

Due to the use of the new FIALA2 manikin model there is no need of predefining sectors on each body element in THESEUS-FE. The sector subdivision is based on the available boundaries in the STAR-CCM+ model and is detected automatically at the start of the simulation.

A new steady-state example demonstrating this coupling is available in the CoSimulation manual.

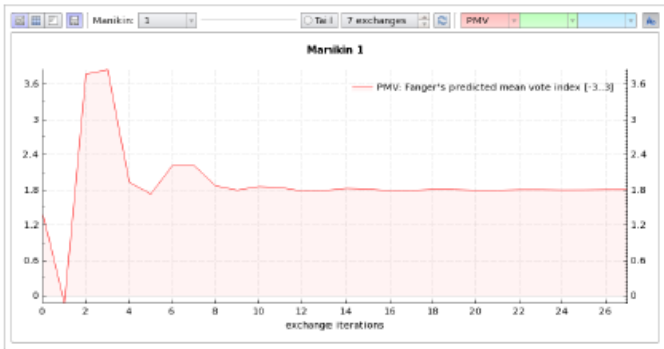
An easy-to-use wizard-like dialogue guides the user to the process of setting up the coupled simulation.



Preparation of manikin clothing in the new coupler UI

Various clothing templates for summer and winter scenarios are shipped with THESEUS-FE which can be extended easily by the customer.

Basic evaluation and monitoring can be done directly in the user interface. Reports and plots can be exported easily for evaluation.



Monitoring the predicted mean vote

Manikin data like

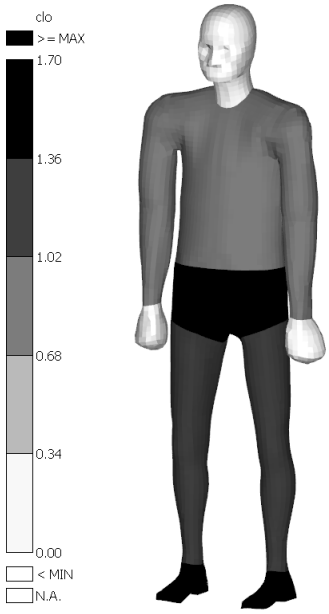
- Equivalent temperature
- Zhang local comfort index
- Zhang local sensation index
- Predicted mean vote
- Passenger clothing
- Passenger activity

are also passed to the Star-CCM+ case for further postprocessing.

Enhanced Thermal Manikin Features

Already in version 6 the THESEUS-FE manikin model has been extended with a new flexible type called „FIALA2“. For release 7.0 we added many helpful new features customers have been asking for:

- Read/write setpoint files for FIALA2 and use them as Zhang setpoints, for initialization or as Fiala active system setpoints. The creation of such a new setpoint file (with suffix .man) is based on a stand-alone uncoupled FIALA2 model using one single sector per body element.
- The manikin surface A_{sf} in equation (3.58) of the Theory Manual contains only non-contact areas. This results in a better approximation for T_{rad} but might lead to small variations in PMV (towards version 6).
- Extended PMV calculation considering the contact heat flux with Keyword MANFPMVC.
- The global clothing insulation I_{cl} will be derived automatically from the local clothing ensemble. This makes the PMV calculation much easier.
- Define local clothing parameters for each shell group (Keyword: SHELLTYP) of a FIALA2 manikin. In the past it was only possible to define clothing for whole body elements.
- Visualization of local clothing insulation I_{cl}* with the new field result type MNICL:



Summer: local clothing insulation I_{cl} in [clo]*

More boundary condition types (BC-RAD, BC-HEAT) are now supported on coupled manikins:

- BC-RAD applies long wave radiation heat transfer from a given wall temperature T_{rad}
- BC-HEAT applies a user-defined contact heat flux in [W/m²]. This feature has been used for the following Thermal Comfort Study

Thermal Comfort Study

This thermal comfort study was driven by a customer and contains all of the new manikin features mentioned above. The original tfe models used for the study are available from the download section of our website. Cloth insulation values from literature[1] have been applied (see table 1) based on relations shown in the new version 7 Theory Manual, Appendix H:

$$I_{cl}^* \approx 1\Big/\left[\frac{1}{x(I_{cl}+I_a/f_{cl})}-\frac{1}{I_a}\cdot\frac{1-x}{x}\right]-0.8/f_{cl}^*$$

$x=A_{cl}/A$ is the relation between the clothed and total surface area and I_a=0.8 clo represents typical environmental conditions.

For each garment the table below shows relations between the original I_{cl} values from literature[1] and the derived local I_{cl}* values required for the THESEUS-FE simulation:

			x	(1-x)/x/0.8	fcl*	Icl	fcl	Icl*
Shirt	Long-sleeve, shirt collar	broad cloth	0.51	1.20	1.12	0.33	1.07	0.91
Trouser	Straight, long, loose	denim	0.45	1.53	1.27	0.32	1.06	1.20
Underwear	Briefs	knit	0.12	9.17	1.01	0.05	1.01	0.58
Socks	Ankle length athletic	knit	0.07	16.61	1.01	0.03	1.01	0.63
Shoes	Hard-soled street	vinyl	0.07	16.61	1.03	0.04	1.01	1.11
Socks + shoes					1.03			1.74
Trous. + underw.					1.27			1.78

How to derive local I_{cl} from global I_{cl} for single garments*

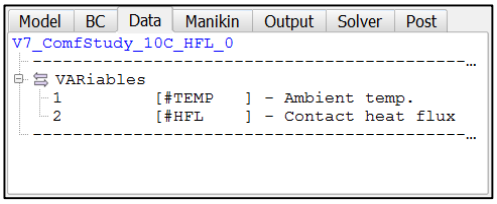
The I_{cl}* values are demonstrated in the figure on the left side. The global clothing insulation I_{cl}=0.85 clo of the complete ensemble will now be derived automatically from

$$I_{cl} = 1\Big/\left(\sum\frac{A_{sk,i}/A_{sk}}{I_{cl,i}^*+I_a/f_{cl,i}^*}\right)-I_a/f_{cl}$$

[1]) *McCullough E.A., Jones B.W., Huck J. 1985. “A Comprehensive Data Base for Estimating Clothing Insulation”. ASHRAE Trans., vol.91, pp.29-47*

The two tables on the right side show global thermal comfort indices from a single manikin under 9 different boundary conditions. Each job uses the new concept of placeholder variables:

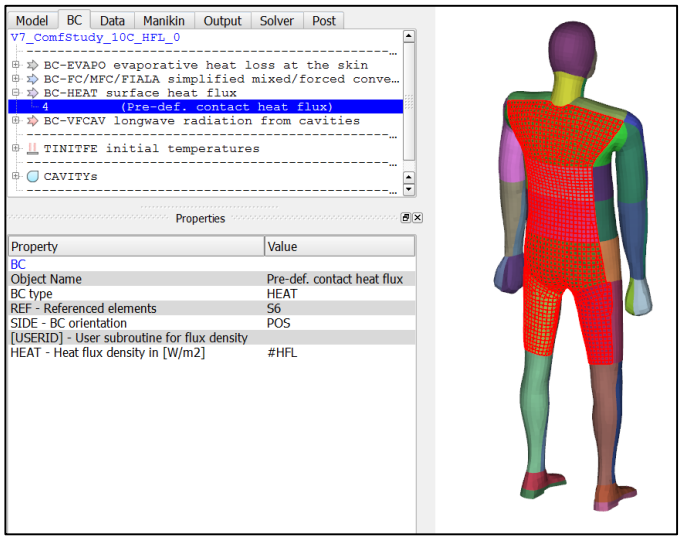
- #TEMP is the ambient temperature used for radiation and convection
- #HFL is the contact heat flux (applied on the back as shown in the figure below)



Further model parameters of the comfort study:

- Ambient humidity: 45%
- Activity level: 1.0 met
- Radiation surface emissivity: 0.99/0.95 (skin/cloth)
- Background wall emissivity: 0.9
- Air velocity: 0.1m/s
- Initial temperature and manikin setpoints have been derived from clothed manikin neutrality (MODE=UNCPLD) and read in via MANFSETP. These are completely new features for FIALA2.
- Optional: contact heat flux = 200 W/m^2

Radiation and convection boundary conditions do not act on contact regions.



Instead of the old MANFPMV keyword we use the new MANFPMVC formulas that consider additional contact areas and contact heat fluxes.

For variants without contact heat flux (#HFL=0) the contact area (red in the figure above) is adiabatic.

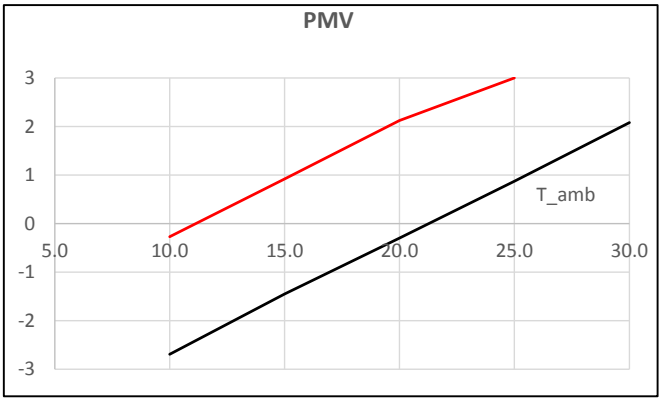
	#TEMP=10C , #HFL=0W/m2	#TEMP=15C , #HFL=0W/m2	#TEMP=20C , #HFL=0W/m2	#TEMP=25C , #HFL=0W/m2	#TEMP=30C , #HFL=0W/m2
ambient temp. = #TEMP	10.0	15.0	20.0	25.0	30.0
contact heat flux = #HFL	0.0	0.0	0.0	0.0	0.0
PMV	-2.7	-1.5	-0.3	0.9	2.1
DTS	-2.0	-1.3	-0.4	1.4	2.7
avrg Teq	14.6	18.8	22.9	26.9	31.0
global ISO 14505	1.0	1.2	2.3	3.5	4.8
global Zhang sens.	*-0.3*	*0.1*	*0.5*	*0.8*	*0.8*
global Zhang comfort	*-0.3*	*0.3*	*0.9*	*1.0*	*0.5*

global thermal comfort indices (without contact heat flux)

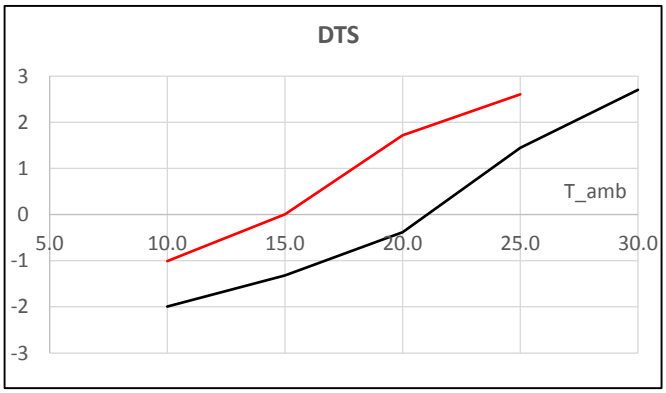
	#TEMP=10C , #HFL=200W/m2	#TEMP=15C , #HFL=200W/m2	#TEMP=20C , #HFL=200W/m2	#TEMP=25C , #HFL=200W/m2
ambient temp. = #TEMP	10.0	15.0	20.0	25.0
contact heat flux = #HFL	200.0	200.0	200.0	200.0
PMV	-0.3	0.9	2.1	3.0
DTS	-1.0	0.0	1.7	2.6
avrg Teq	25.2	29.3	33.4	37.5
global ISO 14505	3.0	4.3	5.0	5.0
global Zhang sens.	*0.7*	*1.1*	*1.2*	*1.3*
global Zhang comfort	*-1.1*	*-0.9*	*-0.8*	*-0.7*

global thermal comfort indices (with contact heat flux)

The diagrams below show the influence of contact heating on the global thermal comfort indices PMV and DTS:



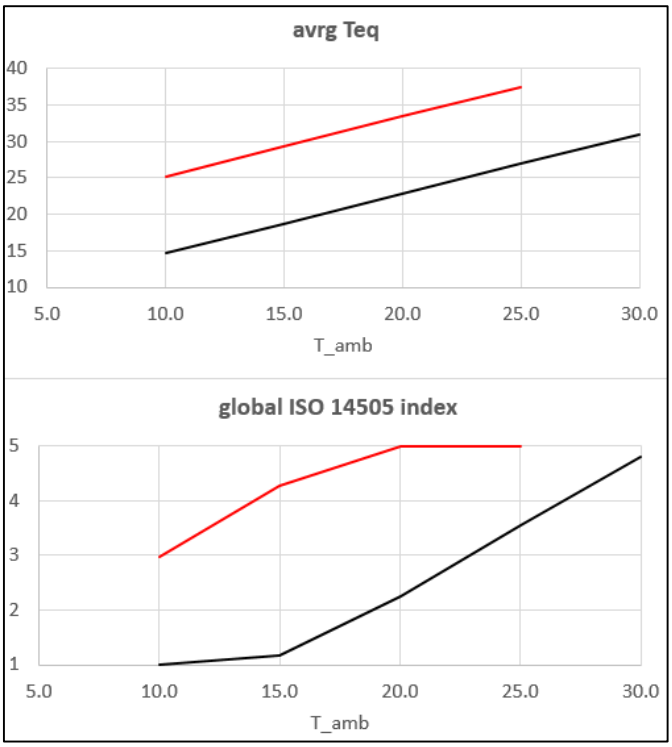
Extended MANFPMVC calculation: PMV=3 : hot. PMV=-3 : cold.



Fiala: DTS=3 : hot. DTS=-3 : cold.

As expected, both diagrams show that additional contact heat fluxes (red curves) lead to higher values for PMV and DTS.

The two tables below show the average equivalent temperature T_{eq} and the global ISO 14505 index. Both values show a strong impact on contact heat fluxes. The values for T_{eq} increase by 10°C.



Equivalent temperature and ISO14505 index (summer)
1 – too cold (uncomfortable)
2 – cold, but comfortable
3 – neutral
4 – warm, but comfortable
5 – too warm (uncomfortable)

E-Coating

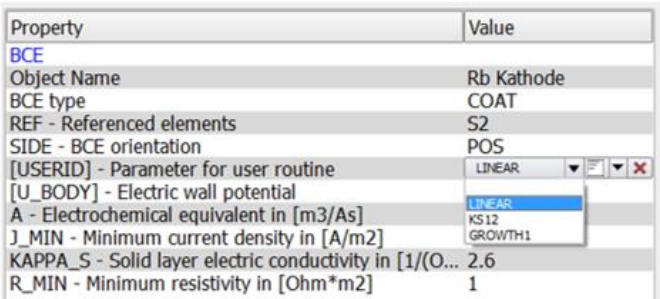
The THESEUS-FE E-Coating module has been significantly improved during the last year. The new features available in version 7 include:

- Advanced nonlinear coating relations
- New time stepping
- Reduced HDF result file size
- Faster solver
- New contact algorithm
- New E-Coating restart technology

Details about the new features will be discussed in the following chapters.

Advanced nonlinear coating relations

Two new functions for the specific electric resistance R have been introduced. You can select them for the cathode BCE-COAT as shown below:



Property	Value
BCE	
Object Name	Rb Kathode
BCE type	COAT
REF - Referenced elements	S2
SIDE - BCE orientation	POS
[USERID] - Parameter for user routine	LINEAR
[U_BODY] - Electric wall potential	
A - Electrochemical equivalent in [m3/As]	
J_MIN - Minimum current density in [A/m2]	
KAPPA_S - Solid layer electric conductivity in [1/(O...	2.6
R_MIN - Minimum resistivity in [Ohm*m2]	1

The old LINEAR relation between R and d only depends on the material parameter κ_s

$$R(d) = max\left(R_{min}, \frac{d}{\kappa_s}\right)$$

The minimum value $R_{min} = 1\,\Omega m^2$ is a constant we use for numeric stability reasons in E-Coating simulations.

A new nonlinear relation is now available that uses two different solid layer electric conductivities κ_{s1}, κ_{s2}.

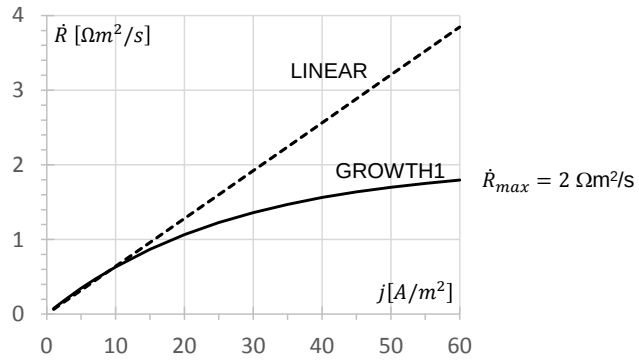
$$R(d) = max\left(R_{min}, d\left[\frac{1}{\kappa_s} + \frac{ln(1 + d \cdot 10^6)}{\kappa_s}\right]\right)$$

Alternatively the following GROWTH1 function is available now. It results in a nonlinear relation between the growth rate of the resistance $\frac{\partial R}{\partial t}$ and the electric current j.

$$\dot{R} = \dot{R}_{max}\left[1 - e^{-\beta(j - j_{min})}\right]$$

The paint material parameters are β and $\dot{R}_{max}$ (the maximum growth rate reached for higher values of j [A/m²]).

The new GROWTH1 law had been presented in literature[2] and is based on experimental measurements that indicate that $\frac{\partial R}{\partial t}$ tends to a maximum of 2 Ωm²/s for the very high electric current values that are typical for the early phase of e-coating.
A comparison between LINEAR and GROWTH1 laws is shown in the figure below:



Simulations show that the LINEAR law is often sufficient because the very high electric current values only occur during the first seconds of e-coating. Afterwards a thin layer is already deposited and the cathode electric current decreases (typical values are <15 A/m²).

New time stepping

For the E-Coating module it is now possible with keyword SOL to start the simulation with a small initial time step. A value of 1 second for MINDT is recommended here, for example. Afterwards the time step will be doubled until time t = DT0 is reached, for example DT0 = 5 s.

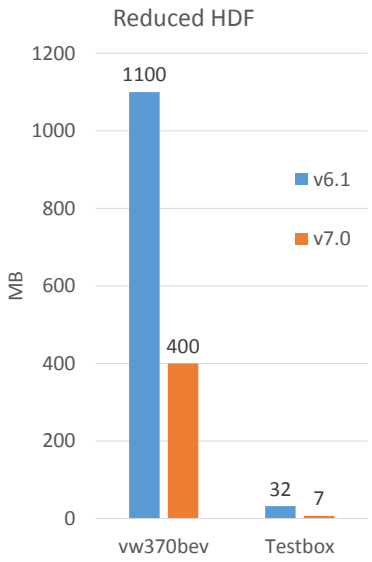
Property	Value
Object Name	
[STYPE] - Solver type	ELECTR
[TTYP] - Time step type for transie...	
[DT0] - Initial time step in [s]	5
TEND - Ending analysis time in [s]	280
[ADPTOL] - Adaptive tolerance in [...	
[MXDT] - Maximum time step in [s]	
[SSCOND] - Steady state condition ...	
[CRIT1] - Maximum relative energy...	
[MINITR] - Minimum number of no...	
[MAXITR] - Maximum number of n...	
[MAXSTP] - Maximum number of ti...	
[RELAX1] - Temperature relaxation...	
[PRED] - Order of explicit predictin...	
[DIVISOR] - Divisor for the linear it...	
[CRIT2] - Maximum temperature c...	
[MINDT] - Minimum time step in [s]	1

time step	dt	t
1	1	1
2	2	3
3	2	5
4	5	10
5	5	15
6	5	20
7	5	25

[2]) *Kurz, O.: "Virtuelle Fertigungsprozessabsicherung und –optimierung. Einsatzpotentiale numerischer Berechnungsmethoden im Rahmen der Digitalen Fabrik". Ph.D. thesis, Technische Universität Clausthal, 2006*

Reduced HDF result file size

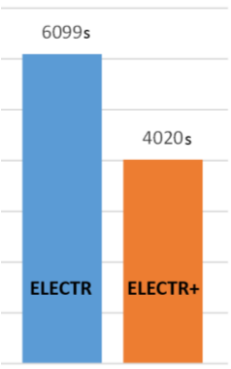
During an E-Coating analysis the liquid paint elements and grids are no longer stored in the HDF result file when no nodal results are written out.



This enhancement is always active in E-Coating. But it is possible to deactivate this exception with keyword POSTDOF.

Faster solver

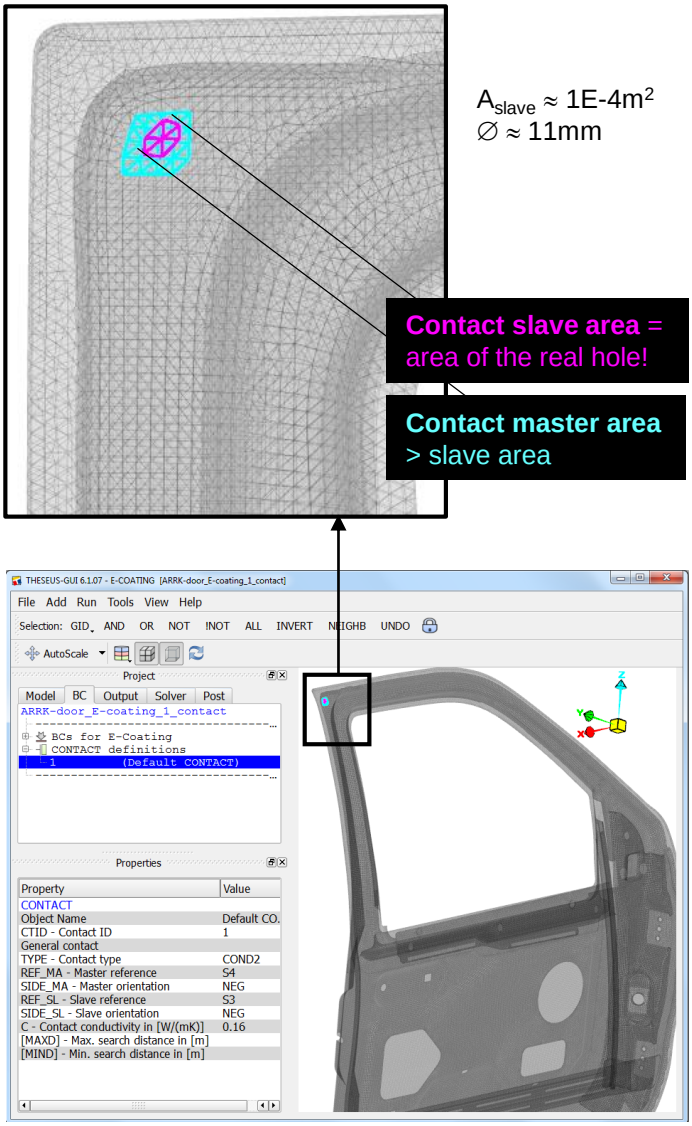
The new solver type ELECTR+ now enables to run E-Coating simulations even faster than before. See the figure below. Validations showed that the coating thickness results only change marginally.



Property	Value
SOL	
Object Name	
[STYPE] - Solver type	ELECTR+
[TTYP] - Time step type for transient solver	
[DT0] - Initial time step in [s]	5
TEND - Ending analysis time in [s]	280
[ADPTOL] - Adaptive tolerance in [°C]	
[MXDT] - Maximum time step in [s]	
[SSCOND] - Steady state condition in [°C/s]	
[CRIT1] - Maximum relative energy residual	
[MINITR] - Minimum number of nonlinear...	
[MAXITR] - Maximum number of nonlinea...	
[MAXSTP] - Maximum number of time steps	
[RELAX1] - Temperature relaxation param...	
[PRED] - Order of explicit predicting temp...	
[DIVISOR] - Divisor for the linear iteration...	
[CRIT2] - Maximum temperature correctio...	
[MINDT] - Minimum time step in [s]	1

New contact algorithm for E-Coating

During 2017 we initially tested contact algorithms to insert small holes in E-Coating models. After some algorithmic adjustments, we achieve a good fit between coating results of models with holes geometrically represented in the solid mesh and models using contact definitions instead. For the contact definition it is very important to choose a set of shells (as slave) with approximately the same area as the real hole.



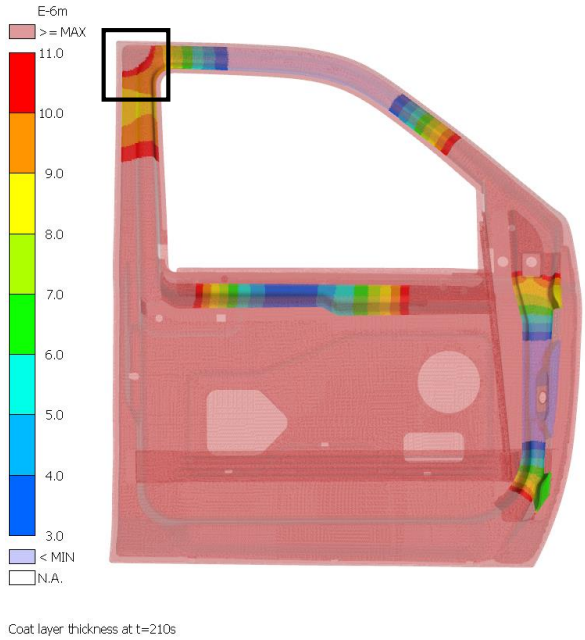
ARRK door: new contact definition (type=COND2)

Besides the definition of slave and master surfaces it is necessary to define the fluid paint electric conductivity κ_f for the contact of type COND2

Electric current I[A] between slave and master:

$$I = A_{sl}\frac{\kappa_f}{d}(U_{ma} - U_{sl})$$

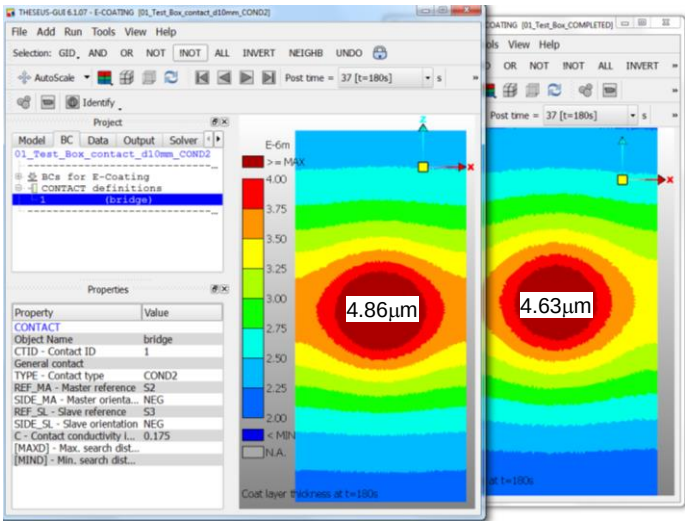
d is the master slave distance that will be derived automatically by contact pair search algorithms.



ARRK door: inside paint layer thickness results [μm]

For validation reasons we compared the paint layer thickness on plate C of the E-Coating tutorial 1. The figure below shows two different simulation results.

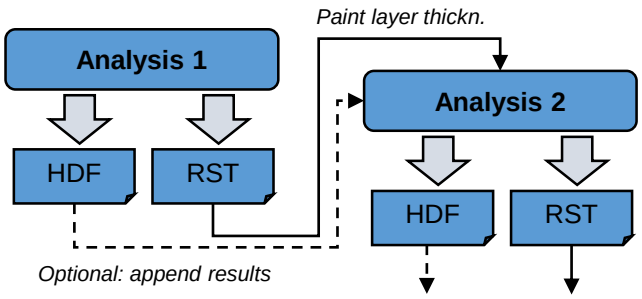
- A new model with contact definition replacing the original hole on plate B
- The original model with the geometric hole on plate B



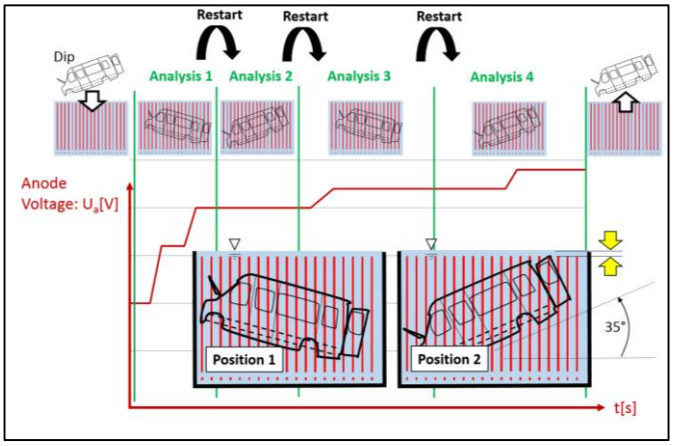
E-Coating Tutorial 1 (test box) plate C coating with contact and real hole

Restarts in THESEUS-FE E-Coating

In some of our E-Coating projects it was necessary to modify the tank position of the BIW relative to the anodes. For example, a rotation as shown in the figure. For that reason we have implemented the new restart technology.
The user starts the paint layer thickness simulation with analysis 1 in position 1. The final state of painting from analysis 1 will be stored in a restart file that can be used for initialization in analysis 2. As shown in the figure,, analyses 2 and 4 use the same mesh (position 2) that shows a very low liquid paint coverage in the rear roof area.

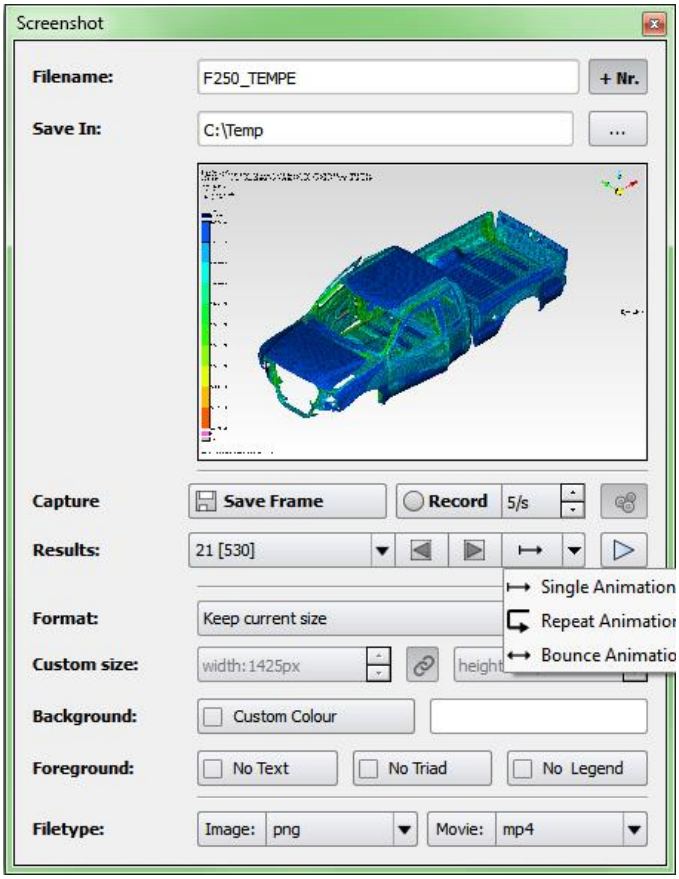


The only restriction on such a restart simulation is that both jobs (analyses 1 and 2) should use the same shell mesh on anode and cathode. But no further restrictions exist for the volume mesh of the liquid paint. In addition to that, it is easily possible to work with different volume meshes. For that reason it is recommended to use only shell elements on anode and cathode but none within the solid mesh.



Advanced Screenshots and Animation

It is possible now to animate and export results directly from the user interface. Basic output settings like video framerate and size can be easily manipulated from the revised dialogue.



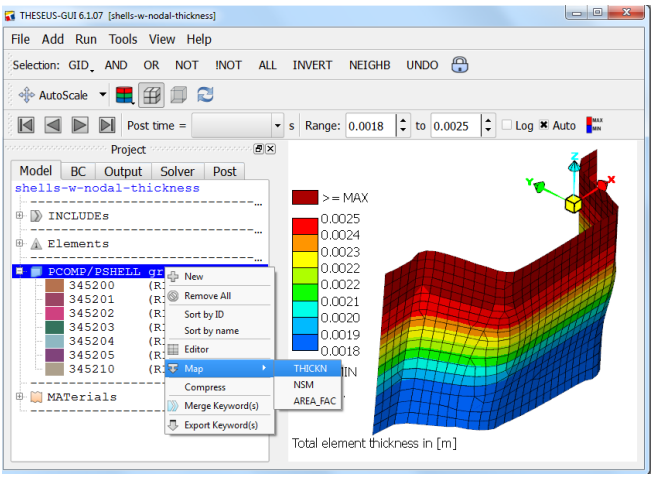
New Screenshot Dialogue

The available movie formats include:

- MPEG-4 Part 2 (using Xvid)
- MPEG-4 Part 10 (= H.264 or AVC)
- Animated GIF

Additional GUI topics

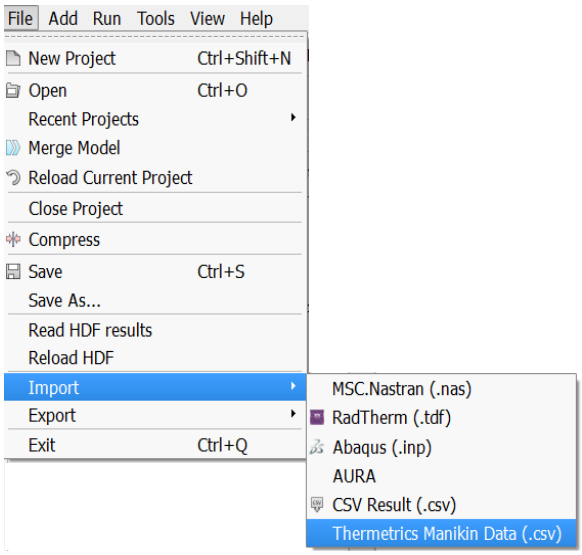
The **visualization of the shell thickness** distribution is now possible as shown below.



This is a convenient tool to check your model for correct shell thickness values!

It is now possible to use shell elements with a nodal thickness distribution stored on each CQUAD4 and CTRIA3 element. In this case it is also helpful to check it in the GUI as shown in the figure above.

New interface for hardware manikin data:
Thermetrics Manikin Data from thermal measurements on hardware manikins can easily be imported for a simulation.
A test model is included in the models for this newsletter that are available in the download section of our website.



The minor changes in the GUI include:

- Abaqus Import Interface: general improvements
- Probing Tool: spatial interpolation for hits on elements
- Optimization: replace #VAR with values from the optimization report file
- Transform Tool: new copy mode and possibility to set the translation vector by picking
- Clipping Planes: added support for rotation of planes
- Analyzer: added option to calculate exposure times on subsets and POSTDAT keywords

Generalized concept for user-defined variables

The usefulness of variables has been greatly improved with version 7 of THESEUS-FE.

Variables now …

- have unique names by which they are referenced
- can be used in nearly all input deck locations
- may contain integer, string or floating-point values
- are available in any solver module, i.e. now also in the classic thermal module
- can now also be used as convenient placeholders to define commonly used values in a single, central location

Here is an example that shows the usage of variables as convenient placeholders (red: variable names, blue: default values, green: description text):

```
$-------2-------3-------4-------5-------6-------7-------
$ boundary condition reference
VAR     BC_REF  2
$ convection: fluid temperature
VAR     conv_T  TAB1_2
$ convection: heat-transfer coefficient
VAR     convHTC 10.0
$ solver type
VAR     SOL_TYP TRANS
$ solver end type
VAR     SOL_END 25600.
$ unused variable
VAR     Unused
$-------2-------3-------4-------5-------6-------7-------
BC      C       #BC_REF POS             #conv_T #convHTC
$
SOL     #SOL_TYP                #SOL_END        100
$-------2-------3-------4-------5-------6-------7-------
```

Upgrade of FlexNet Licensing

THESEUS-FE 7.0 uses an updated version of FlexNet Licensing, namely version 11.14.0.2. Please keep this in mind when using existing license servers to serve licenses for THESEUS-FE 7.0. It will be necessary to upgrade your license server “lmgrd”, maintenance tools like “lmutil” and our vendor daemon “puzld”. Suitable versions of all programs are included in the installation packages or can be downloaded from our website separately. Be sure to stop a running license server first, such that existing files can be overridden during the installation – this is especially important on Windows systems.

End-of-support for RHEL/CentOS 5

Starting with THESEUS-FE 7.0, the support for Linux distributions RHEL and CentOS 5 is dropped. If you still need these in production, you may use version 6.1.08 which is equivalent in features to version 7.0.00.

The list of officially supported systems for version 7.0 is:
- Linux: RHEL/CentOS 6 & 7
- Windows: 7 & 10

Other modern Linux distributions should work without issues.

Further Changes and Improvements

Some smaller changes which are good to know are:
- The E-Coating solver now uses the CG solver with SSOR pre-conditioner as a default (previously: BiCGStab with ILUT) – overall this has shown to be the best setting for nearly all models
- Keyword VFCTRL is now available in the Oven module so that the user has full flexibility in choosing the refinement settings for radiation view factor calculation
- Nozzles in the Oven module now may have opening angles up to 360° which allows for virtual ball shaped nozzles for example

For a list of all noteworthy changes and improvements, please consult the release notes which accompany every installation of THESEUS-FE.

Future plans

Especially for users of the THESEUS-FE Advanced module and for Generator cabin simulations we are planning to introduce our own CFD solver in 2019. This solver will be based on the *Finite-Volume-Method*.
In a first step it will not be necessary for our users to deal with CFD meshes. New Generator cabin models with predefined fluid volume meshes will be part of version 8.

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