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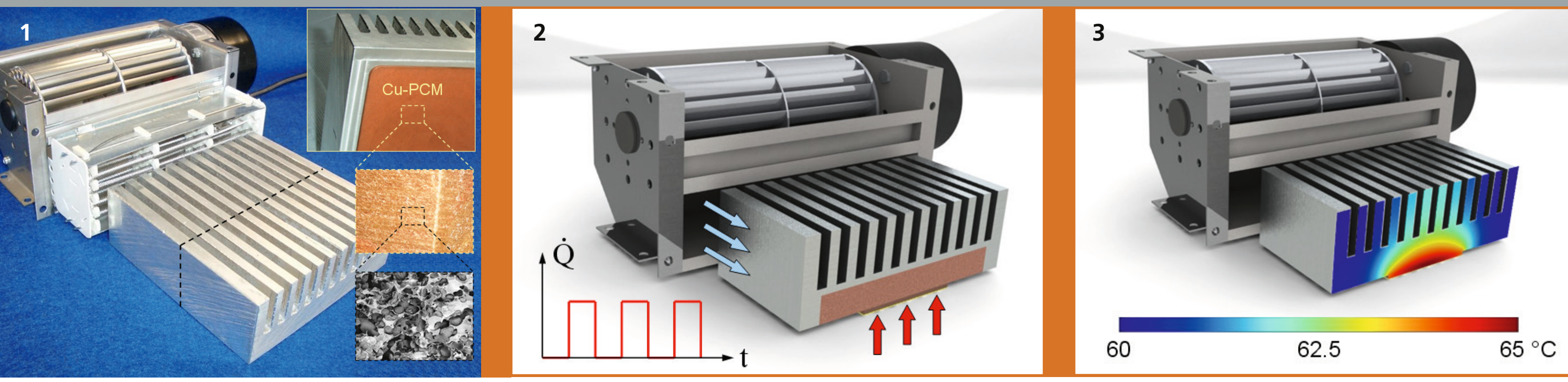
FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY
AND ADVANCED MATERIALS IFAM, BRANCH LAB DRESDEN



1 *Finned heat sink with included latent heat buffer storage (powder-metallurgically manufactured copper-paraffin-composite)*

2 *Simulation model with air flow at the finned surface and cyclic thermal load at the bottom side*

3 *Calculated temperature distribution at a special time step (paraffin melting temperature 65 °C)*

NUMERICAL SIMULATION - HEAT, FLOW, FORCE

Motivation

For the development of tailored material systems it is of basic importance to adjust the final properties according to the requirements of a later implementation in a technical system. Additionally, the optimised use of available materials mostly offers a significant improvement of the system performance. In all cases the investigation of the special system behaviour is needed.

In comparison to a mostly very expensive experimental method numerical simulations represent a flexible and cost-efficient alternative solution. Special advantages are the comfortable variation of different influencing parameters as well as the modelling of operating conditions which could not be investigated experimentally. Any successful numerical simulation requires a detailed understanding of the basic physical phenomena.

Simulation competency

Additional to multiple experiences in programming individual solution procedures at the Fraunhofer IFAM Dresden, an efficient software package (COMSOL Multiphysics) is available for the numerical simulation of multi-physical phenomena. The modelling of heat and mass transfer problems, fluid and electrical flow and phase changes are possible in the same way like mechanical stresses, chemical reactions and the coupling of all these effects.

Typical applications are:

- calculation of steady-state and transient temperature fields in (an-)isotropic bodies,
- modelling of velocity and pressure distributions,
- simulation of heat conduction, convection and radiation and
- determination of thermo-mechanical stresses in composites.

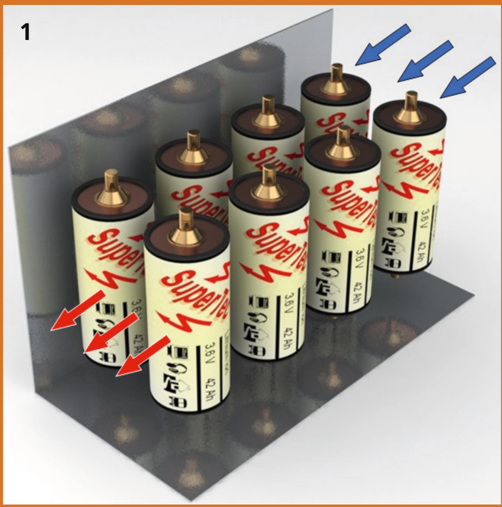
Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM Dresden Branch

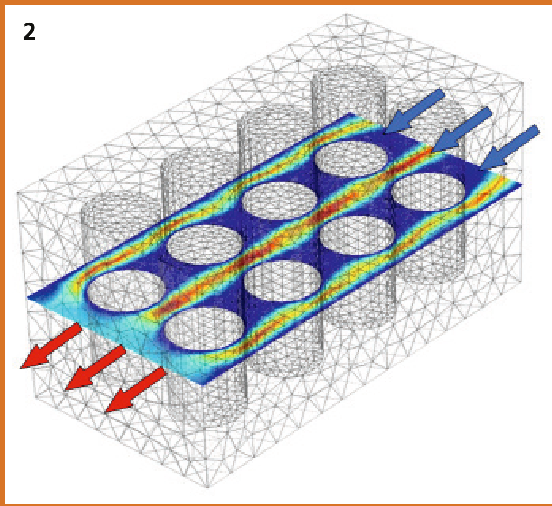
Winterbergstrasse 28
01277 Dresden I Germany

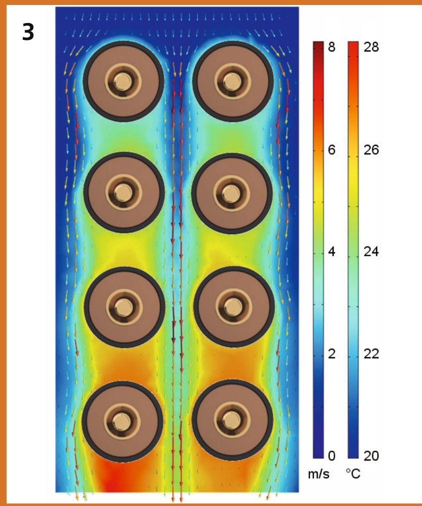
Contact

Dr.-Ing. Marcus Rohne
Phone +49 351 2537 472
Telefax +49 351 2537 399
E-Mail: Marcus.Rohne@ifam-dd.fraunhofer.de

www.ifam-dd.fraunhofer.de







Criteria of success

The reliability and clearness of numerical simulation as a preliminary stage to an engineering validation depend on different factors, the most important are

- the simplified and qualified reproduction of the system which has to be described,
- the numerical discretisation adopted to local and temporal gradients,
- the availability of reliable properties and transport coefficients,
- the choice of a convergent solution procedure and
- the professionally based interpretation of the final results.

The use of commercial software packages is not always necessary. More simple problems often are to be programmed in a time efficient and scientifically transparent way based on own algorithms (e.g. in MS Excel).

The business unit *Energy and Thermal Management* comprises many years of experience in modelling diverse physical phenomena by means of analytical and numerical methods. This includes

- the derivation and simplification of the differential equations describing the problem including boundary and initial conditions,
- the choice of numerical consistent solution algorithms and their programming,
- the experimental determination, empirical simulation and software implementation of required properties and transport coefficients,
- the evaluation and interpretation of the calculated results and their representative graphical visualisation.

The measurement of needed material properties and transport coefficients as well as the validation of numerical results with prototypic technical devices using experimental methods are supported by the high-class equipment of the thermo-technical laboratory at Fraunhofer IFAM Dresden.

Selected applications

Selected applications, which could be simulated by means of numerical methods, are presented in the different figures. For instance, the calculation and experimental investigation of time-dependent temperature distributions in a finned heat sink is shown. To buffer cyclic thermal load peaks this heat sink includes a composite material manufactured at Fraunhofer IFAM Dresden which consists of each 50 vol.-% copper and paraffin (phase change material, latent heat storage).

A further example is the thermal management of heat generating electric storage cells – arranged to a battery configuration

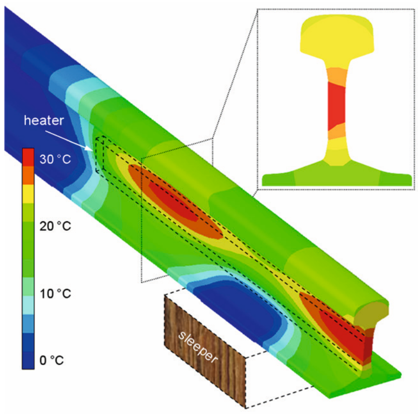
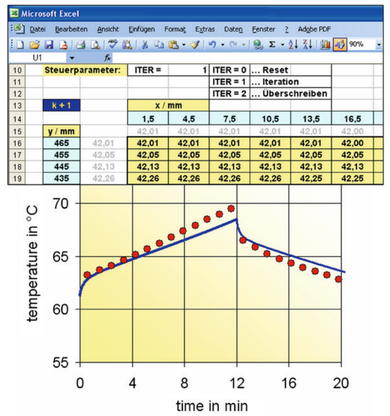


Fig. 1 Temperature distribution on a railway track with lateral heater



10	Steuerparameter:		ITER =	1	ITER = 0	... Reset			
11					ITER = 1	... Iteration			
12					ITER = 2	... Überschreiben			
13	k + 1		x / mm						
14			1,5	4,5	7,5	10,5	13,5	16,5	
15	y / mm		42,01	42,01	42,01	42,01	42,01	42,00	
16	465	42,01	42,01	42,01	42,01	42,01	42,01	42,00	
17	455	42,05	42,05	42,05	42,05	42,05	42,05	42,05	
18	445	42,13	42,13	42,13	42,13	42,13	42,13	42,13	
19	435	42,26	42,26	42,26	42,26	42,26	42,25	42,25	

Fig. 2 Transient temperature plot from an Excel-simulation compared with measuring results

– by means of an air flow. Based on the measurement of heat generation rates in a single cell depending on the charging electric current a qualified flow and heat transfer model was created and used to simulate various operating conditions.

The list of typical technical systems which could be designed effectively and reliably using numerical simulations is to be continued almost arbitrarily. Finally are named

- the calculation of temperature distributions in a railway track with extruded metal profiles to contact the turnout heating thermally,
- the determination of the temperature of a LED as light and especially heat source considering thermo-mechanical aspects at the junction of different materials.

1 *Scheme of an air cooled battery consisting of eight cylindrical cells*

2 *Calculation grid for simulation of heat transfer and flow*

3 *Velocity and temperature distribution (top view)*