Motivations for 1D Simulation in a 3D World

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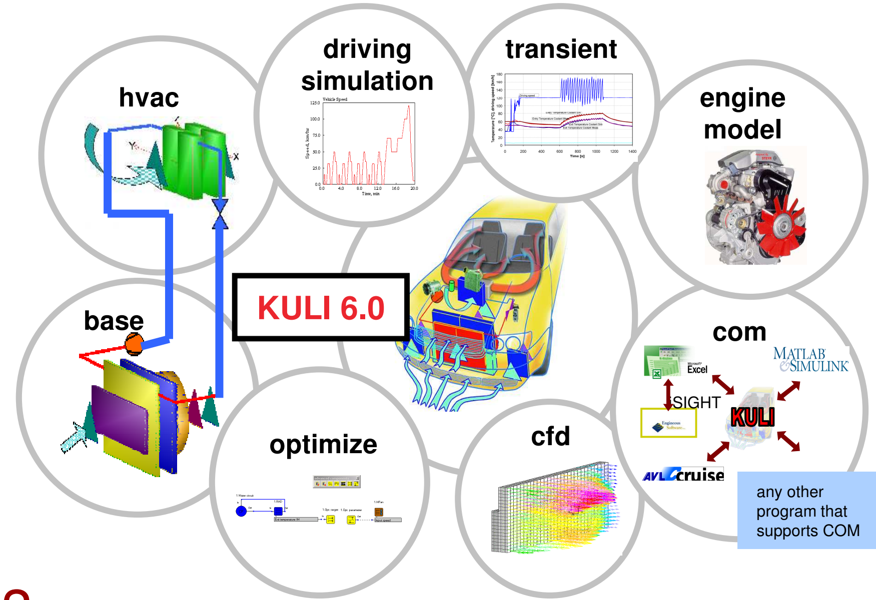
KULI 6.0 - A 1D Simulation Tool

In **Version 6.0** KULI is still a mainly **one dimensional** simulation tool.



This raises some fundamental questions:

- Is KULI still „state of the art“ ?
- Is KULI based on outdated technology ?
- Is there a use for 1D simulation in a 3D world ?

In the following we shall try to find answers to these questions…

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Is 1D Simulation Outdated?

Faster computers and better algorithms make 3d simulation more and more feasible. Computational time goes down, while the quality of the results improves.

But:

- *Computational effort is still quite high* and requires investment in *expensive* top level computers.
- Definition of precise boundary conditions, geometry and meshes is still *a lot of work, most of which cannot be automated.*
- *Sometimes 3d results are simply not required for answering specific questions.*

How KULI combines 1D and 3D Elements

As KULI is a 1d Tool, we get

Very short computation times: Usually some seconds instead of several hours!

Where 1d simulation alone would not lead to sufficiently precise results,

KULI offers the possiblilty to work with 3d data generated by external tools, although KULI does not generate 3d data itself.

The Range of Application for 1D Simulation

1 dimensional simulation of course *cannot replace 3d methods where 3 dimensional results are required* (e.g. the air flow in a passenger cabin), but…

… where one is only *interested in 1d results* (e.g. the exit tem-perature of a cooler), the necessary *precision* can often be obtained by basically 1d approaches.

Combining classical 1d (2d) methods with more advanced strategies often leads to *highly accurate* results in comparatively *very short time*!

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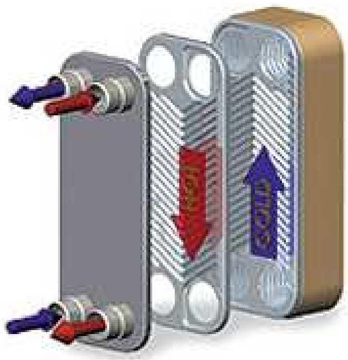
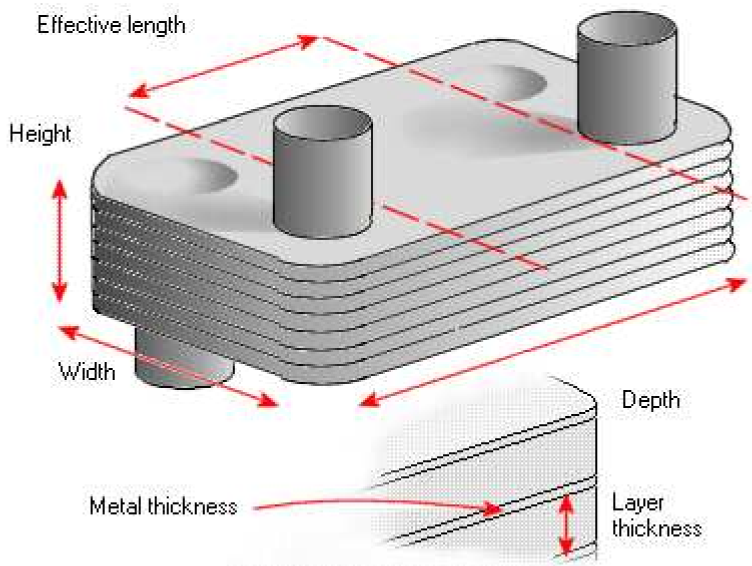
Modelling a Plate Heat Exchanger





Requirements on a Plate Heat Exchanger Model

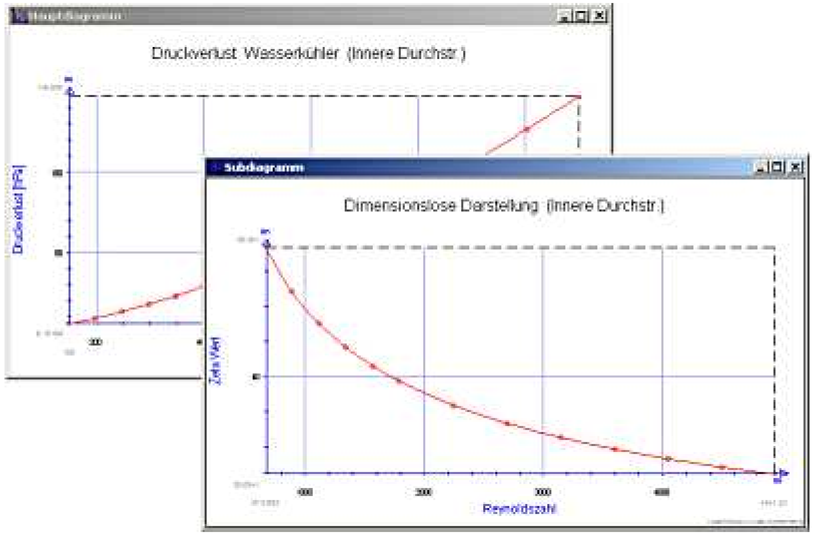
Requirements on the model are:

- The plate heat exchanger should be compatible to other KULI components in design and interface.
- *Only easily measureable data* should be required.
- It must be *fully scaleable* (dimensions, number and configuration of the plates)
- Modelling and simulation have to work almost *completely automated*.

Required results are…

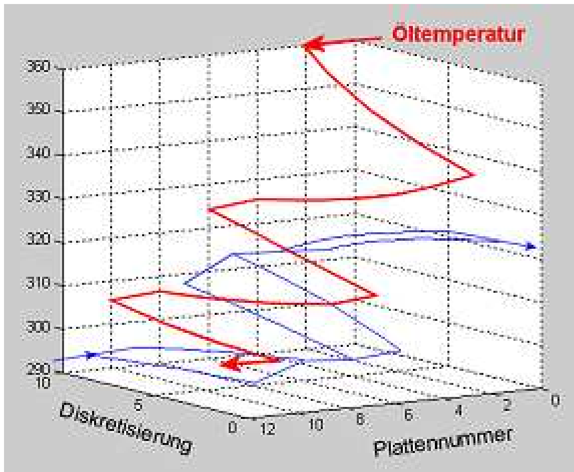
- ***Pressure loss***

  How much pressure is lost in the media on both sides of the plate heat exchanger?



- ***Heat transfer***

  How much heat is transfered from one medium to the other? What are the resulting exit temperatures?



Standard KULI Calculation Method

Characteristic lines approach:

Automatic Conversion

Measured Data (unit dependent)	**Nondimensional Characteristic Line**
Easy and direct Input of measured data!	Easily scaleable! (Operating points and dimensions)

Characteristic Lines Approach for the PHE

- **Works well for the calculation of the pressure loss!**

  Based on a *pressure loss characteristic line for one plate*, arbitratry configurations can be evaluated.

- **Characteristic lines approach does not work for heat transfer!**

  The plates *can not be described independently* from each other, therefore scaling becomes *very complicated and imprecise*.

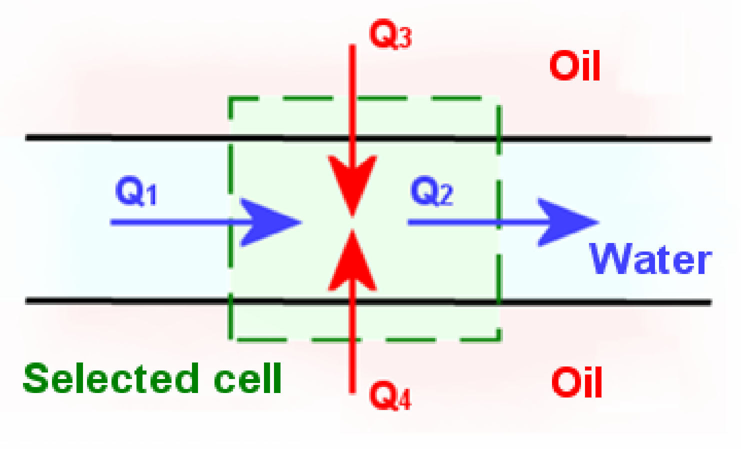
A Description Using Finite Differences

Q_1 … Heat flow into cell (water)

Q_2 … Heat flow from cell (water)

Q_3 … Heat conduction from oil (from above cell)

Q_4 … Heat conduction from oil (from cell below)



Applying a *stationary equilibrium condition* yields:

$$Q_1 + Q_3 + Q_4 = Q_2$$

Advantages and Disadvantages of Finite Differences

Pro:

- Makes *temperature data available for the whole cross-section* of the plate heat exchanger!
- Direct calculation means that there are *no restrictions regarding scaling*!

Con:

- Successful calculation now requires *information on local heat transfer* and flow properties as well! This data is very *complicated to obtain*!

Solution to the Problem

- The local heat transfer is described by a *parameterized function α(Par)*.

$$\alpha_{ij} = o + c \cdot \mathrm{Re}_{ij}{}^{m} \cdot \mathrm{Pr}_{ij}{}^{n}$$

$$Par = \{o, c, m, n\}$$

- The measured data is then used to *automatically determine parameters, so that α(Par) describes the measured heat transfer*.

- By doing so we have *completely described* the finite difference model for the plate heat exchanger *without requiring additional complicated data*!

An Optimization Problem

Formally writing this as:

Find parameters Par so, that

$$\left| Q_{CALCULATED}(Par) - Q_{MEASURED} \right| \xrightarrow{\lim} 0$$

where Q … total heat exchanged in the plate heat exchanger.

We get an *optimization problem*!

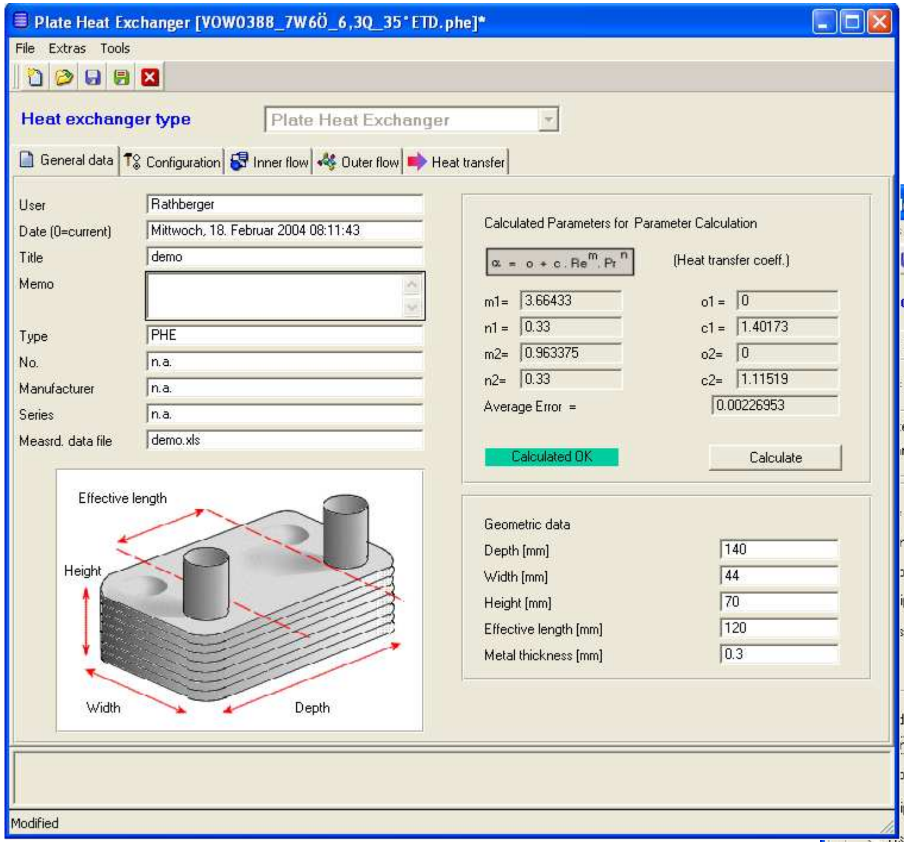
Usage of the Plate Heat Exchanger

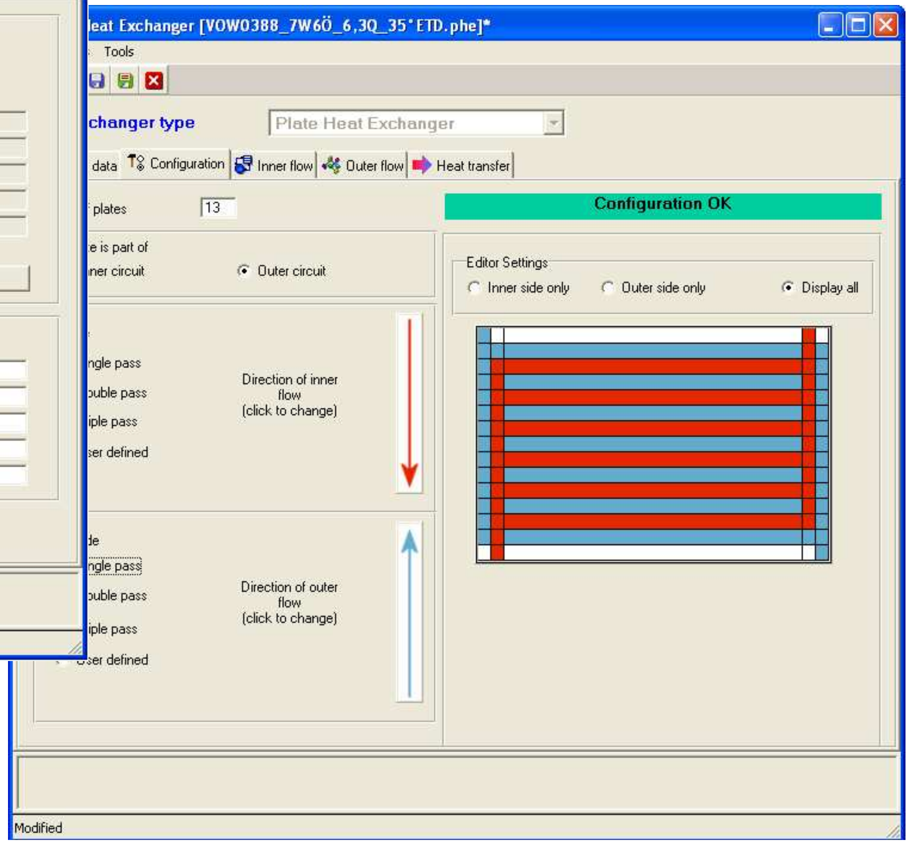
1) The user has to *specify geometry, configuration, pressure loss data and heat data*.

2) The *automatic optimization* process can be started when all required input data is available. Calculation can take several minutes.

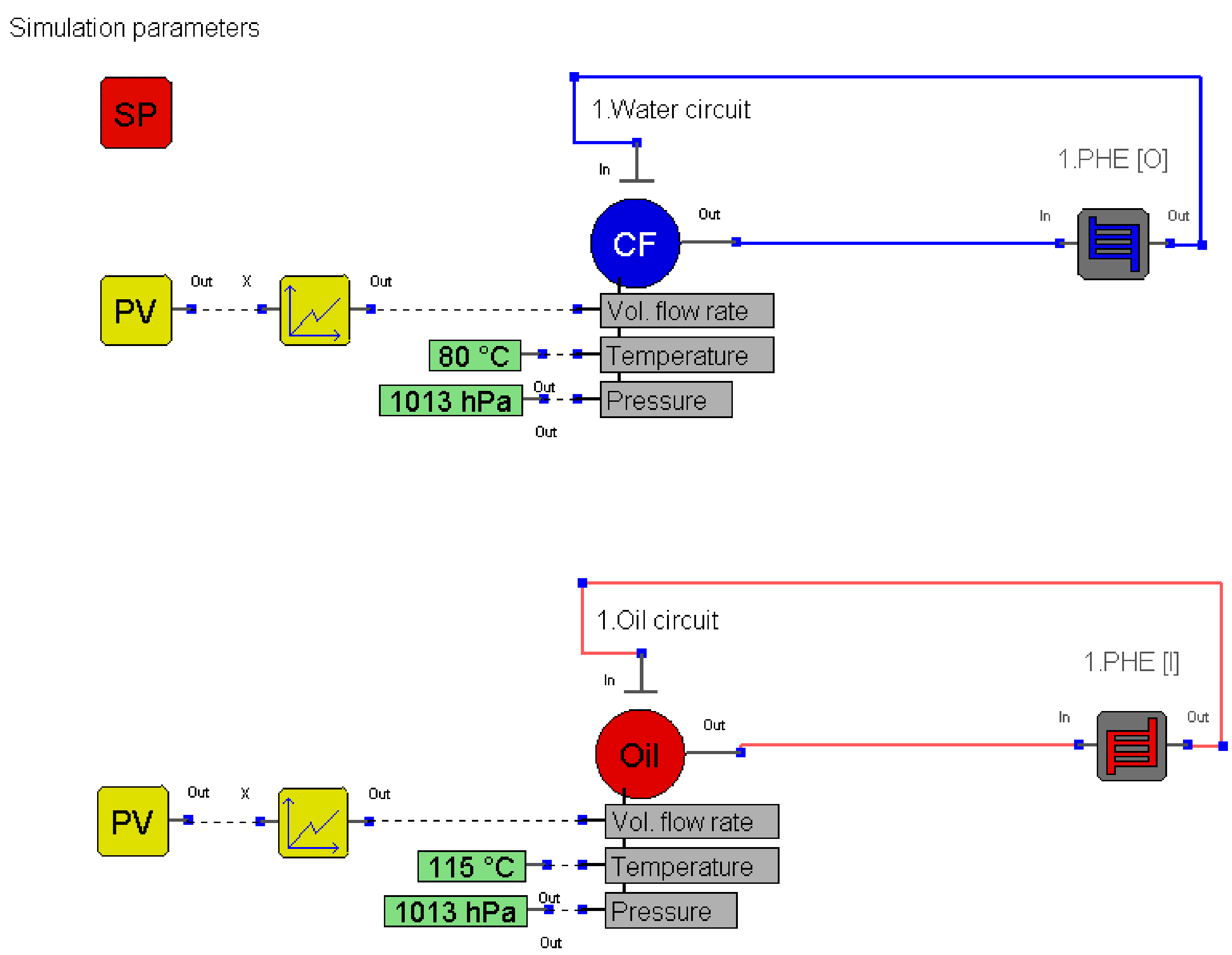
3) With the parameters for the local heat transfer determined, *the plate heat exchanger can now be used in KULI!*

The KULI User Interface for the PHE

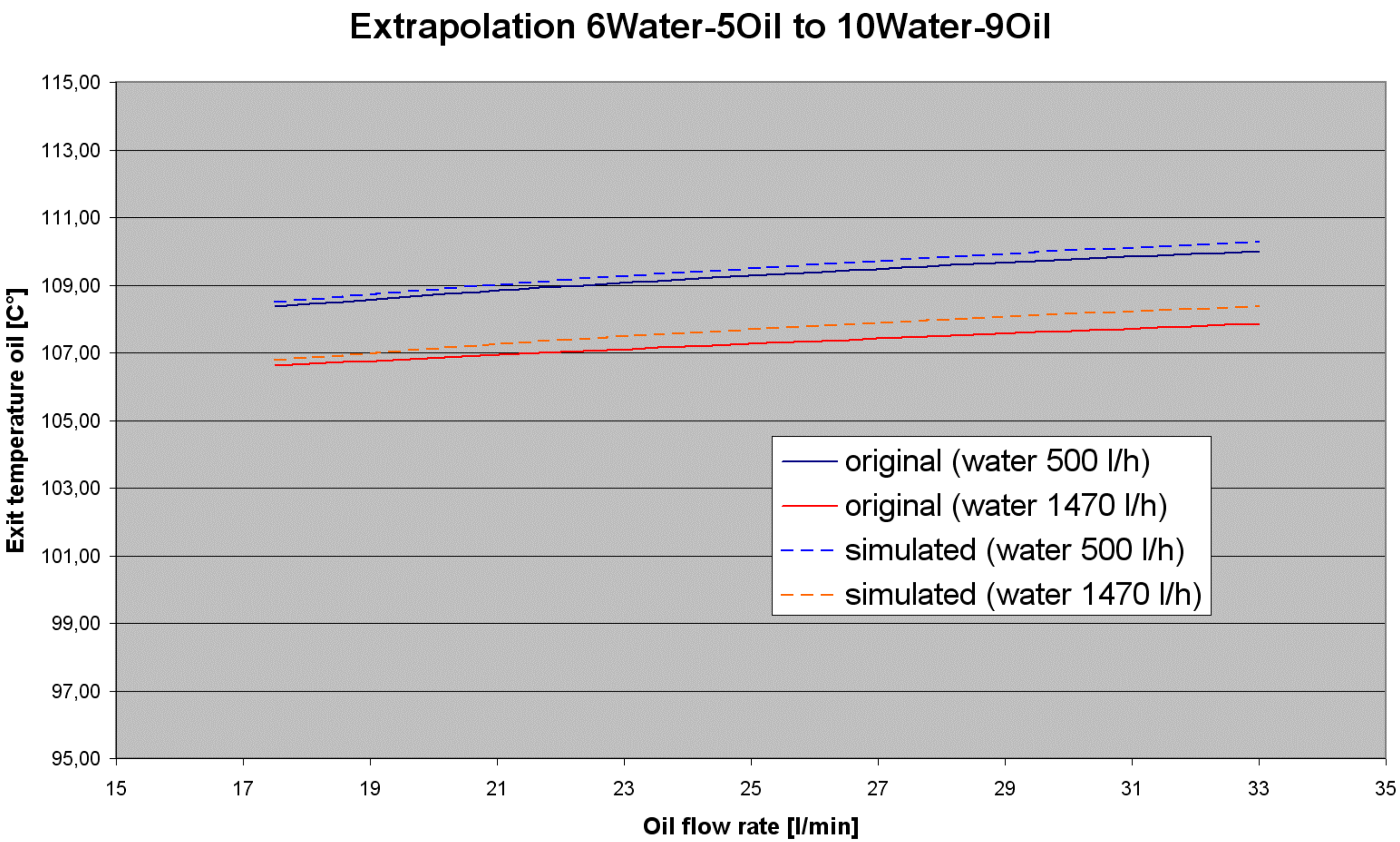




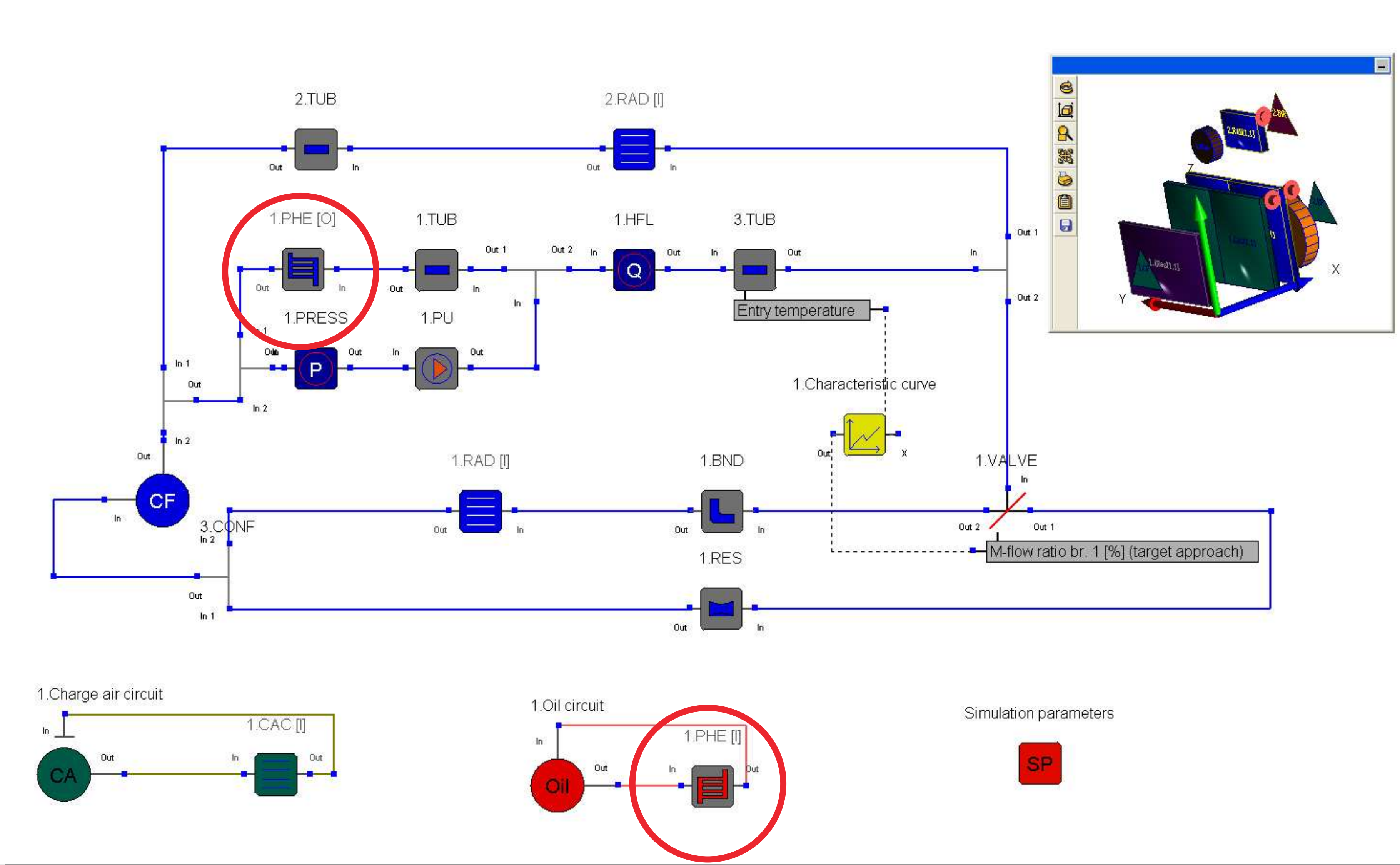
A Simple Parallel Heat Exchanger Testbench



Scaling the Number of Plates



Using a Plate Heat Exchanger in a Simple Car Model



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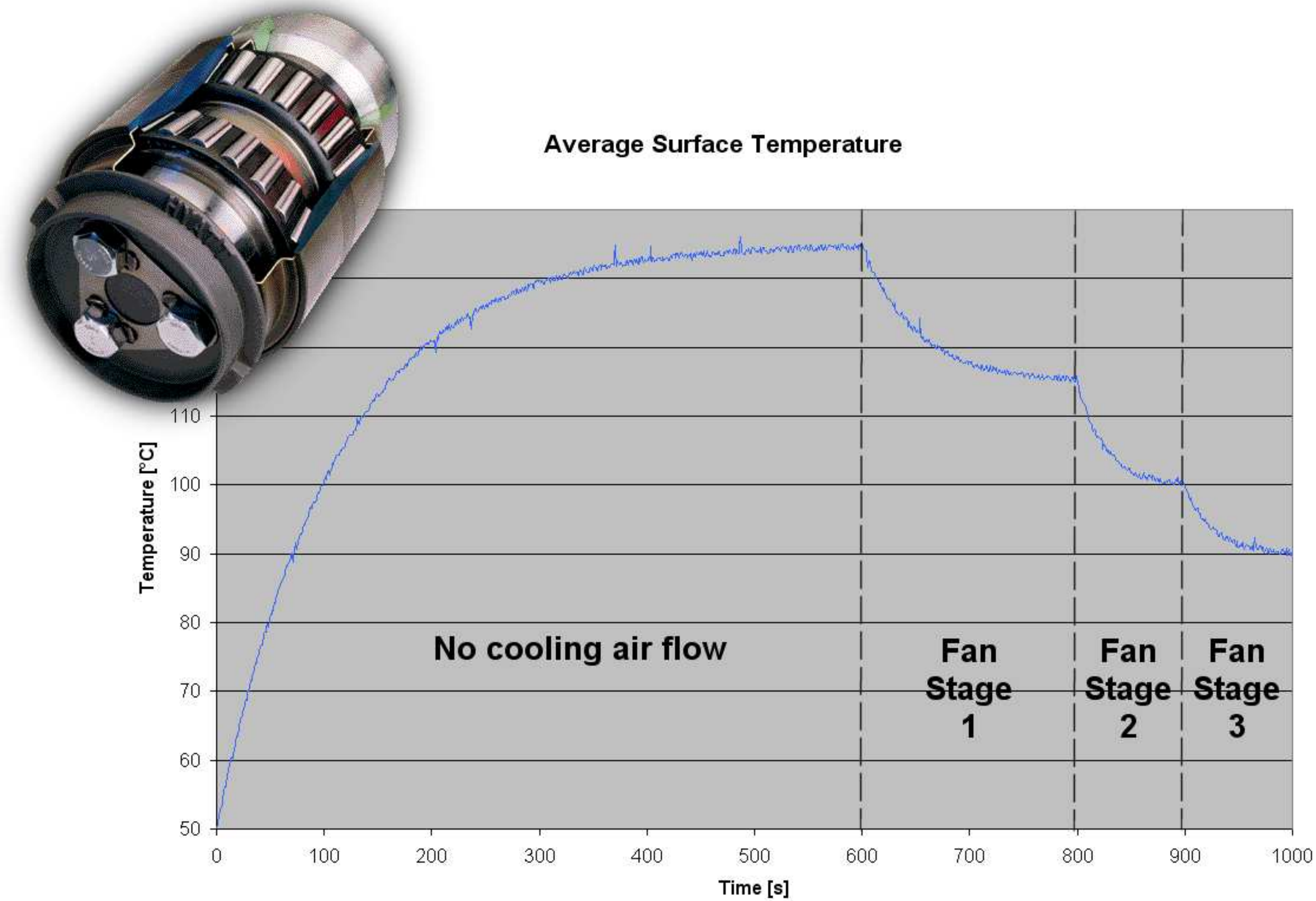
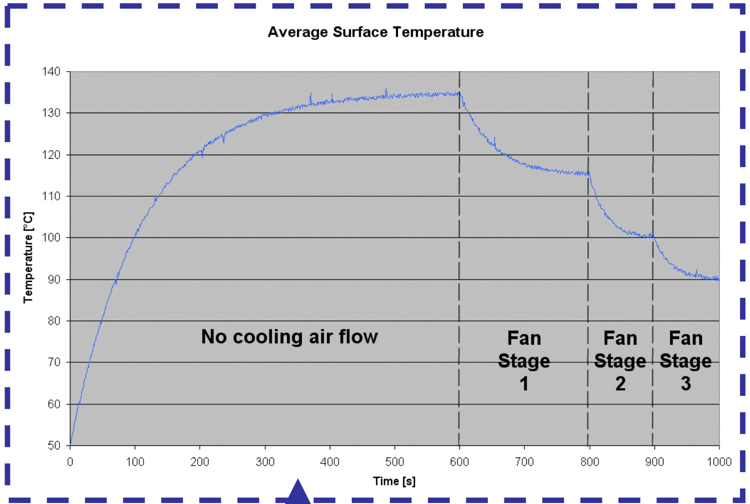
Measured Temperature Pattern of a Component

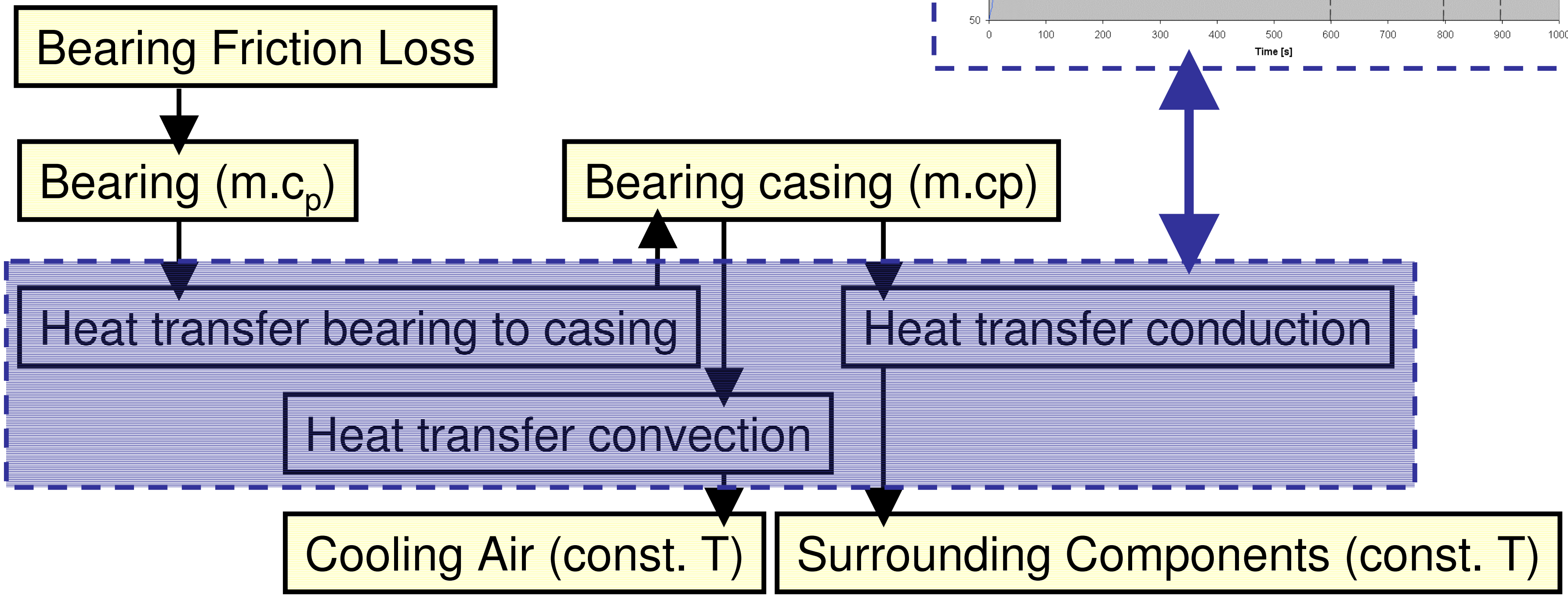


Calibrating an Excel Model

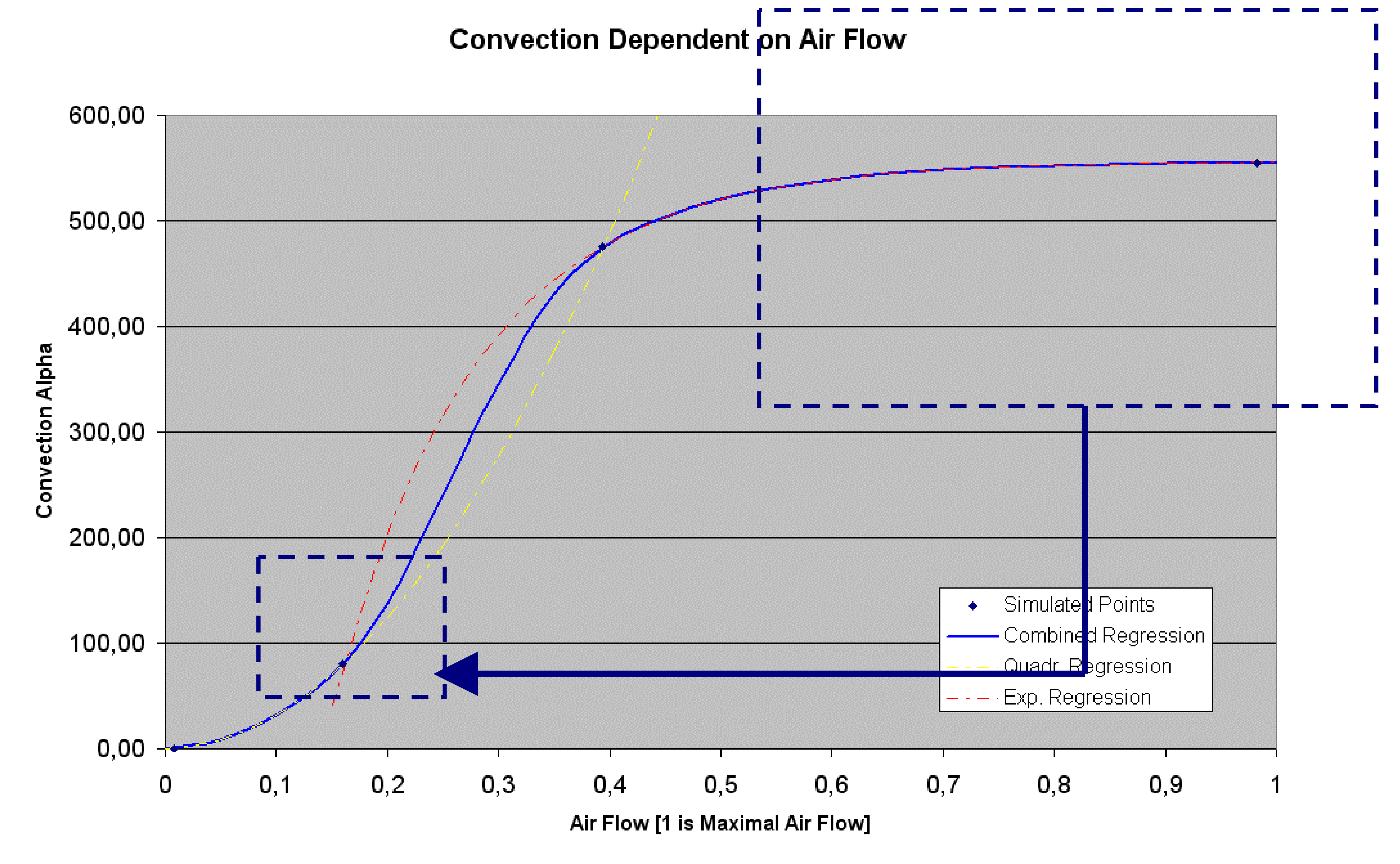
First the system is described in an *EXCEL model*.

Then the *heat transfer coefficients are calibrated* using the measured temperature pattern.

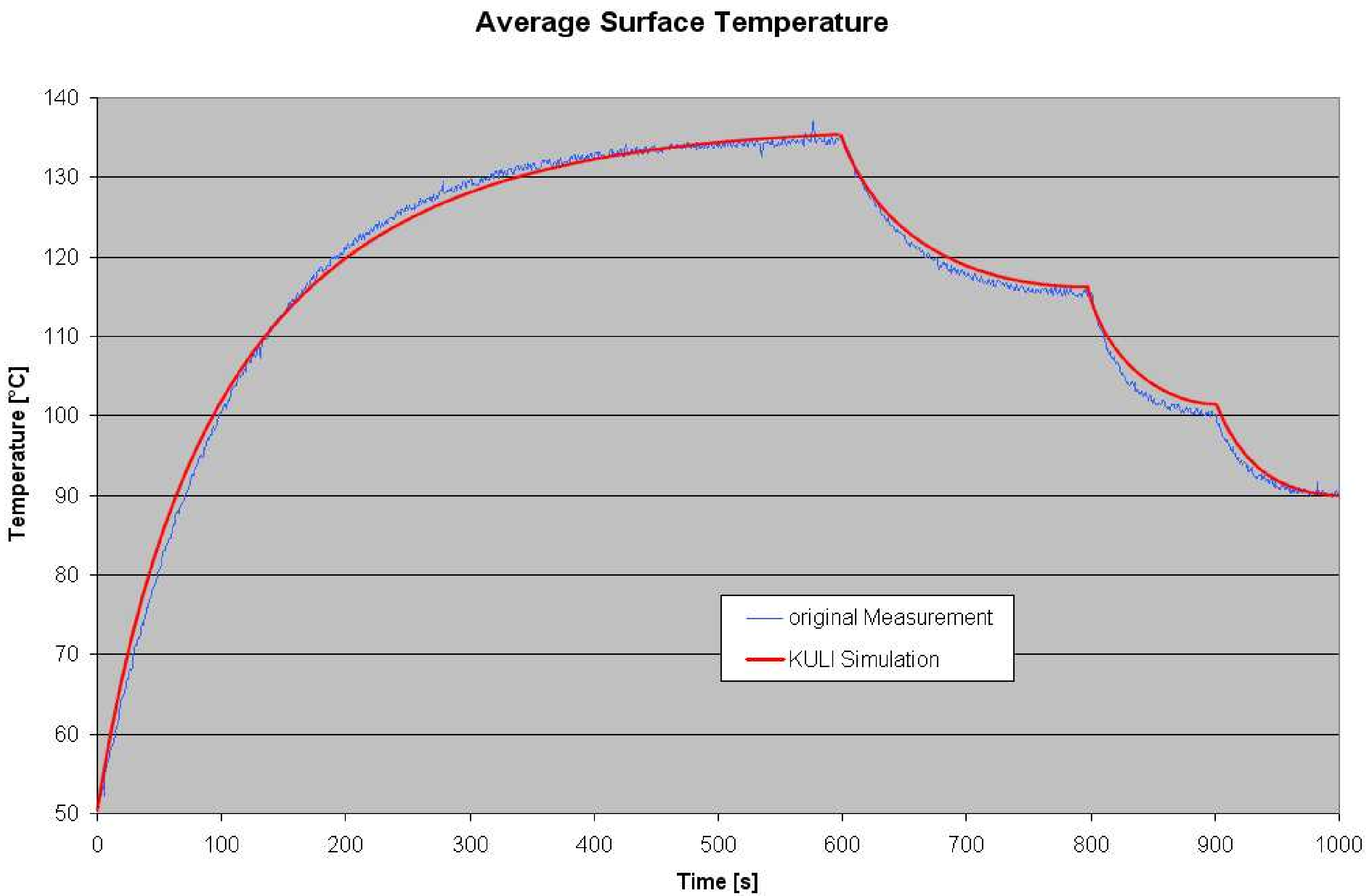




From Excel to a KULI Model



Verification of the KULI Model



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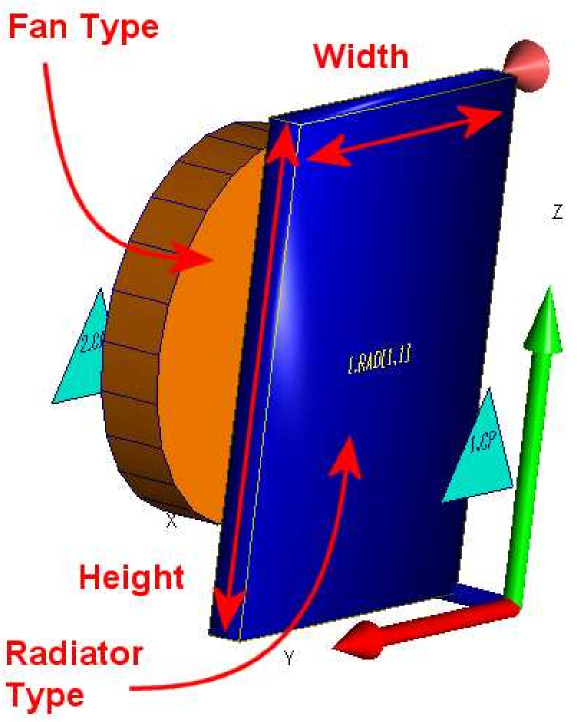
A Simple Example for a Concept Study



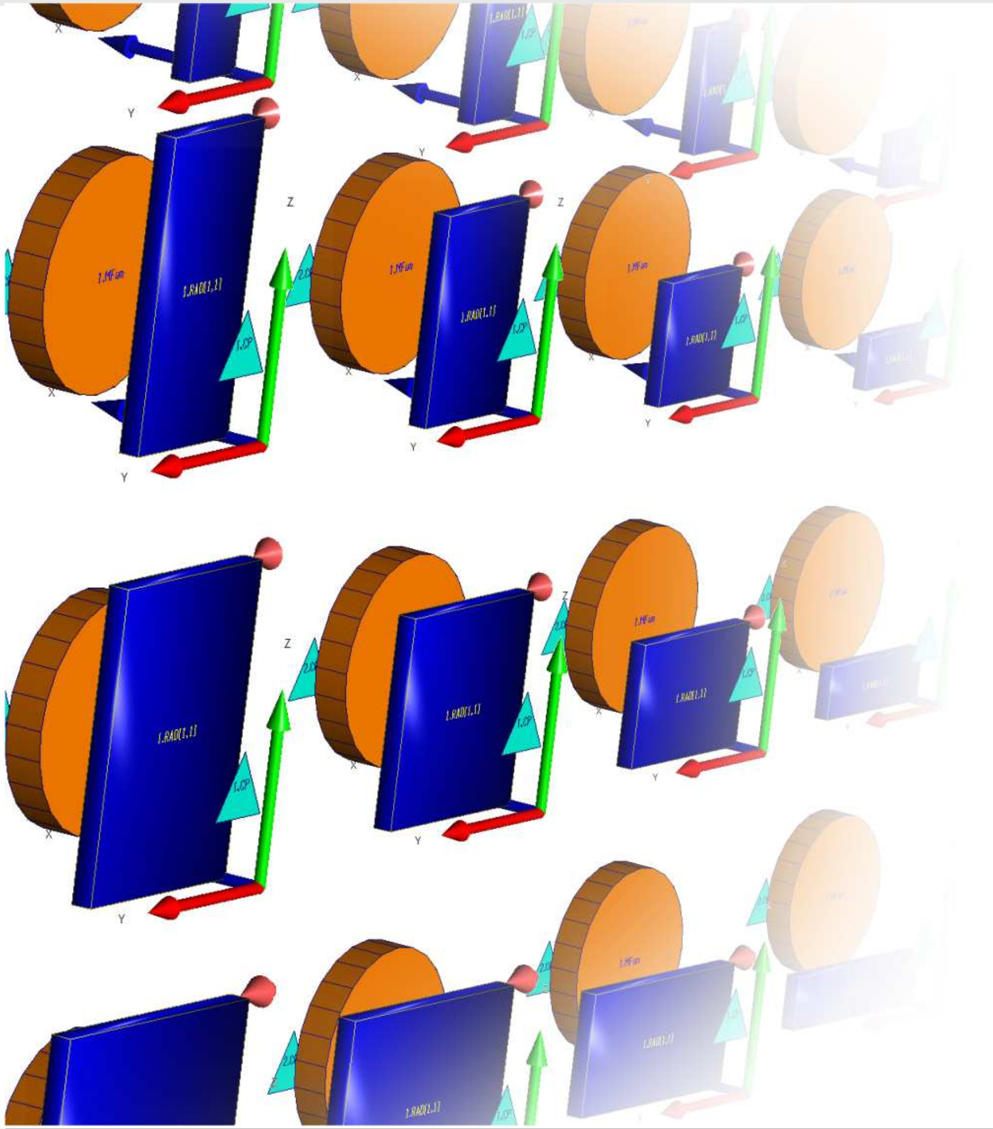
A specific cooling system contains several components with certain dimensions (e.g. width or height).

If we can change some or all of these parameters,

Which possible configuration is the best?

The easiest solution is to simulate all possible configurations and simply find out…

The Difficulty Behind Case Studies



Let us assume that we have…

4 parameters

which can each assume

20 different values.

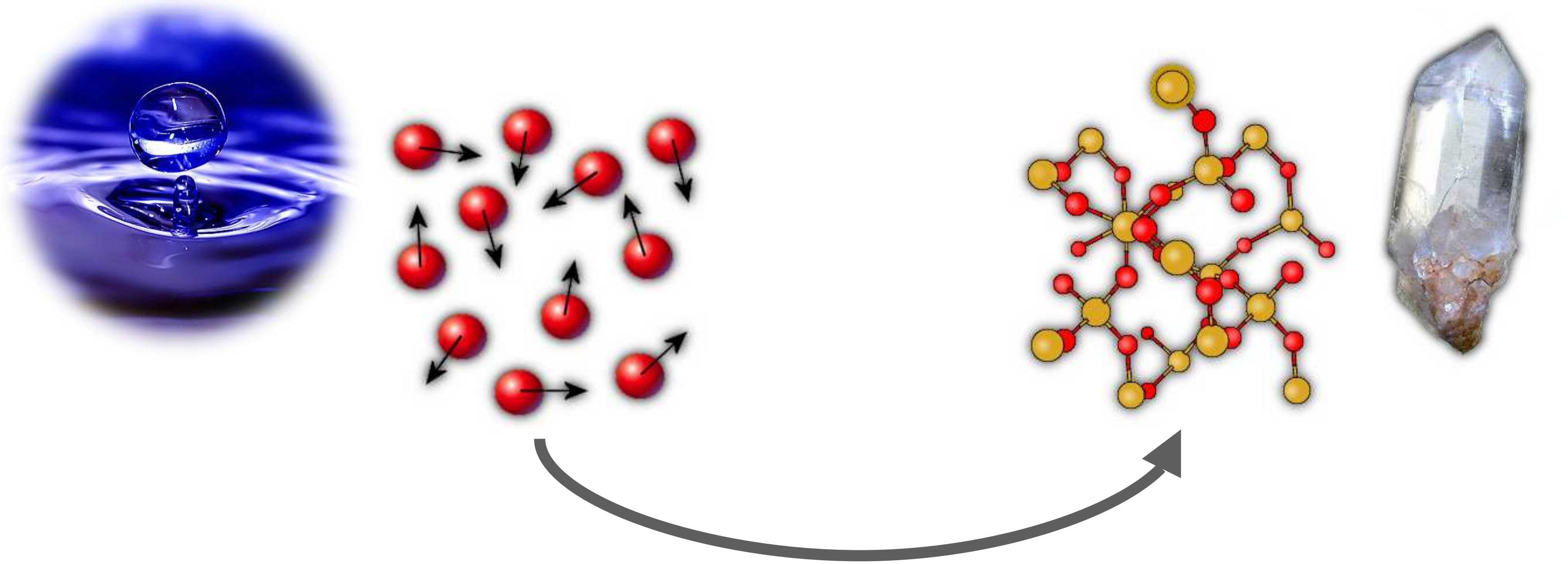
This leads to

20^4 = 160.000

possible configurations!

We´ve got a problem!

How Nature Solves this Problem



Slowly cooling down a fluid (random initial state) leads to crystallization (energetically optimal final state).

Nature finds an optimal solution!

Some Mathematics…

Depending on the *temperature*, the molecules move more or less.

$$par_{new} = par_{old} + rand(T)$$

This can lead to *energetically better or worse configurations*.

$$dE = E(par_{old}) - E(par_{new})$$

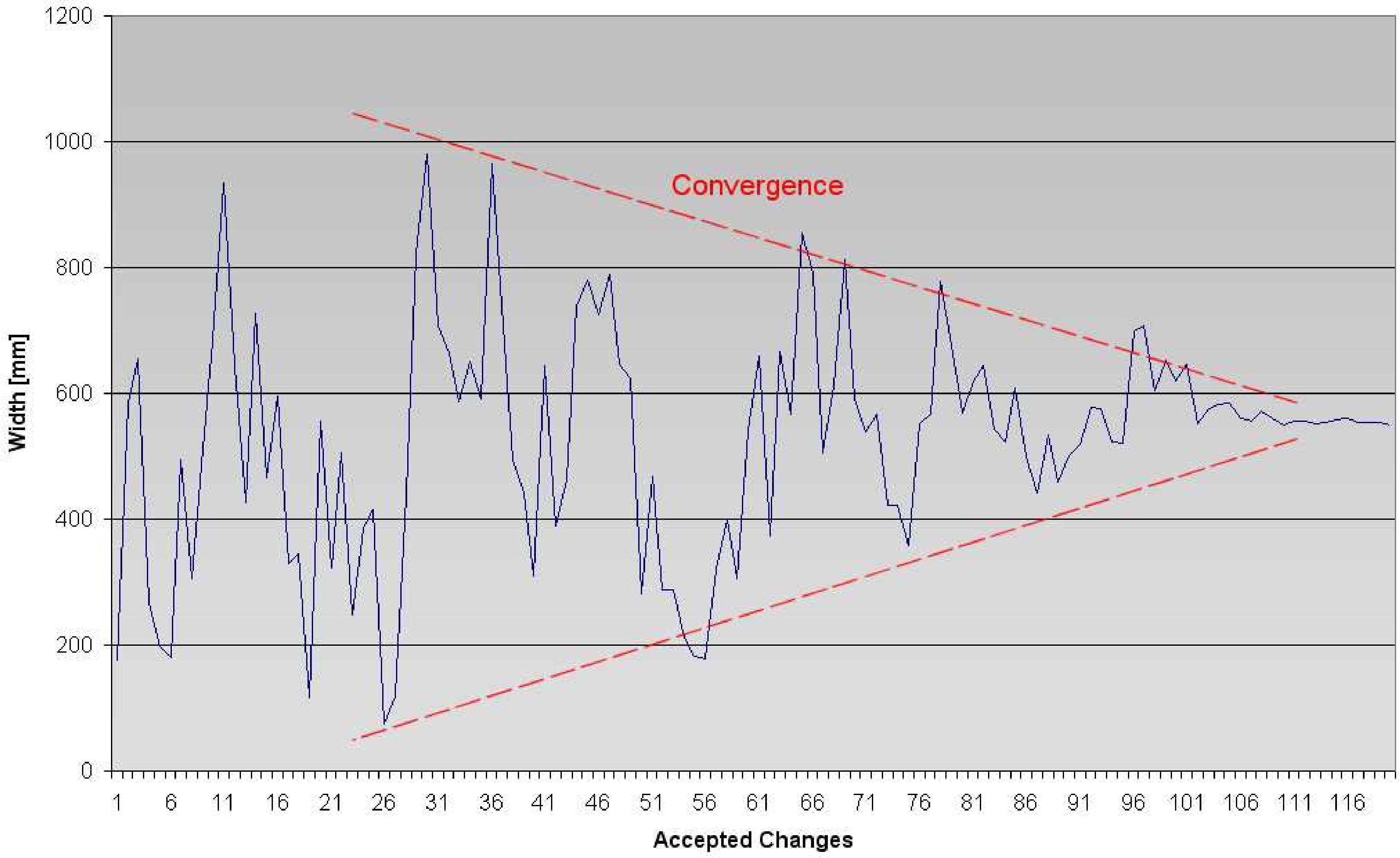
For *low temperatures*, there is only enough energy for changes *´down´ to energetically lower (=better) configurations of the molecules*.

$$prob(dE) = \min(e^{-\frac{dE}{T}}, 1)$$

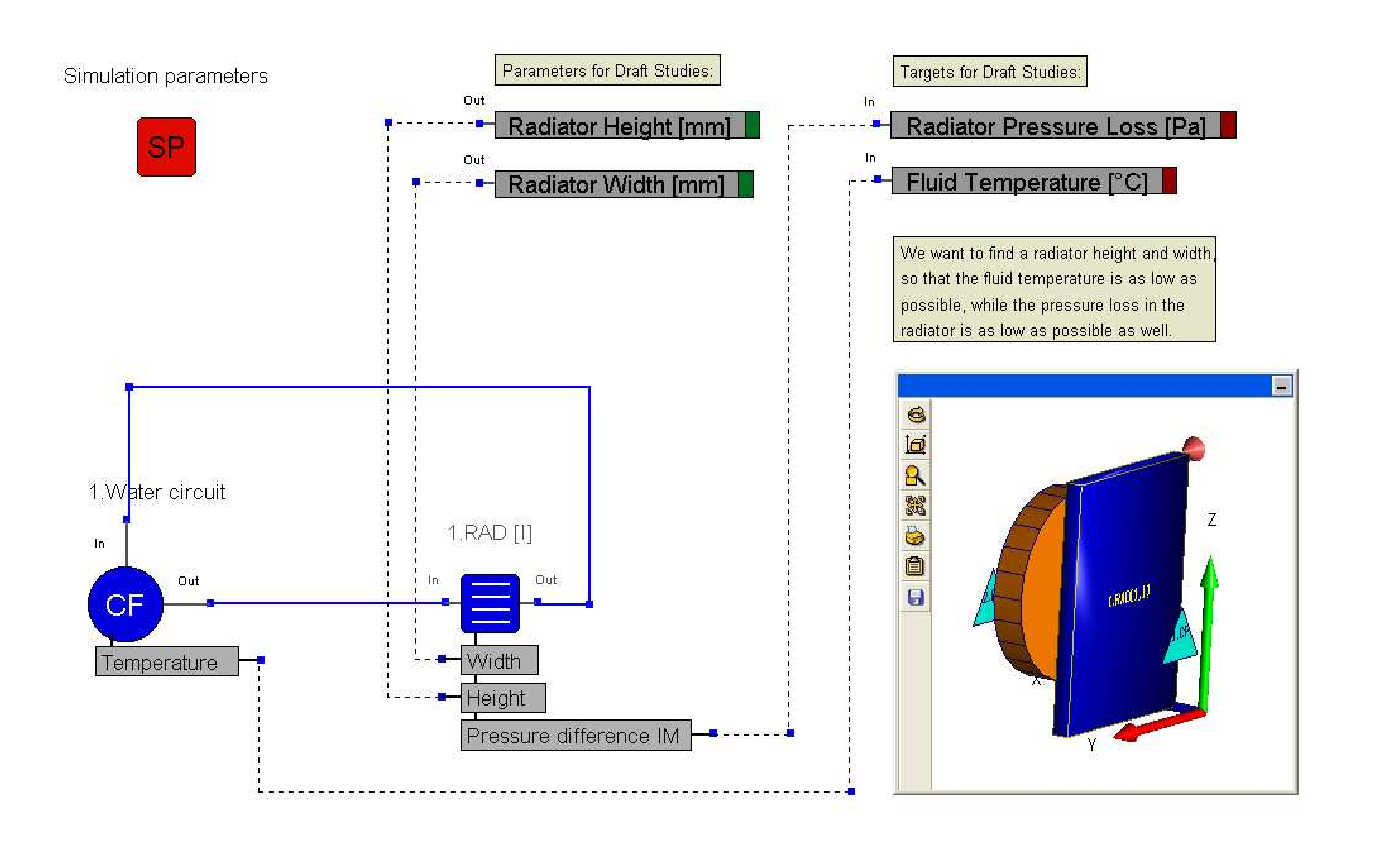
If the cooling down process is slow enough, an *optimal configuration is reached!*

$$E \xrightarrow{par \rightarrow par_{ideal}} \min$$

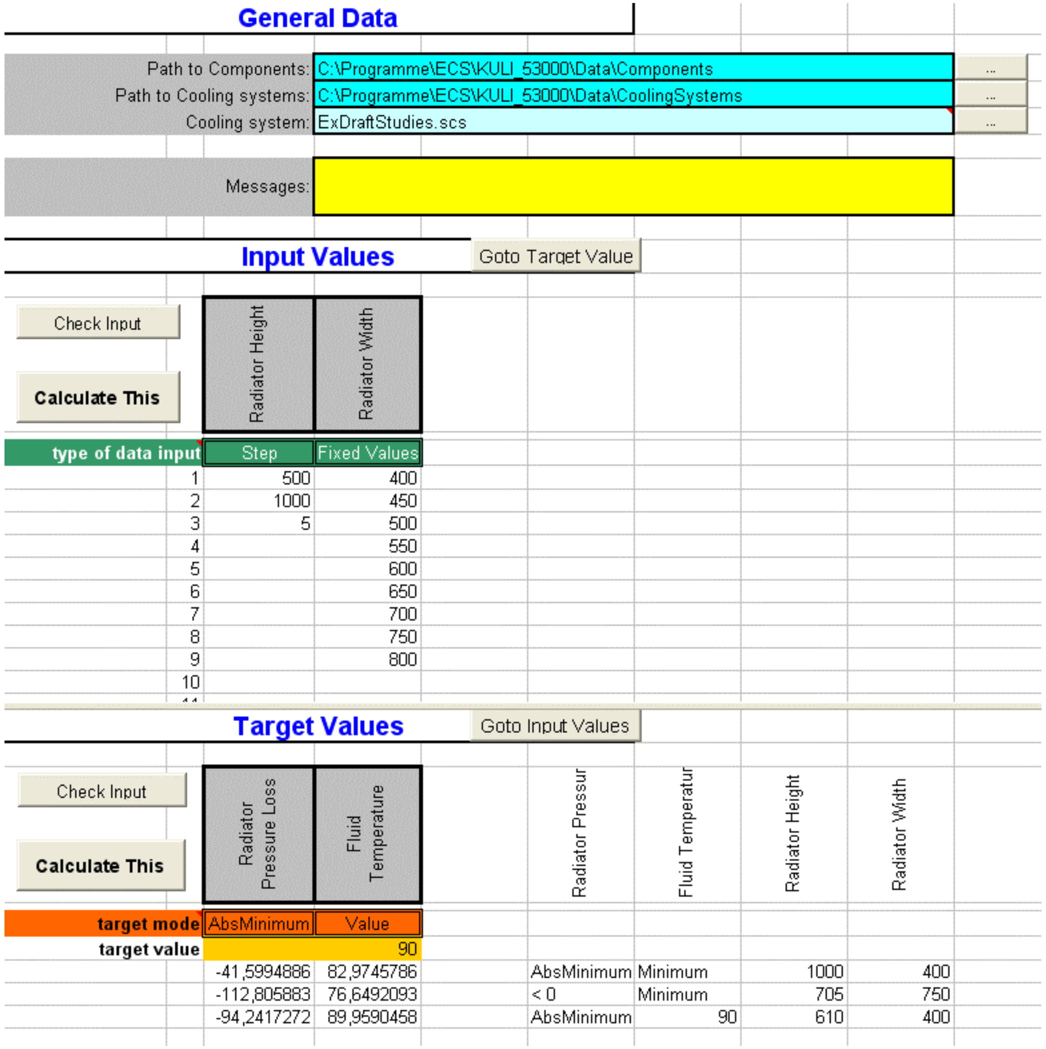
Convergence of the Simulated Annealing Algorithm



A KULI System Prepared for Draft Studies



The Draft Studies Interface



Parameter ranges can be defined by:

- A set of possible values
- An Interval with stepwidth
- Filenames

Possible *targets* are:

- Min or AbsMin
- Max or AbsMax
- A target value
- Smaller or larger than a limiting value

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Conclusions

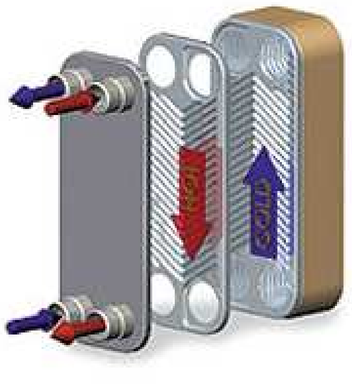
Let´s return to the question from the first slide:

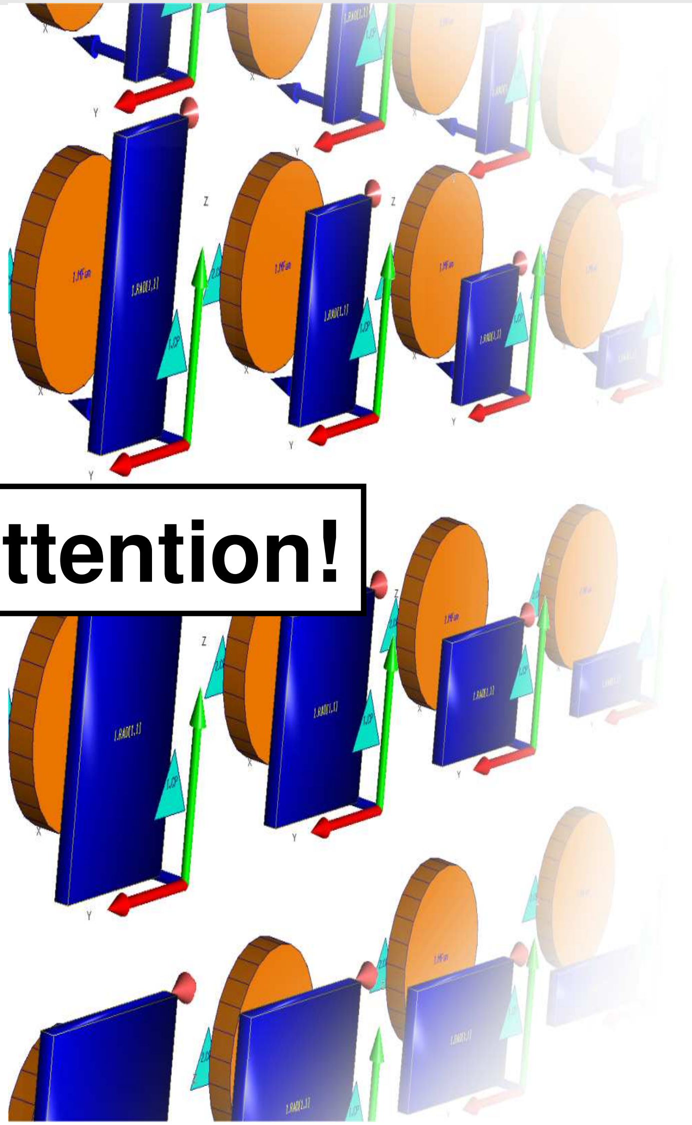
Is 1d simulation outdated?

No, it is definitely not!

For many applications the required results do not justify the much higher effort of 3d simulation. And due to much more complicated boundary conditions, often 3d simulation cannot guarantee better results a priori.

Especially in the *area of optimization and concept studies* 1d simulation tools like KULI make *important contributions to ongoing innovations*.





Thank you for your attention!