



Forward. For all.

FEMEFAT MELCOM Software

Christian Neubacher, MSc

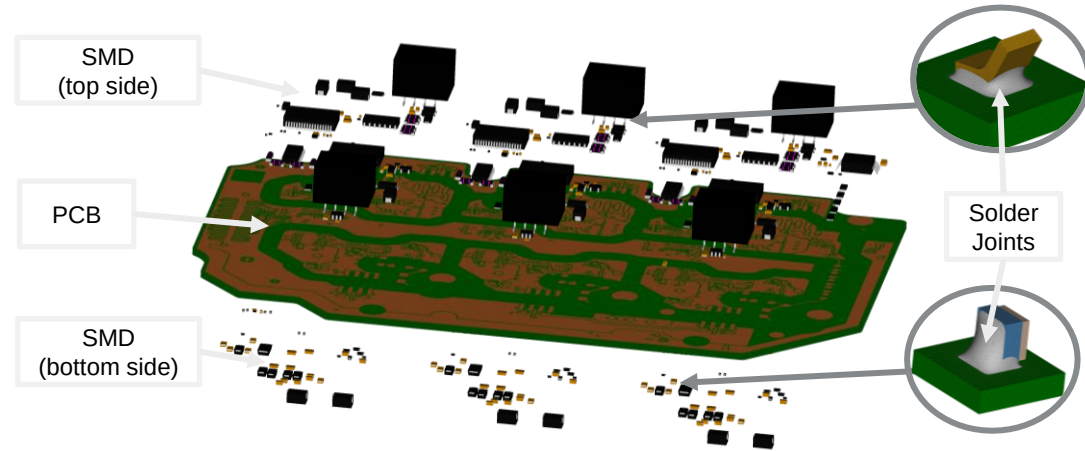
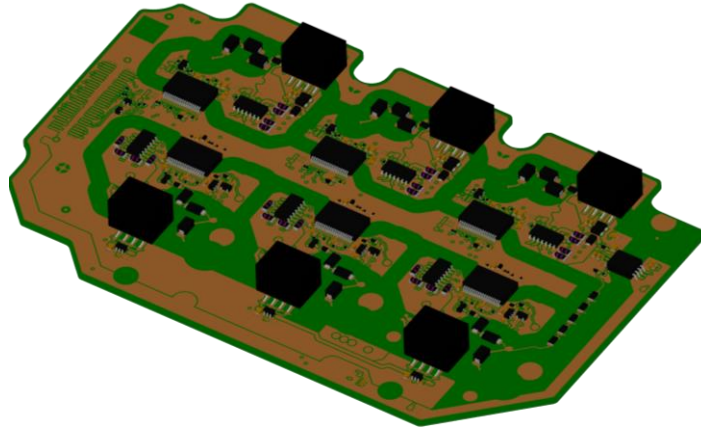
Engineer Dynamics and Acoustics

Date 2025-05-14

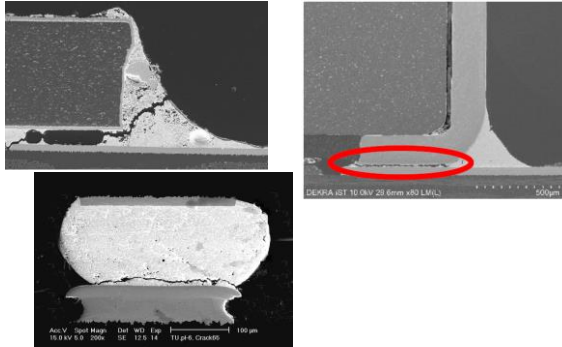
Agenda – FEMFAT MELCOM

- 01** Overview
- 02** Modelling Techniques
- 03** Solder Joint Fatigue Analysis
- 04** Chip Crack Analysis
- 05** Thermo-mechanical Analysis

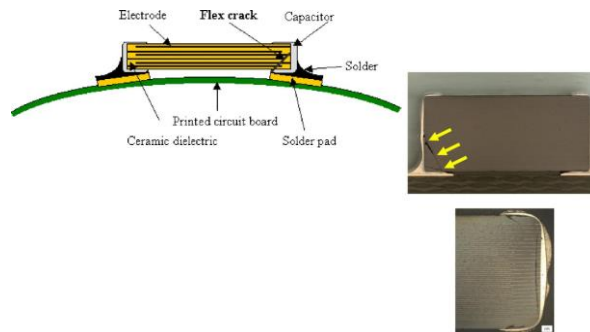
FEMFAT MELCOM Software



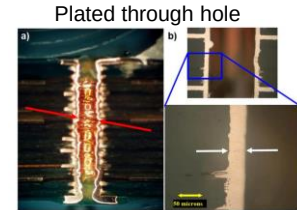
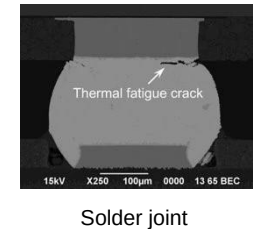
Vibration fatigue cracks in solder joints



MLCC flex cracking



Thermal failure of solder joints and PCB



FEMFAT MELCOM Software

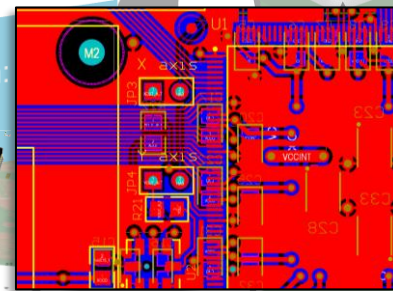
Mechanical Design

Finite-Element Modelling of Inverter,
PCBs and SMDs

Electronic Design

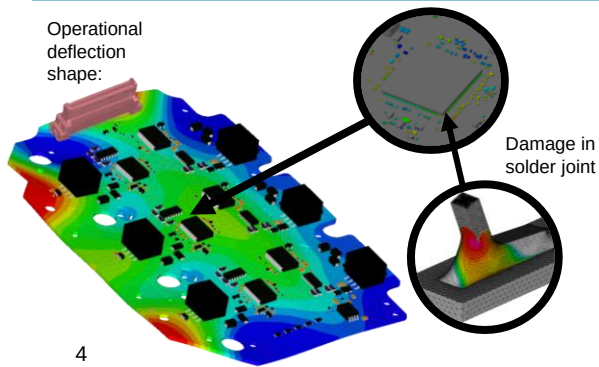
Classic FE-Modelling
with: .CatPart, .step...

PCBA Modelling with:
ODB++, Pick&Place

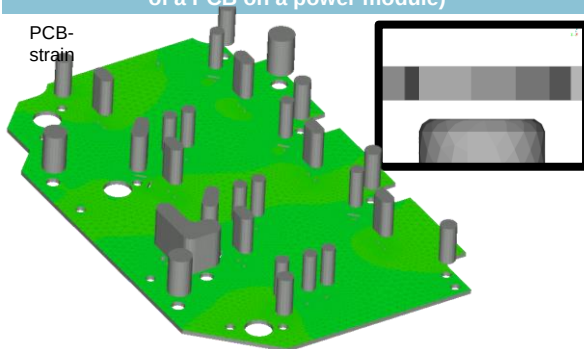


Dynamic Analysis:
Vibration analysis and
calculation of solder-joint fatigue

Operational
deflection
shape:

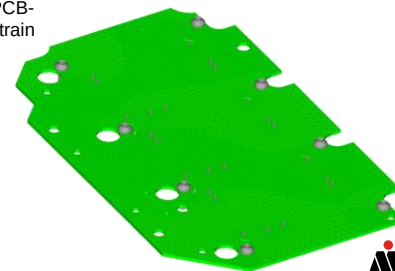


Static Analysis:
Calculation of chip-crack zones (e.g., mounting
of a PCB on a power module)



Thermo-Mechanical Analysis:
PCB-strain calculation for thermal load case

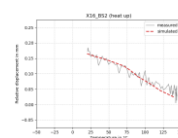
Heat-up of Inverter
from 20° C to 140° C
PCB-strain



Measurement with
stereo camera:



Comparison of
vertical deformation:

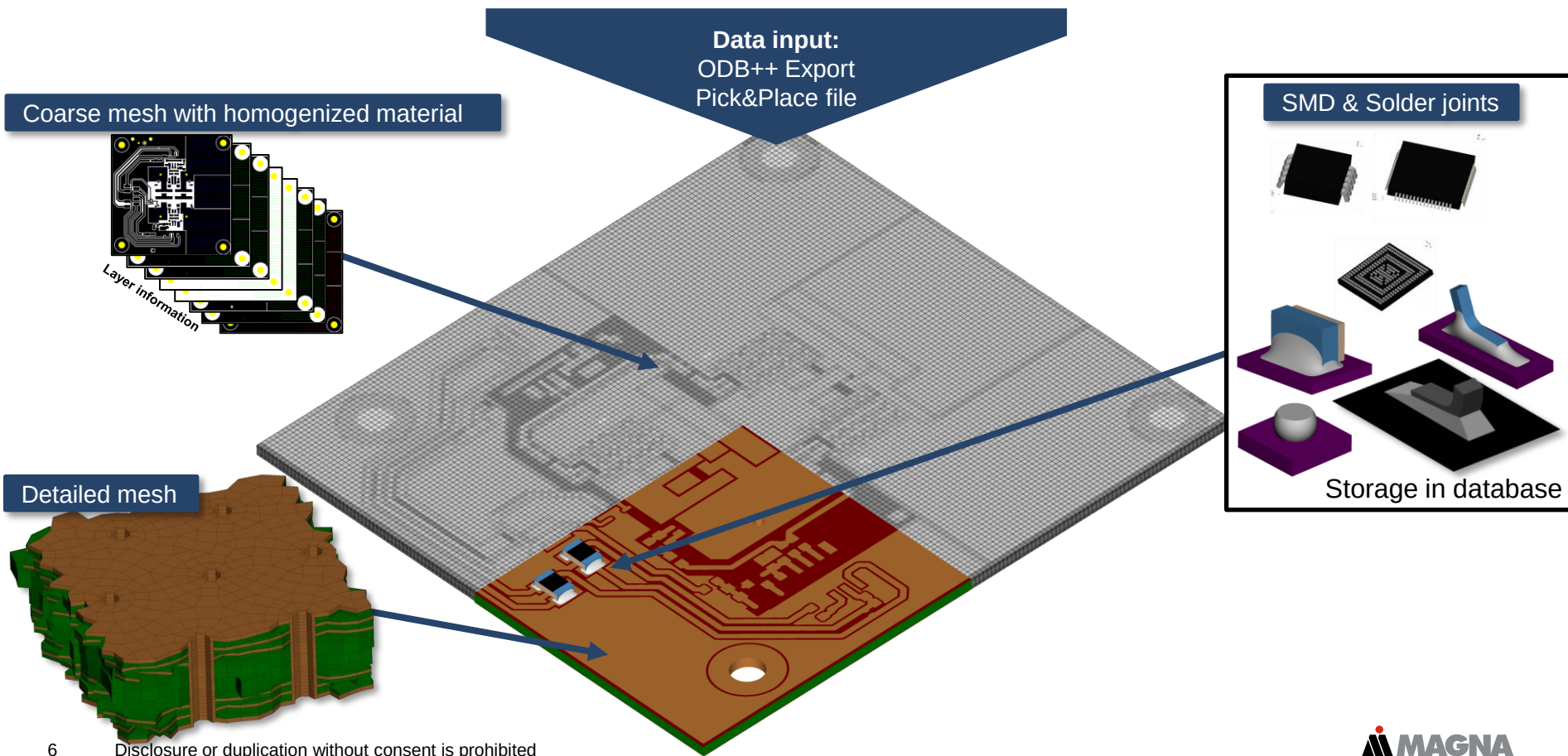


A long-exposure photograph of a road at sunset. The sky is a mix of dark blues, purples, and oranges. The road is dark, and the light trails from cars are visible as bright red and orange streaks. The number '02' is overlaid in large white font on the left side of the image.

02

Modelling Techniques Overview

Automated PCBA Modelling Techniques





02

Modelling Techniques

PCB

PCB - Fine Modelling

E-CAD (ODB++) to M-CAD:
Traces

E-CAD (ODB++) to M-CAD:
Drills

Generate Volumes by Extrusion
Final CAD-File: Embedded Design

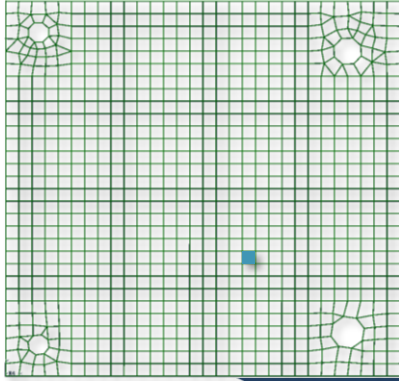
Mesh-Generation Shells:
Mesh size defined by feature size

Mesh-Generation Solids:
Extrusion of Shell mesh

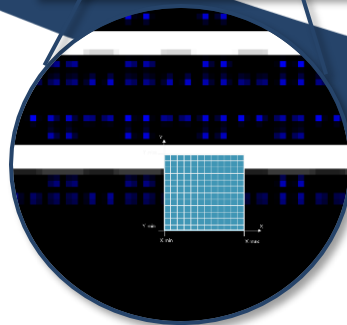
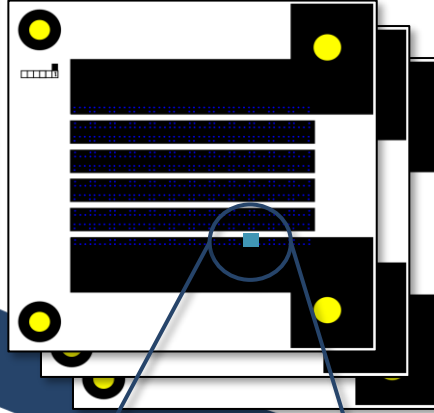
Automated process

PCB - Homogenization

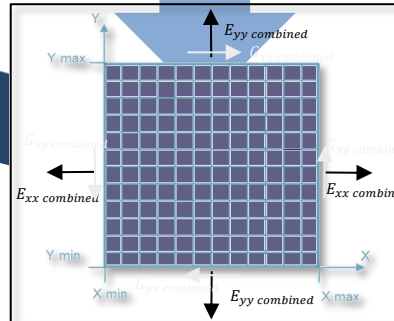
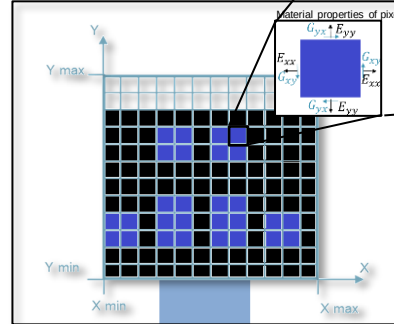
E-CAD (ODB++) to M-CAD:
Mesh of PCB Profile incl. holes



Finite Element borders get mapped
over the PCB layer information



Every pixel-color represents a material:
Copper, FR4, Resin
For every direction:
Homogenization of materials



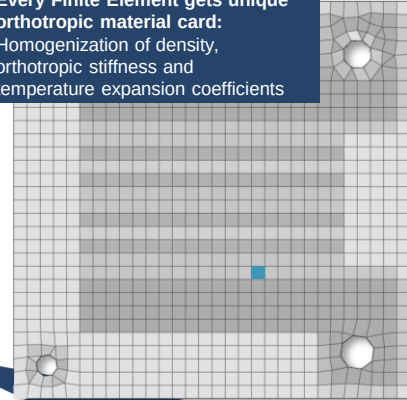
Reuss (isostress):

- $E_{eff} = \frac{E_A E_B}{\Phi_A E_B + \Phi_B E_A}$
- $\nu_{eff} = \frac{\nu_A \nu_B}{\Phi_A \nu_B + \Phi_B \nu_A}$
- $G_{eff} = \frac{G_A G_B}{\Phi_A G_B + \Phi_B G_A}$
- $\alpha_{eff} = \frac{\alpha_A E_A \Phi_A + \alpha_B E_B \Phi_B}{\Phi_A E_A + \Phi_B E_B}$
- $\lambda_{eff} = \frac{\lambda_A \lambda_B}{\Phi_A \lambda_B + \Phi_B \lambda_A}$
- $\rho_{eff} = \Phi_A \rho_A + \Phi_B \rho_B$
- $C_{eff} = \Phi_A C_A + \Phi_B C_B$

Voigt (isostrain):

- $E_{eff} = \Phi_A E_A + \Phi_B E_B$
- $\nu_{eff} = \Phi_A \nu_A + \Phi_B \nu_B$
- $G_{eff} = \Phi_A G_A + \Phi_B G_B$
- $\alpha_{eff} = \Phi_A \alpha_A + \Phi_B \alpha_B$
- $\lambda_{eff} = \Phi_A \lambda_A + \Phi_B \lambda_B$

Every Finite Element gets unique
orthotropic material card:
Homogenization of density,
orthotropic stiffness and
temperature expansion coefficients



Automated process

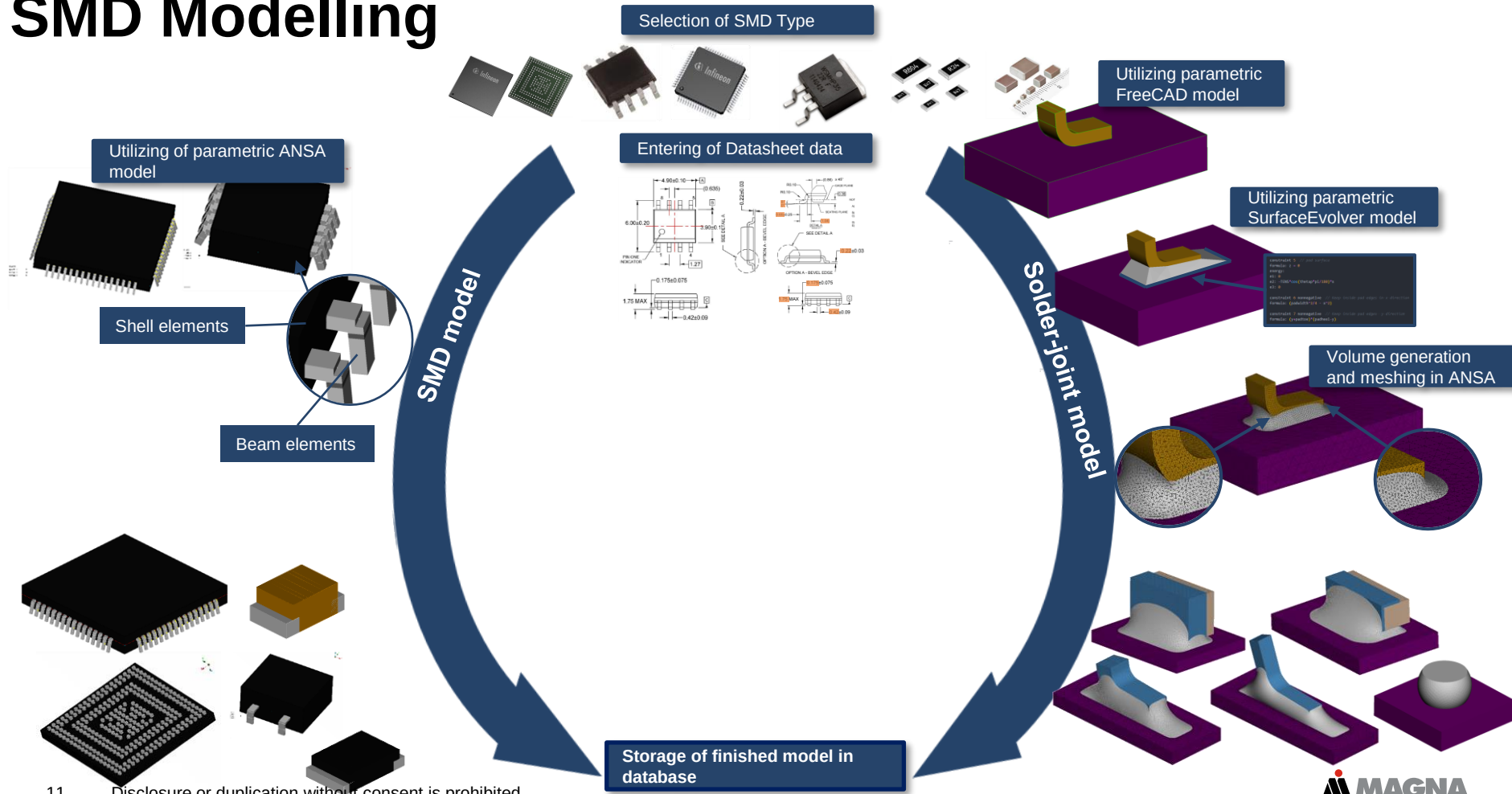


02

Modelling Techniques

SMD

SMD Modelling



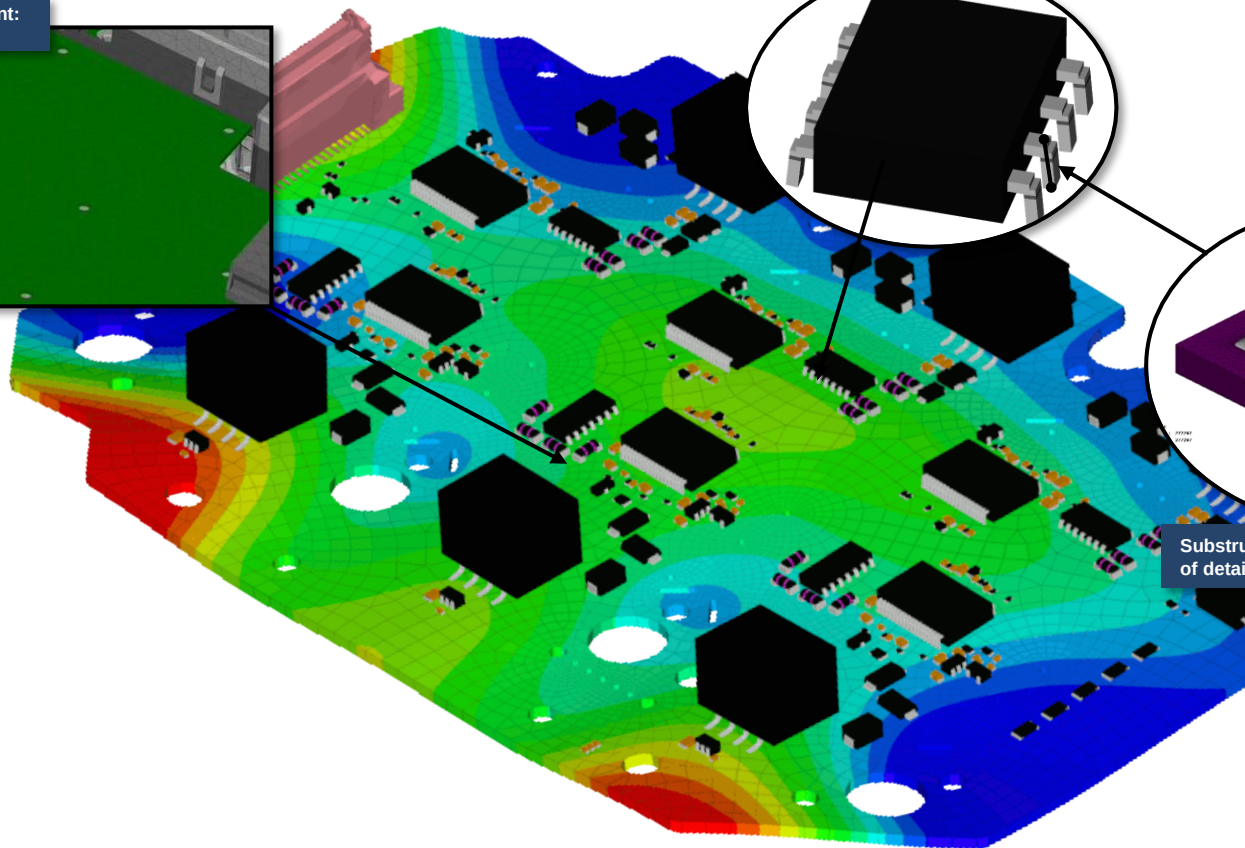


03

Solder Joint Fatigue Analysis Process

Solder-Joint Analysis

Automated placement:
via Pick & Place file



Substructures contain stiffness matrix
of detailed Solder-joint model

Solder-Joint Analysis

Modal Analysis

Automated placement:
via Pick & Place file

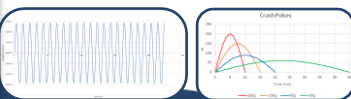
Frequency Response
Analysis

Export of nodal displacements
(Substructure) over frequency

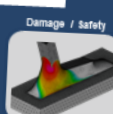
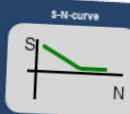
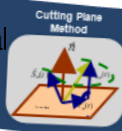
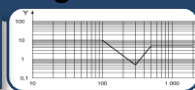
Unit displacement
stresses from database

Automated process

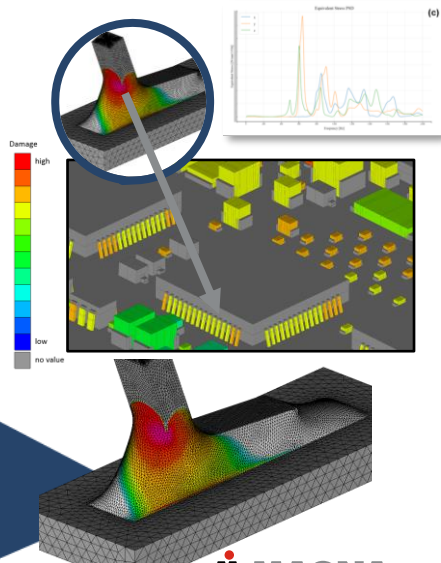
Magna FEMFAT max



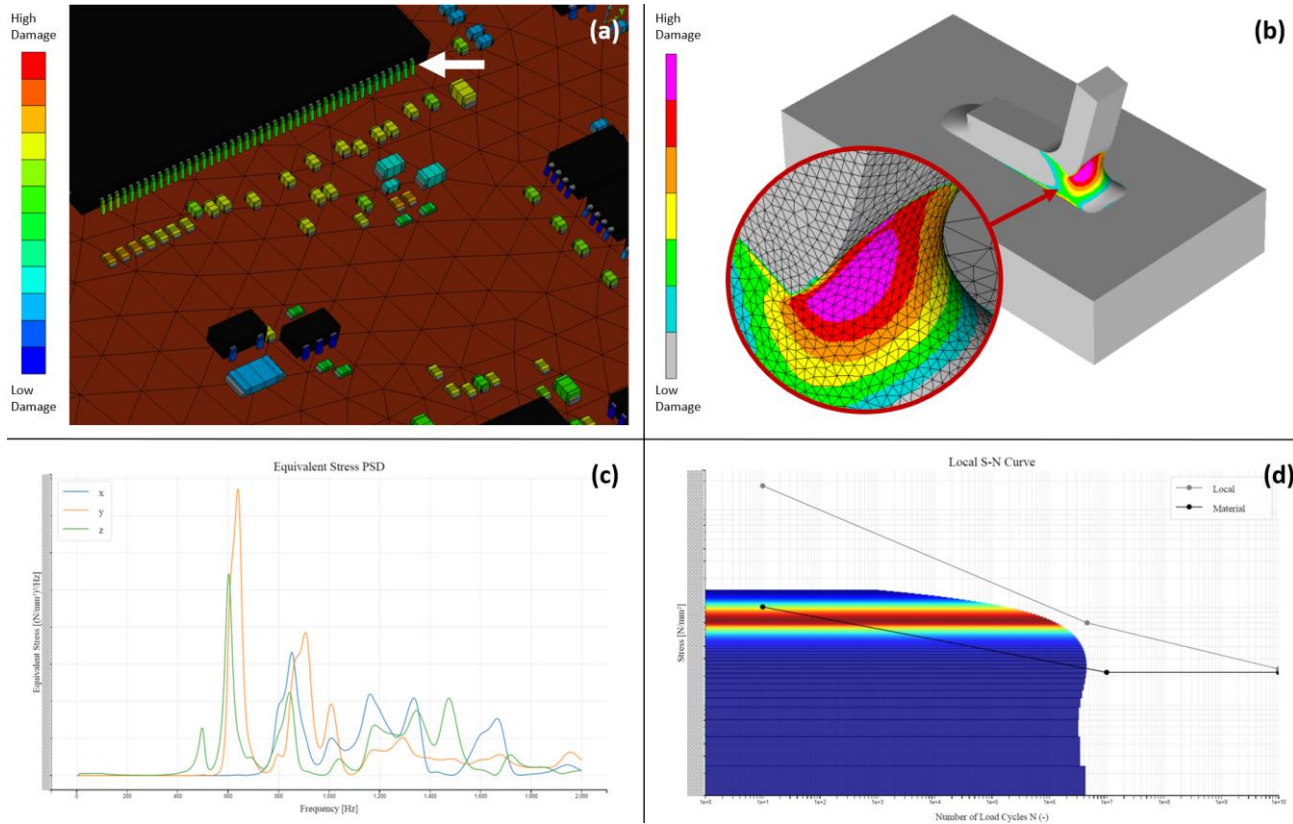
Magna FEMFAT spectral



Substructures contain stiffness matrix
of detailed Solder-joint model



Solder-Joint Analysis



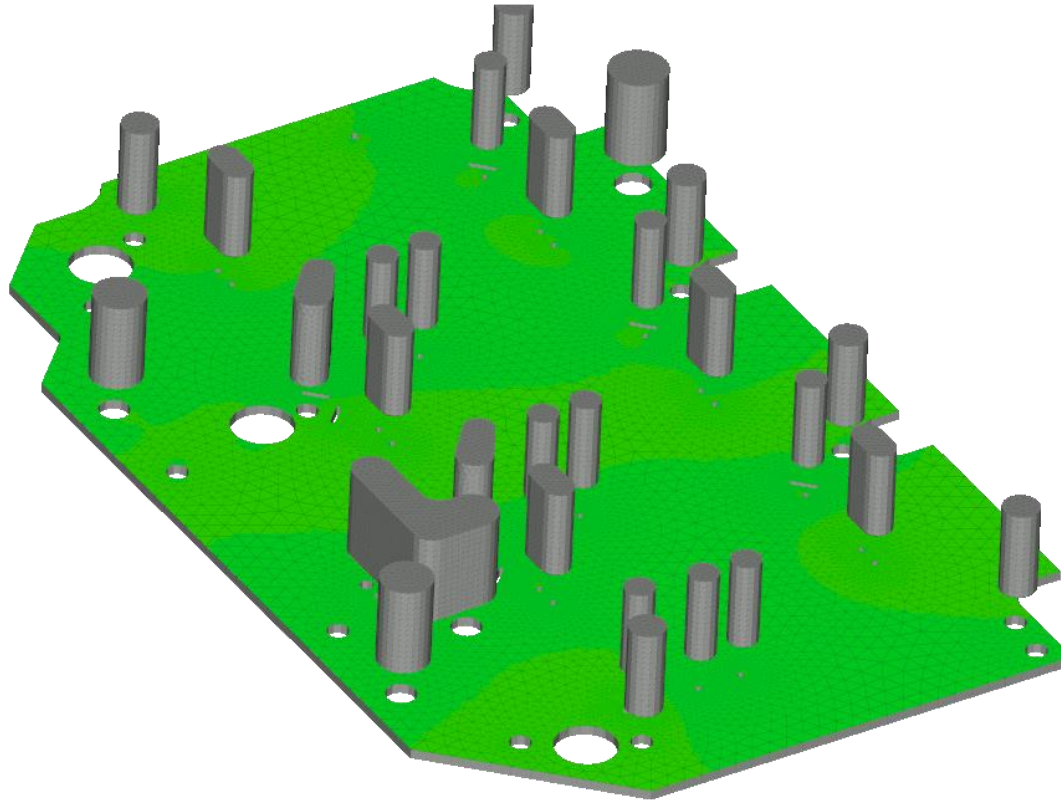
Mapped damage values of all pins of the substitute FE-models **(a)**. Damage values for a specific sub-model (marked by the white arrow in (a)) in FEMFAT visualizer **(b)**. Equivalent stress PSDs in the most damaged node of the sub-model (b) for all acceleration directions **(c)**. Local S-N curve for the most damaged node of the sub-model **(d)**.



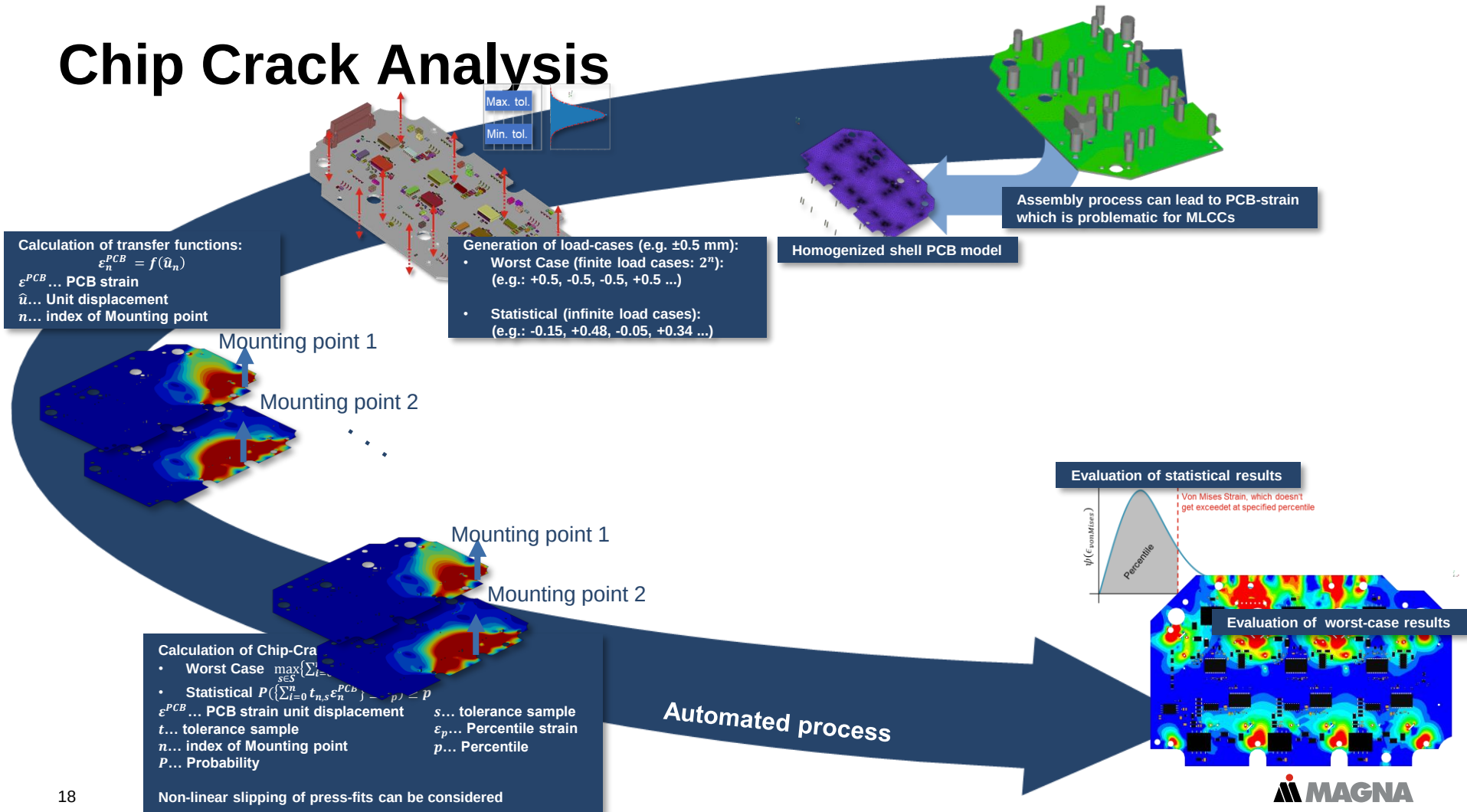
04

Chip Crack Analysis Process

Chip Crack Analysis



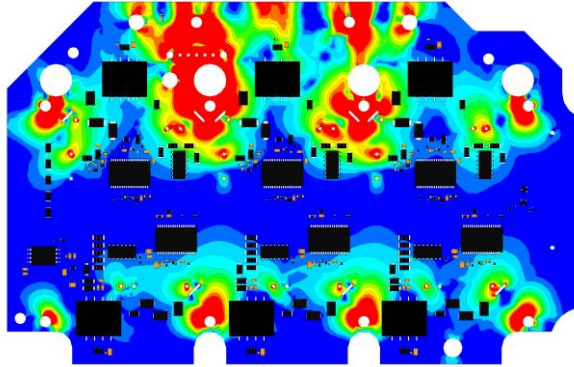
Chip Crack Analysis



Chip Crack Analysis

Worst case approach

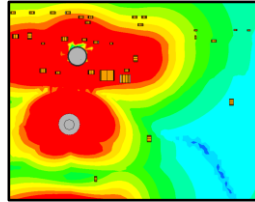
- For every element of the PCB the max. occurring strain is calculated and plotted in one contour plot
- The resulting contour plot therefore shows the worst possible strain that can occur



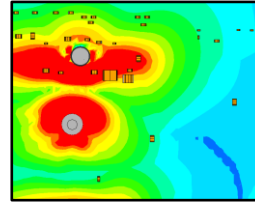
Statistical approach

- Probability of exceedance – limits are defined (e.g. 50%, 32%, 10%, 5%, 1%, 0%)
- The maximum value of simulated PCB-strains can be determined for various probabilities of exceedance (50%, 32%, 10%, 5%, 1%, 0%)

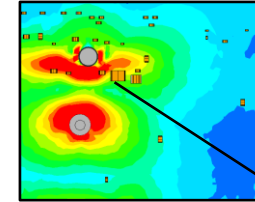
0.01% - Limit



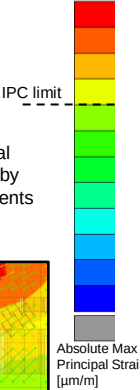
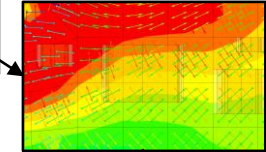
1% - Limit



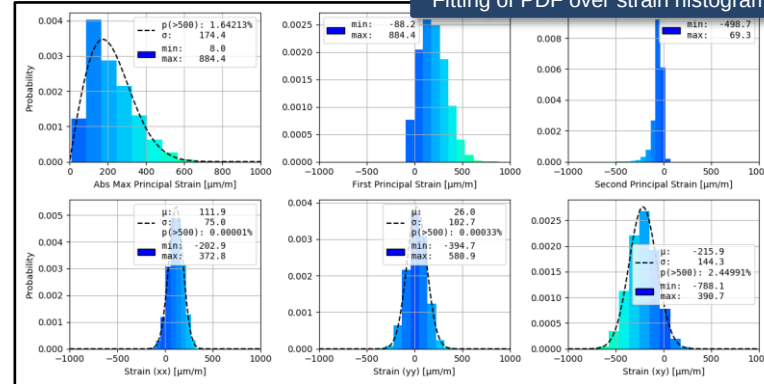
5% - Limit



Additionally, the principal strain tensor visualized by the main strain components using vectors can be evaluated.



Fitting of PDF over strain histograms





05

Thermo-Mechanical Analysis Process

Thermo-Mechanical Analysis

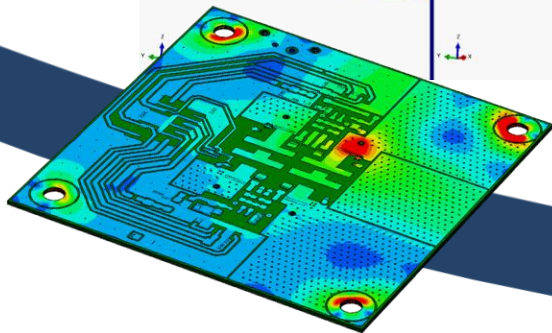
Generation of PCB detailed model:

- Whole PCB
- Custom PCB area

Calculation of custom thermo-mechanical load case

Stresses

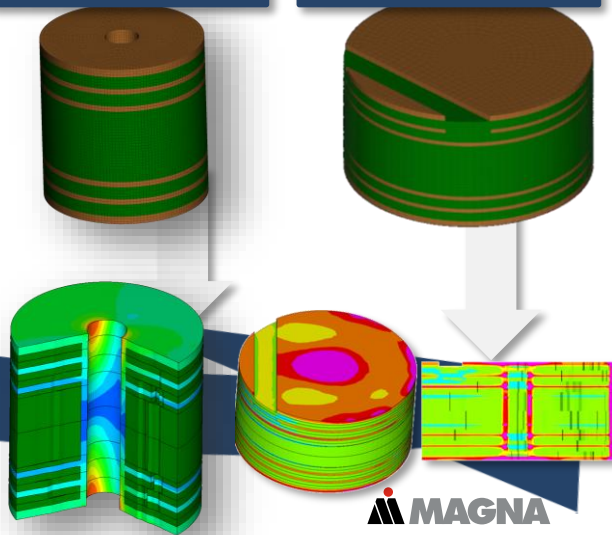
Temperature



Generation of sub-models

PTH detailed sub-model

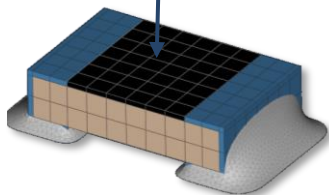
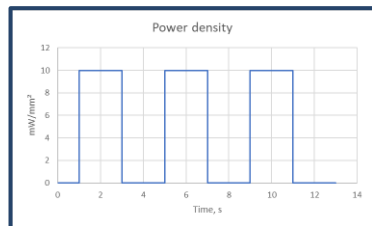
custom detailed sub-model



Thermo-Mechanical Analysis

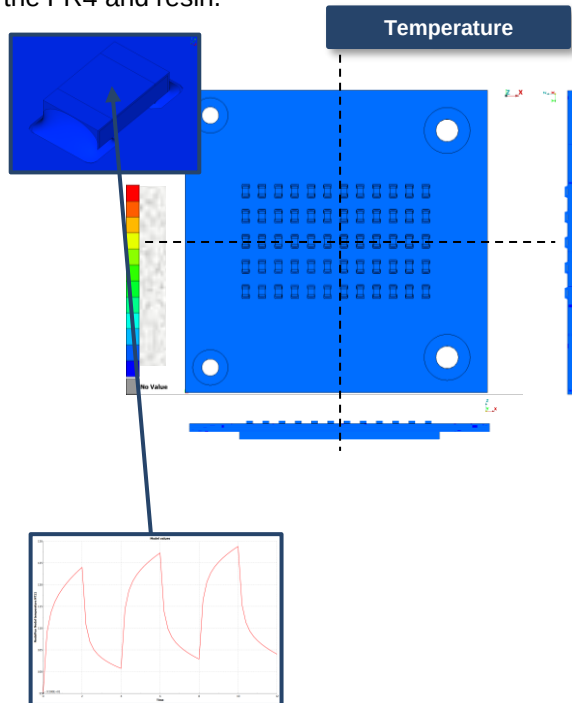
Load-definition

The definitions of transient loads are possible. In this case three power-dissipation cycles were applied on the upper side of a resistor array.



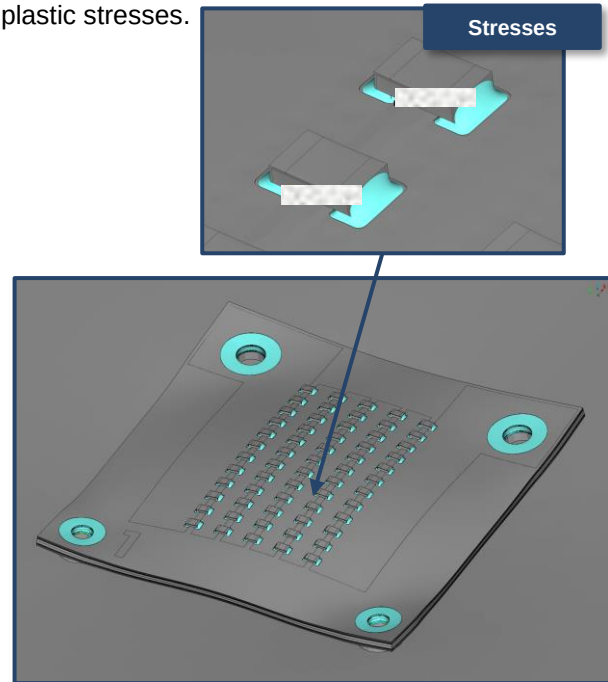
Thermal Results

The resulting power dissipation leads to an inhomogeneous heat up of the PCB. The Copper has a higher thermal conductivity than the FR4 and resin.

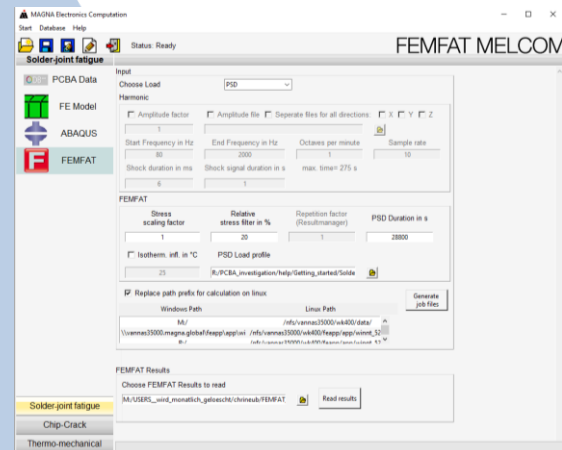
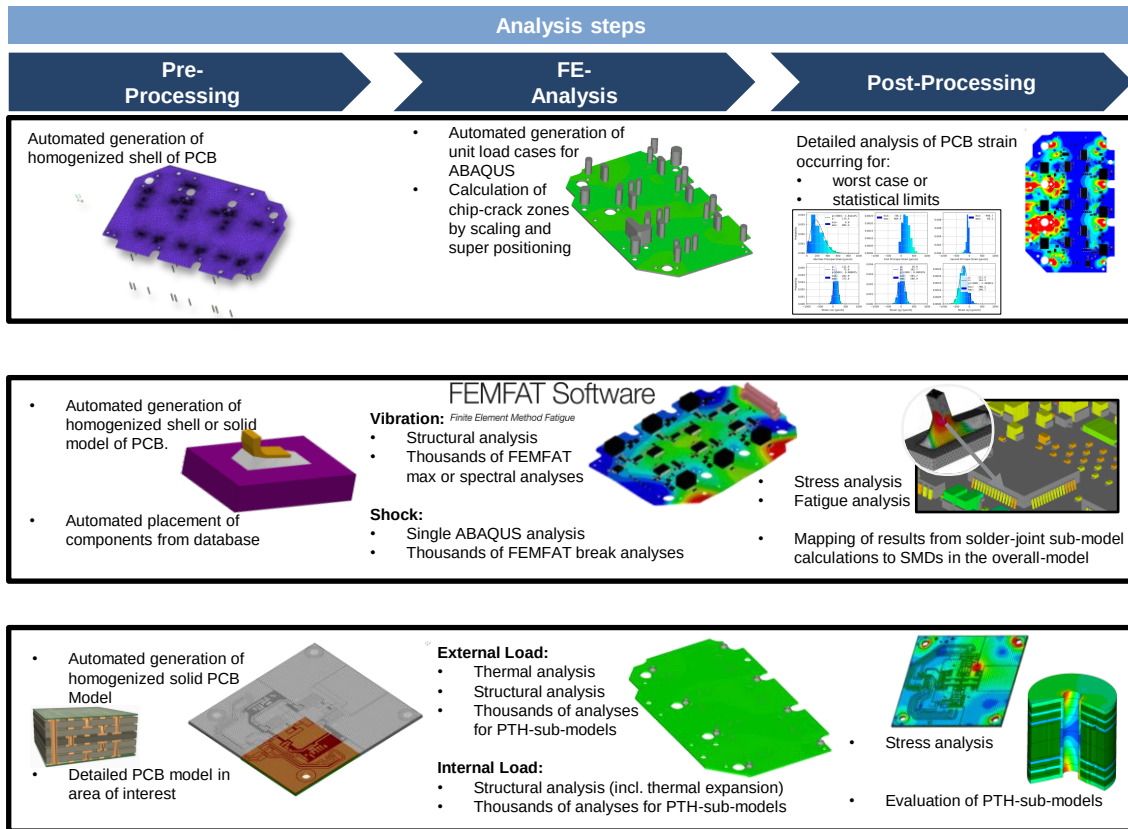


Mechanical Results

The inhomogeneous heat up of the PCB can lead to high strains and stresses in different regions of the PCBA. In this example the solder joints of the SMDs experience elasto-plastic stresses.



FEMFAT MELCOM Software - Summary





Forward. For all.

Christian Neubacher, MSc
Engineer Component Acoustics Analysis

ENGINEERING CENTER STEYR GMBH & CO KG
MAGNA POWERTRAIN
Steyrer Straße 32, 4300 St. Valentin, Austria
OFFICE +43 7435 501 2339
Christian.neubacher@magna.com
engineering.mpt.magna.com