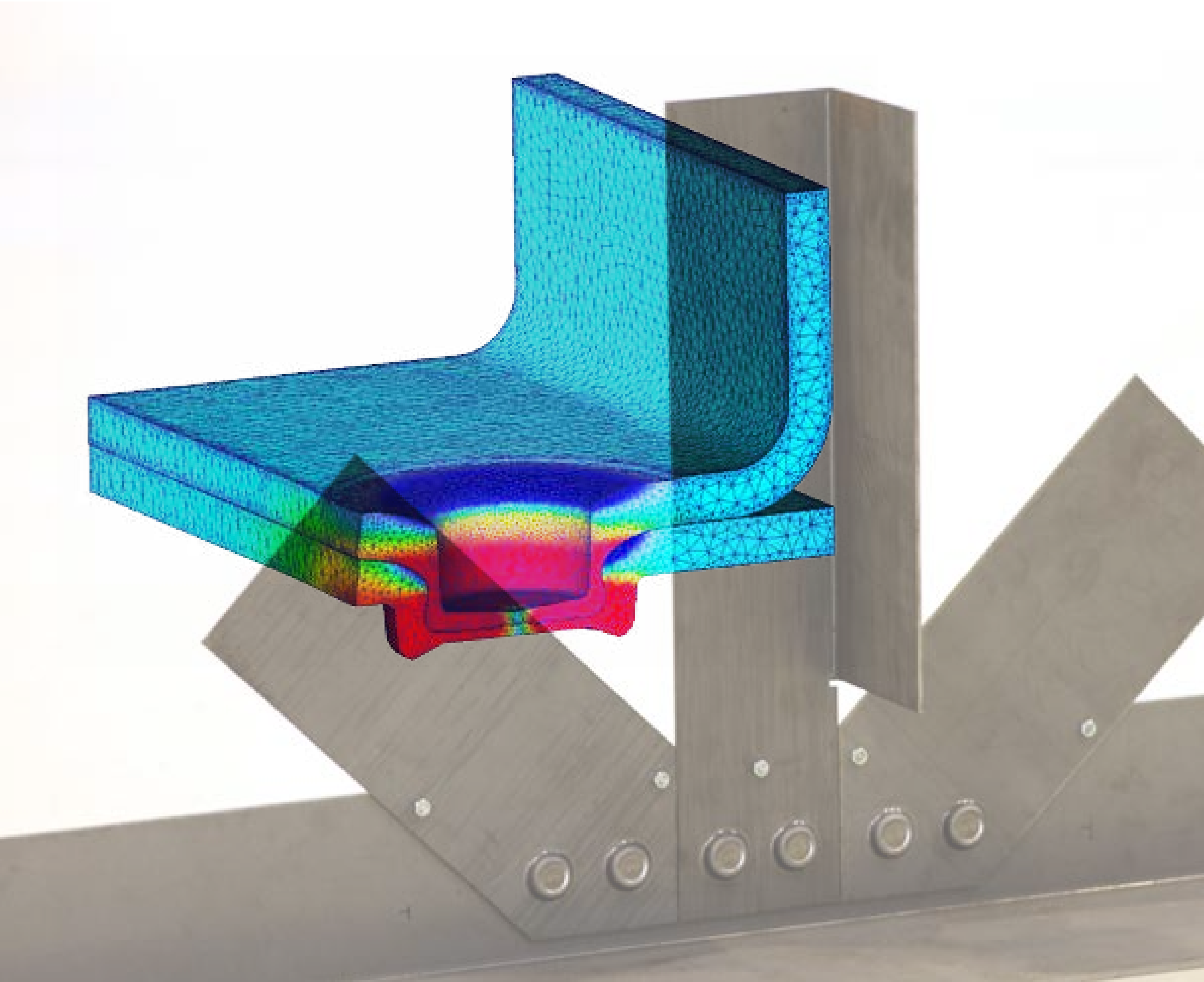
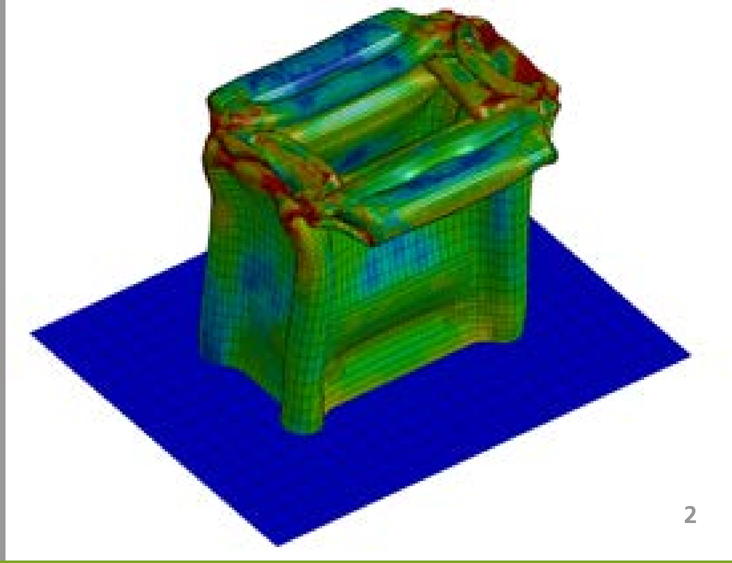
Fraunhofer IWU

FRAUNHOFER INSTITUTE FOR MACHINE TOOLS AND FORMING TECHNOLOGY IWU

NUMERICAL SIMULATION IN MECHANICAL JOINING





NUMERICAL SIMULATION
... FROM JOINING TO CRASH

ANALYSIS AND DESIGN OF PROCESSES, TOOLS AND STRUCTURES

The multi-material design places different demands on mechanical joint properties and associated joining processes. Hence, the design of a spot joint as well as the development of the appropriate joining process is often a very complex task. By using calculation models and analyses, the numerical simulation serves as a support in the early planning stages.

We use numerical simulation for the following fields of mechanical joining:

Joining process
- Process development
- Process analysis, process optimization and design of robust joining processes
- Optimization of joining tools and auxiliary elements (e.g. rivet)

Process chain
- Prediction of geometry deviations caused in the process steps of clamping, joining (clinching, self-piercing riveting, resistance spot welding, laser welding, hemming), industrial heating and drying oven processes and assembly
- Design of clamping devices and optimization of joining sequences

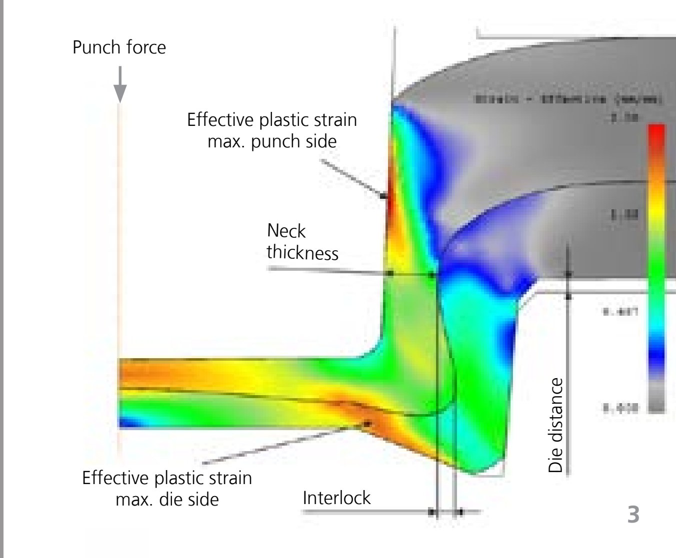
Design
- Design of joints and verification of strength
- Evaluation of stiffness and ultimate strength under operational loading (static, cyclic and crash loads)

Our range of services

The appropriate simulation software is chosen according to the respective task. The calculation software can be adapted on the one hand and special models will be developed, if necessary. Furthermore, numerically determined results are verified by experimental studies.

Equipment for joining close to production conditions is available at Fraunhofer IWU. Comprehensive measurement technology completes the experimental testing.

1 *Self-piercing riveting of an aluminum-CFRP-joint (left-hand side: experiment, right-hand side: FEM simulation)*
2 *Simulation of a crash box*
3 *Quality evaluation of a clinch spot using FEM simulation*



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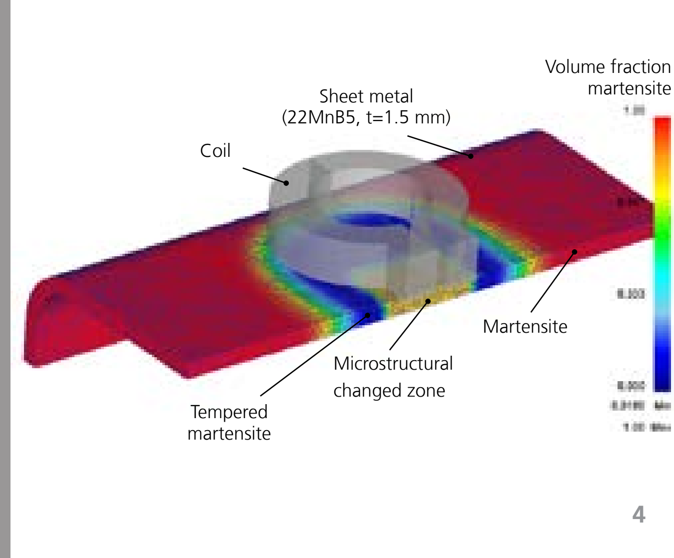

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PROCESS SIMULATION
… DETERMINATION OF THE FEASIBILITY

SOPHISTICATED ANALYSIS OF JOINING PROCESSES

Process development is supported by numerical simulation. It is difficult to realize variations of processes with very complex conditions. It is possible to analyze and evaluate these processes by using numerical simulation. The understanding of the process is increased and the feasibility can be assessed. Usually, experimental verification of the calculation results is only necessary on a random basis.

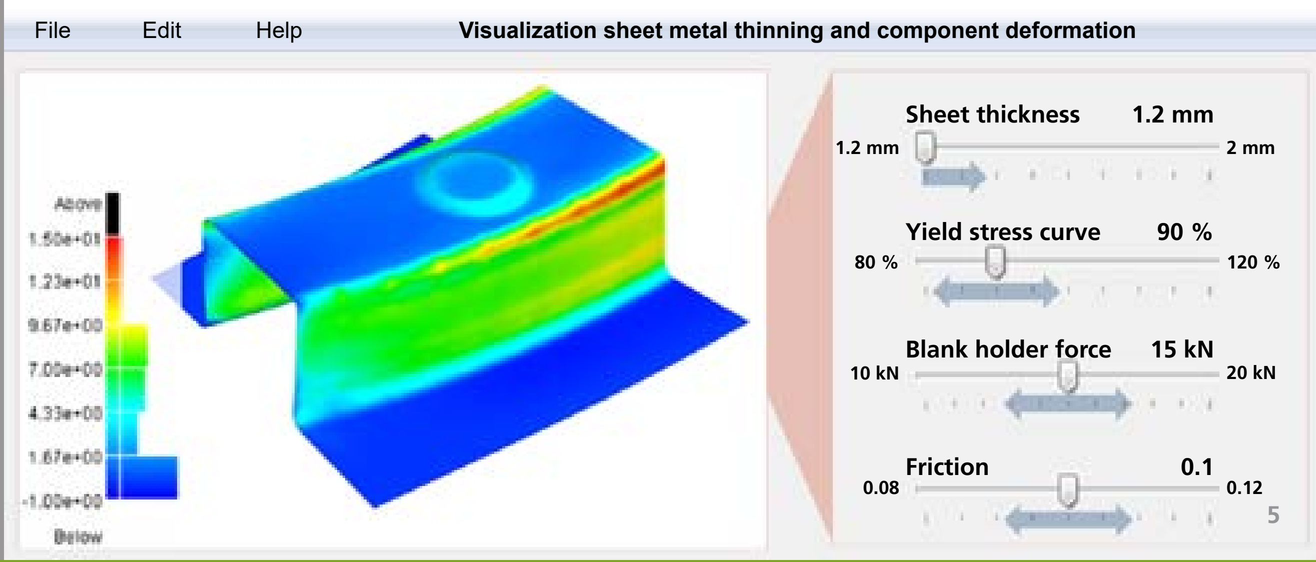
The FEM simulation of a mechanical joining process is comparable with the simulation of a bulk metal forming process. However, there are also specific challenges in the joining simulation: interaction of several elasto-plastic objects, large strains up to material rupture, modeling of the material separation, high strain rates in high-speed processes, local temperature differences and modeling of adhesive between the joining sheet metals.

4 *FEM simulation of the local thermal treatment of a joint zone before mechanical joining takes place*

5 *Interactive visualization of the effect of process parameter changes based on a multidimensional metamodel*

Our range of services

- Development of new joining processes such as clinching with planar counter tool or mechanical joining with special rivets
- Analysis of stress and strain states as well as geometric characteristics of the joint in process derivatives
- Optimization of joining tools and process parameters, especially in terms of process stability and joint quality (strength and stiffness) for a given material combination
- Reduction of number of tool sets for mechanical joining due to development of a compromise tool design
- 3D analyses of local structure deformations in the joint zone caused by a low edge distance of the joint, tool asymmetry or tilt error
- Development of thermally assisted joining processes for high-strength materials such as press-hardened steel, high-strength aluminum and magnesium alloys
- Analysis of damage at the joint zone or the auxiliary joint element



SENSITIVITY STUDIES AND OPTIMIZATION

… APPLYING EFFICIENT NUMERICAL METHODS

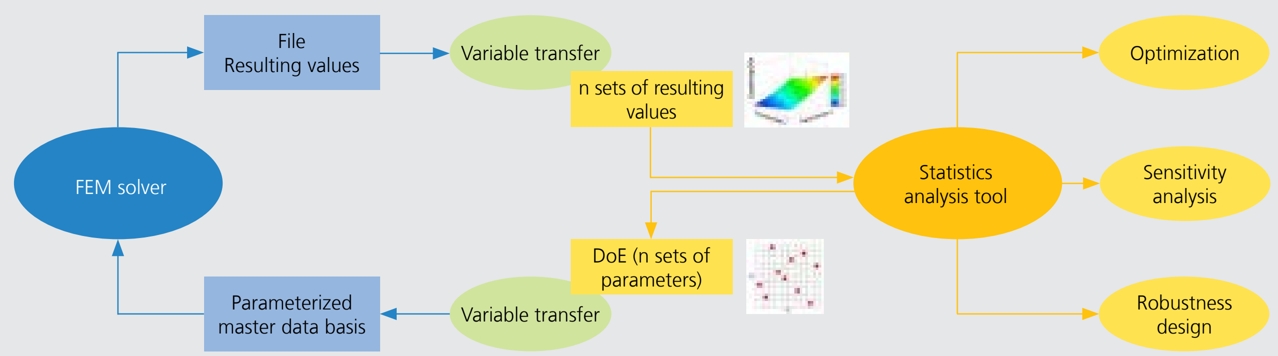
LINKING NUMERICAL SIMULATION AND MATHEMATICAL STATISTICS

The analysis of a huge number of variant calculations facilitates the graphical representation of complex correlations. Using statistical methods, it is possible to link several influence variables with resulting values for different tasks. Parametrized FE models are provided to the solver automatically. After calculation the objective criterion is evaluated. The simulation results of many runs with parameter changes are analyzed statistically and summarized in metamodels.

This efficient method of analysis can be used in mechanical joining simulations to assist in the following scenarios:

- Sensitivity studies for identification of parameters that influence the quality
- Optimization of joining tools and machines as well as joining processes and entire process chains
- Design of robust process, resulting in increased process reliability

Principle of linking FE calculation and statistical methods for sensitivity analyses, optimization calculations and robustness evaluations



CALIBRATION AND VERIFICATION
... FITTING EVERYTHING TOGETHER

IDENTIFICATION OF MODEL PARAMETERS

The numerical simulation solely generates an image of real structures and connections based on assumptions and mathematical models. Besides the selection of appropriate models, the exact identification of model parameters is essential for the high quality of calculation results. These model parameters include variables for:

– Material models (description of elastic, plastic or viscous material behavior, e.g. flow curve and yield locus, hardening laws, thermal material parameters, microstructural changes)
– Friction models
– Damage models (modeling of material separation, process errors, structural failure)
– Simplified models for joints (stiffness, ultimate strength, deformation)

The parameters are identified for the operating area of the model with sufficient accuracy based on experimental tests. On the one hand, the parameters are determined by means of standards and directives. On the other hand, we apply methods that are newly developed at Fraunhofer IWU for the specific requirements of mechanical joining simulation. Here, the focus lies on determining flow curves at very high strains, characteristic damage values as well as evaluating damage in the join parts.

Joints in complex structure simulation models are typically replaced by simplified models. Hereby, the load-deformation-behavior of joints is identified using the experimental method of measuring relative displacements. Exact information about the local deformations of joints is required for simplified models in the projection of tolerances in assembly of sheet metal parts. The measurement of local strain components uses special calibration models, preferably with contact-free optic methods.

Our range of services

We offer the identification of model parameters within research projects or as a separate service.

6 Test set-up for the measurement of relative displacement between joined parts to characterize the loading / unloading behavior
7 Measurement of friction forces at the lateral surface of a self-piercing rivet

Editorial notes

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