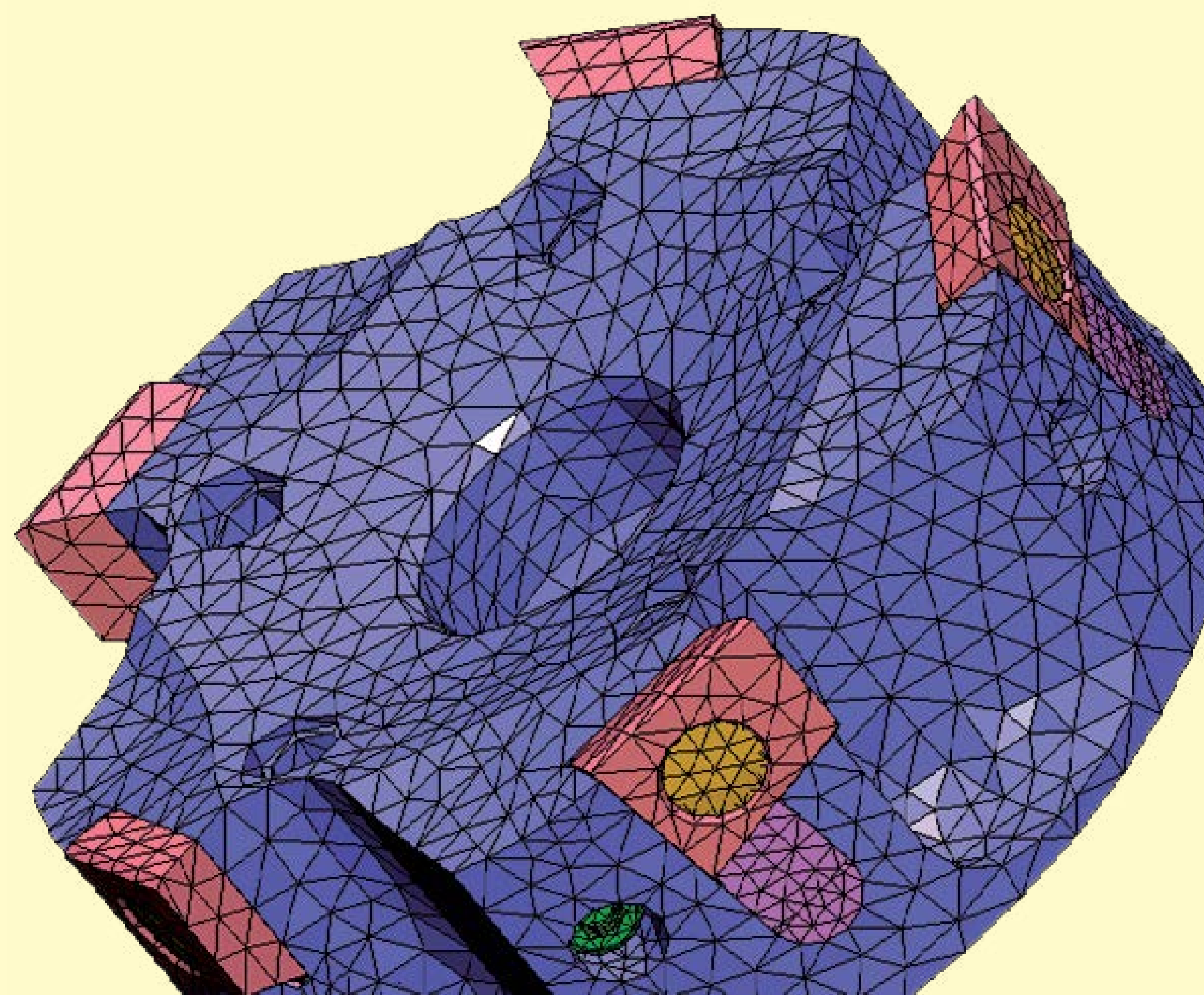
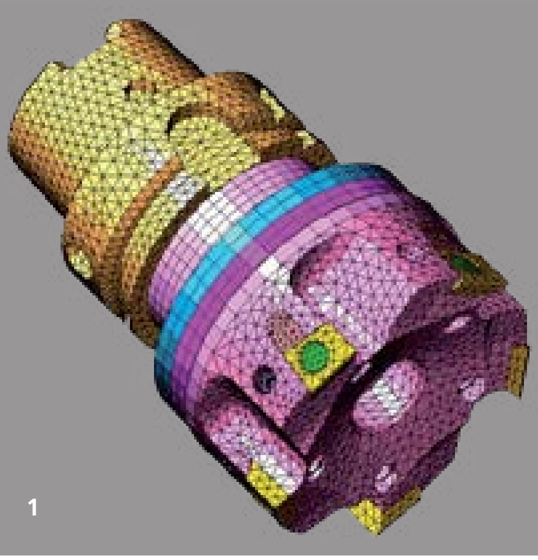
Fraunhofer IWU

FRAUNHOFER INSTITUTE FOR MACHINE TOOLS AND FORMING TECHNOLOGY IWU

SIMULATION FOR METAL-CUTTING PRODUCTION PROCESSES





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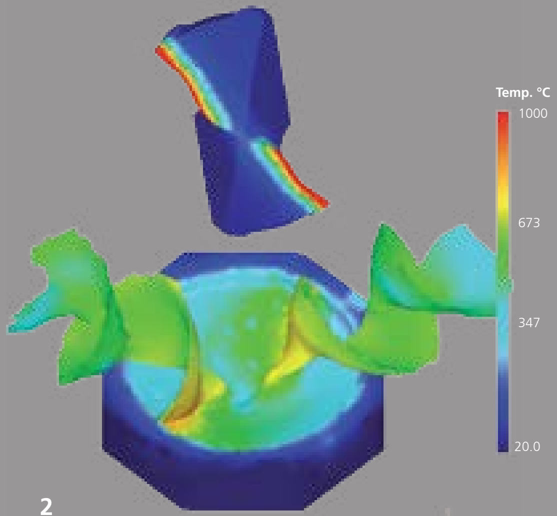

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The foremost factors in maintaining and improving companies' competitiveness is advancing production processes and boosting their performance. In other words, products have to be developed and produced at low prices and a high level of quality. One of the most essential prerequisites is mastering production processes where machining processes have a significant role to play.

Numerical simulation techniques such as the finite element method (FEM) enable us to penetrate deeply into the intricate interrelationships of machining processes while the advancements in hardware and software generate increasingly detailed models. The intimate link between simulation and experiment guarantees the proximity to real-life conditions.

The current trends in precision machining that are the main focus at the Fraunhofer IWU are dry machining, high-speed cutting (HSC) and high-performance cutting (HPC). There are also next-generation developments in the area of near-net-shape production and using new materials and combinations of materials, cutting materials and layer-substrate systems including combinations of and substituting techniques. Other investigations concern themselves with guaranteeing defined component properties by superpositioning active energies such as ultrasonic oscillations, high-pressure cooling or focused laser beams. Furthermore, various types of environmentally friendly, energy-efficient and low-resource machining are commanding increasing attention.

Numerical simulations are a very effective means of analyzing interrelationships and tendencies in combination with a minimum of time-consuming experimentation. It is also of great advantage to observe areas and processes that are only accessible to characterization by measurement techniques with a great deal of effort or not at all for spatial reasons, due to a high level of mechanical or thermal stress or with processes that run extremely quickly. Finally, numerical simulation calculations enable us to take a look at the inside of workpieces or tools and they can even be applied if a high level of costs or occupational safety problems make experimental tests difficult or impossible. In this fashion, we can do without experimental samples in testing tools at an early stage of development to discover weak points and ways to improve them.

Simulating the Machining Process

One substantial area where the simulation of metal-cutting production processes can be applied is calculating the impact of the process parameters and cutting geometries of the tool on

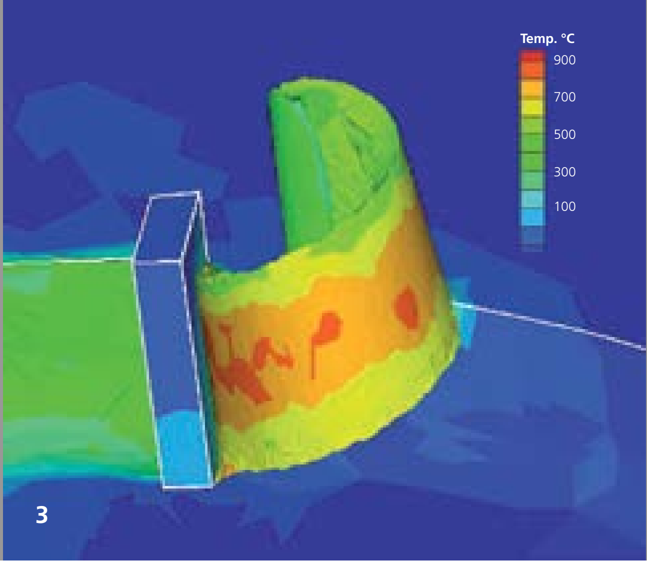
– tool strain and wear and tear,
– chip shapes and chip break and
– burr formation and preventing burrs.

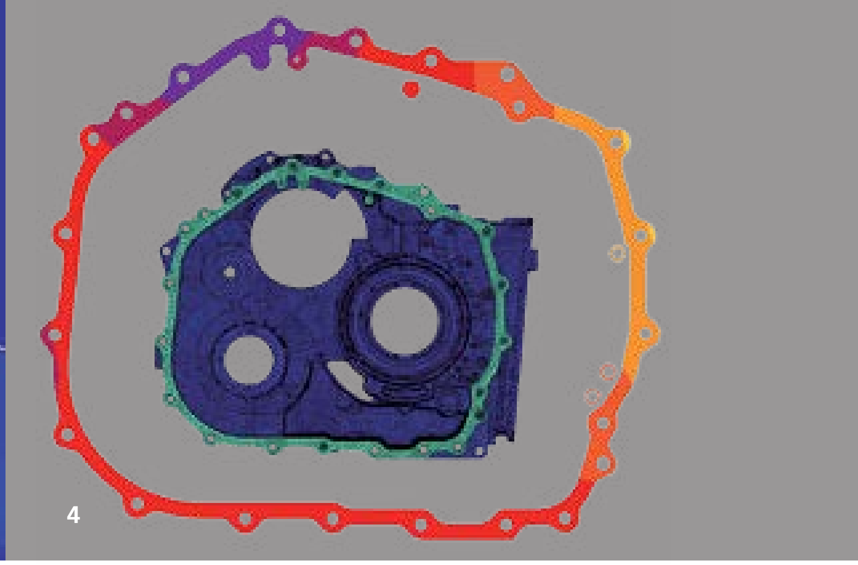
This is where we can investigate a wide range of different materials including a whole series of metals and non-metals or homogenous materials and composite materials. Since the chip formation process is highly intricate, fundamental research coupled with experimental random sample tests is highly of major importance for models and determining model parameters. Even if we still cannot do without machining tests, we can reduce the number of tests needed by making prior calculations.

Simulation in the Development of Cutting Tools

The idea here is designing tools to fit the material and particular form of stress. With precision machining, we normally have to achieve accuracies in the range of a couple of micrometers and even better in situations where there is deformation on this scale at relatively low levels of cutting forces or due to thermal deformation.

The emphasis here is intricate modularly built high-performance and precision cutting tools. Conventional dimensioning equations are no longer adequate for determining the stress and deformation of the components of these tools at the accuracy required. In contrast, complex calculating models based upon FEM also take non-linearity into account due to the relative motion of specific component parts.





Some examples are on clamping and adjusting mechanisms such as with cutting insert seats or coupling joints. Simulations make the interplay of components transparent while providing information on weak points and potential for improvement. They also enable us to analyze the effect of clamping forces and the impact of various combinations of materials. Calculations coupled mechanically and thermally take the process heat released into account along with the way it spreads in the tool and further on into the spindle mounting. Finally, we can analyze the oscillation properties of tools and workpieces in dynamic simulations which enables us to make statements on critical machining situations.

Layer-Substrate Enhancement

It is becoming increasingly desirable to use wearing protection coatings even with hydroforming tools. There are combined stresses due to the high level of contact pressure and friction shearing stress that makes it especially important to design it suitable to the type of loading and coating while applying the tool geometry and properties of the combination of layers and substrate.

Another area of application for numerical simulations is assessing and evaluating mechanical and thermal stability of layer-substrate composites. Beyond this, simulations are also useful for achieving relevant material characteristic quantities in particular of failure parameters. This is the reason why several research projects at the Fraunhofer IWU are concentrating on simulating test processes for characterizing material parameters and modeling damage properties of layers (layer delamination and crack formation) where simulation calculations are used in combination with special experiments for determining unknown failure parameters. One typical area of application is enhancing layer thicknesses to achieve the desired strength and avoid critical concentrations of stress in the layer-substrate interface.

Component Part Deformation due to Production and Enhancing the Sequence of Processes

There are both mechanical and thermal stresses acting upon the tool and workpiece during machining, especially with dry machining, and they cause undesired departures from the targeted contour. Compensating for deformation due to production generally calls for a time- and material-consuming running in process which can be substantially reduced with simulations. Forces and temperature fields from analyses in the machining process act as boundary conditions for simulating component parts and a knowledge of the component part distortion from the process makes it possible

– to select favorable machining parameters and process sequences,
– to determine data for compensation of errors, and
– to enhance workpiece clamping.

These are the goals that the Fraunhofer IWU has for applying simulations in current projects for developing and enhancing adaptive clamping systems such as when using piezoelectrical components. This makes it possible to use optimum process-related workpiece chucking at minimum dimensional deviations.

1 *The FE model of a milling tool*
2 *Simulation of drilling in 42CrMo4*
3 *Chip formation with plain milling TiAl6V4*
4 *Process-related deformation of a housing component with plain milling*

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