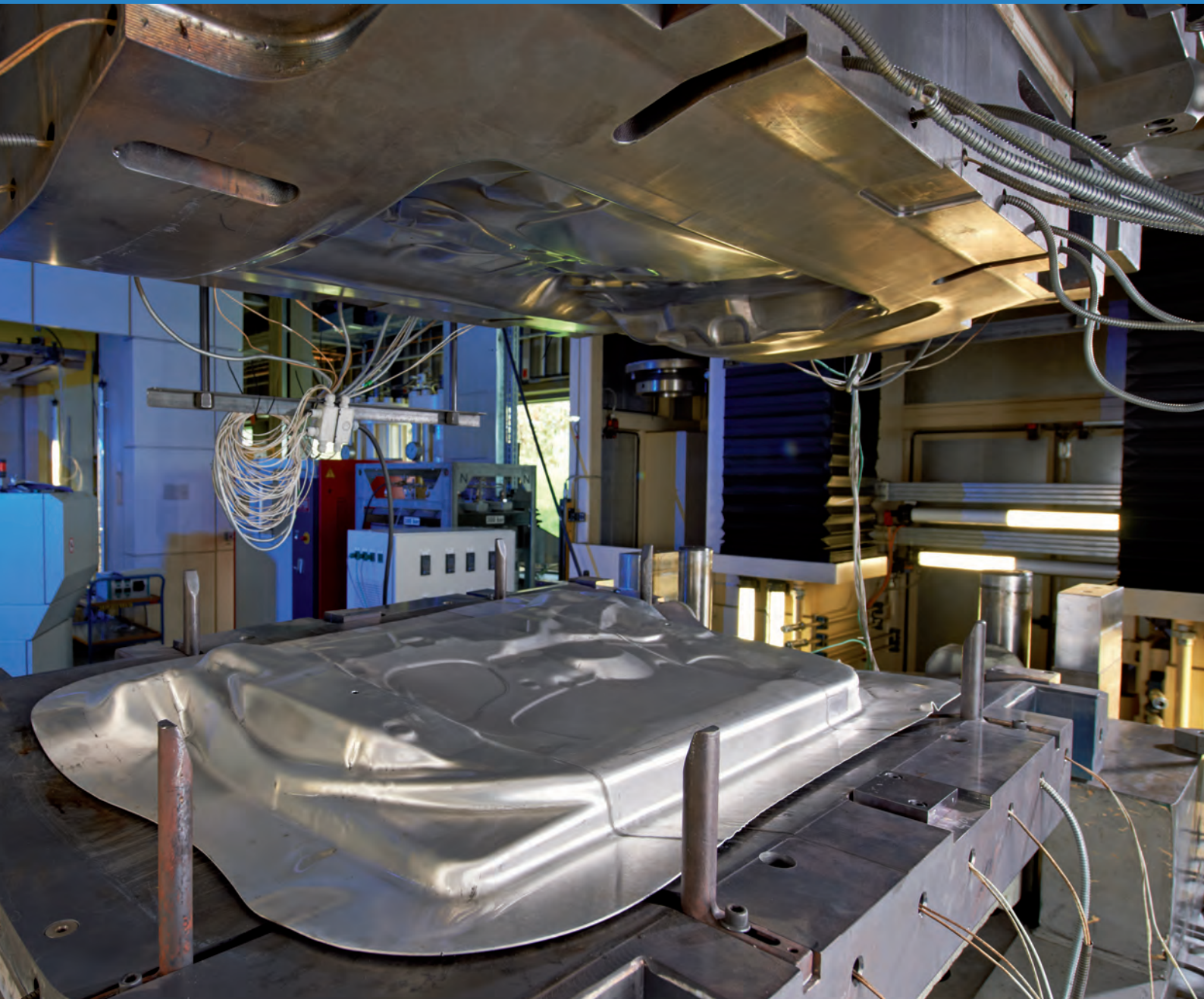


# SHEET-METAL FORMING



The expertise at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in the field of sheet-metal working includes the entire process chain for forming manufacture of optimum-function stress-resistant component parts. That not only means selecting and characterizing the right sheet-metal materials, but also method (stage) planning for all sheet-metal forming processes which is boosted by numerical methods of calculation. Along with developing and launching tool strategies for forming manufacture of single or series production parts, monitoring and regulating systems guarantee the stability and reproducibility of forming processes. Another focus in the display of final component part geometries is the technological and tool design of cutting processes.

Most of our business partners are companies in the automobile industry and their component suppliers. We mainly facilitate small and medium-sized companies with our expertise in areas such as processing difficult-to-form materials and applying new low-resource and low-energy manufacturing technologies. One final focus we are increasingly working on is production technologies to manufacture components for wind power and solar energy systems including electrical mobility.

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## **METHOD (STAGE) AND TOOL PLANNING**

Fraunhofer IWU applies the finite-element method for designing forming and cutting processes as well as qualifying existing processes for new sheet-metal materials and requirements. Feasibility studies, process streamlining and predicting or compensating for spring-back effects are in the main concentrations here.

We use diverse software packages for sheet-metal forming and cutting simulations.

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## **TECHNOLOGY STREAMLINING**

We are active in the field of conventional forming techniques such as deep drawing and stretch drawing, cutting, perforating, bending, folding and flange sheeting. We can provide expertise in the form of processing guidelines for component parts and strategies for subassemblies because we have extensive knowledge and experience in all areas of the process chain for manufacturing complex forming components. This includes:

- new drawing techniques
- combinations of processes
- predicting spring-back behavior
- manufacturing tailored blanks and
- the patchwork technique

### **Process monitoring and control**

Any fluctuations during manufacturing – especially by changing material properties in coils or the different batches – cause faulty components. A system developed by the Fraunhofer IWU for continually monitoring the material flow in deep drawing operations can discover these faults at an early stage and prevent them in time by manually or automatically taking control of the manufacturing process (process regulation).

No-contact sensors (based upon optical or piezoactive devices) are used for process monitoring while specifically modifying the blank holder force for process streamlining.

Using these systems has made it possible to drive down the reject rate 70 percent in industrial applications while using lubricants has driven down the reject rate 50 percent. Simultaneously recording manufacturing parameters provides regular proof of quality.



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## NEXT-GENERATION FORMING TECHNOLOGIES

### Incremental forming

Incremental sheet-metal forming enables you to lower tool costs in prototype and job lot production (restricting the shape storage degree of the active tool elements) by only using one half of the tool and quickly applying the CAD data or model component part.

Beyond that, this technology not only provides a higher level of forming and surface hardening, it also provides minimum sheet-metal thicknesses.

### Roll bending

Highly precise pipe-shaped component parts such as bearing shells and bushings made of blank material can be manufactured with roll bending without mandrels. Furthermore, initializing and dimensioning tangential compressive stresses into the abutting surfaces of the rolled blanks produces gap-less component parts with minimum roundness deviations and diameter tolerances.

### Manufacturing of thin sheet-metal materials

The manufacturing processes in the metal packaging industry are being refined to meet the demands for greater functionality, easier handling and lower resource consumption. These include necking, expanding and incremental processes while FEM simulations make it possible to launch and streamline feasibility studies for new strategies and then develop and launch technological prototypes. The main idea is coming up with and qualifying existing and new processes for machining thinner and high-strength material qualities.

### Electromagnetic forming

Electromagnetic forming is a technique where the impulse energy (i.e., the electromagnetic impulse) is used for forming sheet-metal materials. The greatest benefits of this technology are

- forming without punches to go gentle on surfaces,
- the short process times,
- its excellent reproducibility and
- its low operating expenditures.

This technology can be used for forming and cutting operations, joining processes and welding work using pipes, profiles and flat sheet-metals. The key items in development at the Fraunhofer IWU are designing and laying out tool coils while streamlining process layout.

### Gas generator technology

Manufacturing metallic sheet-metal preform parts based upon active means and compressed gases makes it possible to produce complex component parts and difficult-to-form materials. Gas generators are solid mixtures of materials that can use a combustion reaction to release a large quantity of gas in a short period of time. This property has been used to date in passive safety systems in automobiles (i.e. airbags), although the property of quick gas generation can also be used for forming sheet-metals following hydroforming. The benefits of gas generators in relation to previously applied active means are in a faster build-up of pressure. Igniting the gas generators and the pressure build-up associated with it presses the sheet-metal to be formed into the mould of the matrix.

**TITLE** *Inner part of an automobile door made of magnesium.*

**1** *Incremental sheet-metal forming of a gear carrier.*



## CUTTING TECHNOLOGIES

Cutting techniques have an important role to play in sheet-metal manufacturing because every component part in manufacturing is exposed to one or several punching and separating processes. The tendency is targeting component parts ready for joining that do not require any more reworking. The Fraunhofer IWU has comprehensive test findings for such things as shear cutting with open and closed cutting lines and precision cutting of aluminum alloys, organically coated steel sheets, microalloyed fine grain constructional steels and high/super high strength sheet-metal materials. When streamlining the cutting processes, the tool design (the cutting gap and the geometry of the cutting edges) as well as selecting the right tool materials (fast working steel, cold working steel, powder metal steel, hard metals and ceramics) and coatings (hard material layers and carbon layers) have a pivotal role to play for the results of cutting.

The foremost research and development work carried on at the Fraunhofer IWU is dedicated to pioneering cutting technologies such as precision cutting, high-speed impact cutting and complex cutting of forming workpieces with the gas generator technology.

### Precise cutting

One alternative to fine blanking is precision cutting. Integrating precision cutting tools into follow-on composite tools for manufacturing complex sheet-metal components makes it possible to generate cutting surfaces at a high level of precision even without using a fineblanking press. Cutting surfaces can be generated on conventional and easy-function presses on component parts with a high sheet-metal thickness that have a flash-cut proportion in the range of 60-90 percent while dimensional tolerances range between fine blanking and normal shear cutting. FE simulation enables us to carry out analyses of the stress occurring with varying cutting edge geometries and tribological parameters.

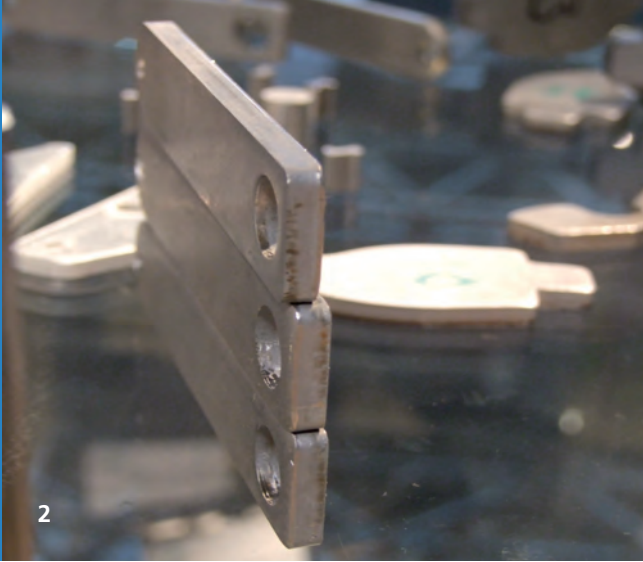
### High-speed shear cutting

This separating technique is based upon the physical phenomenon of "shearing band formation" where there is an extremely high rise in the melting temperature for a very brief period of time ( $< 100$  microseconds) in a very narrow material range ( $< 100$  micrometers). Since this process is very fast and limited locally, the heat developing cannot flow off into the environment of the process zone. There are two contrary processes in the shearing zone with deformation consolidation and the loss of strength caused by the temperature occurring. Then shearing bands form if the softening material behavior gets the upper hand which spells out sudden "sharp" material separation due to the microstructure grains and in the final analysis that brings about a high level of cutting quality. It also has a flat cutting surface with small burrs, an predominant fine-grain fracture zone proportion, a high level of dimensional accuracy and low component part deformation. Some other examples of benefits of this cutting technology are a cutting process without lubricants, reducing edge consolidation and the low web and edge widths.

At Fraunhofer IWU a system for high-speed impact cutting (ADIA7) made by Adiapress is available, whose high-speed hydraulic system provides a maximum energy of seven kilojoules, spelling out punching speeds of as much as ten meters per second.

### Gas generator technology

In cooperation with the Fraunhofer Institute for Chemical Technology in Pfinztal, Germany, the Fraunhofer IWU is delving into the problem of using gas generator technology to cut complex component part geometries from steel and aluminum materials. Utilizing gas as an active means and its even expansion on all sides make cutting possible in any spatial direction. This is an excellent alternative to cutting operations that are not in the main direction of the system used. To date, a complex tool design system (tapered slide valve) has been



used for these cases that was subject to certain constraints such as power and space requirements and that under certain circumstances had to be distributed over several subsequent operations. The cutting edges were formed without burrs due to the high speeds and also virtually free of residues due to using the gas generators on differing materials.

We came up with a tool strategy for the practical use of this technology that is founded upon a basic tool completely integrating these functions. The only thing that necessary is replacing alternating elements that have the shape of the finished part (for forming with gas generators) and cutting inserts (for cutting with gas generators). The gas generators themselves are supplied patterned by the vendor for the specific application.

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## USE OF NEW SHEET-METAL MATERIALS

We take on the challenge of making newly developed lightweight construction materials useful for series production. For example, we ascertain material parameters and forming limits for press-hardening steels (manganese-boron steel 22MnB5/1.5528), aluminum and magnesium alloys, titanium, multiphase steels (DP, TRIP, CP), metal-plastic composites as well as structured sheet-metals.

We make our findings available to users of these sheet-metal materials from the combinations of tool and workpiece materials tested in model tools and demonstrators.

We have extensive experience in the field of processing organically coated precision sheet-metals and we have tested a wide variety of coatings with special active component materials (such as plastic and compact-spray aluminum). We have especially focused on testing and streamlining the tribological

system (tool materials, coatings, lubricants and sheet-metal material) and the quality of the formed component part (such as the degree of gloss and coating adherence) to supply users with reliable machining parameters for coated precision sheet-metals and guidelines for tool design.

### Processing magnesium sheet-metal

The “TEMaK – technology platform for using magnesium wrought alloys for vehicle construction in the product life cycle” growth center looked into the potential of magnesium as a lightweight material by investigating the entirety of its life cycle. Industrial and research partners worked in the areas of magnesium sheet metal production, construction, forming and cutting, joining, surfaces and recycling with the objective of finding joint solutions to specific sub-tasks, and presented an integrated solution using a sample car door. The Fraunhofer IWU focused mainly on developing the technologies needed to form magnesium sheet metal for industrial purposes.

The objective was to develop a structure that is as ready for mass production as possible (car door). A particular focus was on making the door interior extremely easy to form, making it possible to link the various attachments and built-in parts.

Combining electrically heated tools and inductively or magnetically heated semi-finished products proved to have a promising impact on industrial cycles. This approach made it possible to implement mass production cycle times of eight seconds for the outside and inside parts of the door.

**1** *Precision cutting tool for cutting surfaces with a high level of smooth-cut proportion.*

**2** *Low- or no-burr rectangular separating surfaces generated by high-speed shearing cutting.*



Tailored blank circuit boards were heated inductively before being fed into the heated tool. For energy reasons, only circuit board sections with high formability levels were heated directly by a component-specific inductor. A non-isothermal temperature profile was created inside the tool using a number of variable control circuits. This made it possible to make the process differentiated instead of entirely isothermal as it was in the beginning. It also reduced the amount of energy that goes into making a stable good part by over 40 percent.

The demonstrator car door incorporated the findings of our research. The magnesium design of the assembly has similar properties to a steel door, but weighs around 4.6 kg, compared to about 11.2 kg.

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## TOOL DEVELOPMENT AND OPTIMIZATION

We come up with ideas for new tool strategies for manufacturing complex forming components made of thin sheet-metals right down to component parts with sheet-metal thicknesses of more than ten millimeters in the framework of research projects and on behalf of the customer. This focuses in tool design on prototype and small-scale and series production where we apply the latest trends in plant engineering and tool material development. We also realize tool manufacturing and tool specification tests depending upon requirements and project scope.

### Modular tool strategies

The variety of models required by our customers (such as in the automobile industry) often involves proportionally high tool costs because the number of parts of the derivatives produced drops simultaneously. Frequently, these component

parts only differ in specific details so that it is only necessary to change these sections if a modular tool structure is used. The institute has come up with a basic tool strategy which allows short changing times between two or several geometries with a simultaneously high level of component part accuracy and reproducibility.

### Active component coatings for forming and cutting tools

Increasing use of new sheet-metal materials with shape-changing and consolidation properties in relation to conventional sheet-metal materials makes special requirements of tool design. This is the reason why the institute has put its head together with various partners to launch studies in recent years on the application of tool coatings and their properties in the tribological system in forming and cutting tools. Coming up with a coating design that stands up to stress makes it necessary to consider the overall system of the sheet-metal material – coating/lubricant – tool material, harmonizing tool-finish processing on the coating process, taking the changes in the coating properties into consideration with tempered forming and adapting the coating system to each temperature field.

- 1 Heated mold for manufacturing of an inner automobile door made of magnesium.
- 2 In-line process monitoring for a drawing stage.
- 3 Magnetic forming system.



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## SENSORY AND ACTUATOR SYSTEMS IN TOOL DESIGN

Monitoring the production process allows a clear reduction in faulty components in the tryout, start-up phase and series production process because they can be frequently found in the subtle change in material parameters within a coil or batch. The right sensory system can be used to monitor practically all stages of production while evaluation algorithms generate corrective parameters if there are significant departures from the optimum state. Furthermore, using actuator systems built into the tool (such as piezoelements) automatically generates slight changes in the process parameters that guarantee reliable component part quality throughout the entire production process.

### Thin-layer force sensors for monitoring cutting processes

On-line process monitoring is indispensable for economic and high-quality production in shear cutting technology because it provides the foundation for efficient process control while making it possible to react to changes in the shearing cutting process at an early stage to prevent such things as tool breakage. New sensors based upon force sensor coatings (known as thin-layer force sensors) are a low-cost alternative to conventional systems. They are engineered to be tough and they can be built into cutting tools to save space. Comparative measurements with commercially available sensors have shown that these new sensor systems can reflect changes in the force of cutting processes over time in good agreement, however with substantially better resolution.

## EQUIPMENT

### Software tools available

Pro/ENGINEER/CATIA/AutoCAD/PAM-STAMP™/DEFORM™/LS-DYNA/AUTOFORM/ABAQUS/ANSYS

### Plant equipment available

- Hydraulic tryout press EHP4-1600 with multi-point die cushion and high-speed-system (press force: 16,000 kN, table size: 4,000 mm x 2,500 mm)
- MSP4-2000-2.5x1.2-400 multiservopress with 4 main drives (max. compressive force 2,000 kN, ram speed 280 mm/s, table dimensions 2,500 x 1,200 mm)
- Hydraulic double-column frame press HD 315 (press force: 3,150 kN, table size: 800 mm x 1,000 mm)
- Hydraulic double-column press PYZ 250 with multi-point die cushion (press force: 2,500 kN, table size: 1,700 mm x 1,250 mm)
- Hydraulic C-stand press CLDZ 250 with die cushion (press force: 2,500 kN, table size: 1,060 mm x 780 mm)
- Hydroforming presses
  - (1) working area 2,000 x 1,500 mm, clamp force 15,000 kN, max. internal pressure: 4000 bar
  - (2) working area 2,150 x 4,440 mm, clamp force 50,000 kN, max. internal pressure: 2 x 4,000 bar
- Equipment for high-speed impact cutting (ADIA 7)
  - energy capacity 0.7-7 kJ (can be extended)
  - speeds 10 m/s (can be extended to 15)
  - energy generation with high-speed hydraulic systems
  - series suitability to 120 lifts/min
- Cold roll forming system (the profiling machine is approximately 6 m, bandwidth 100-500 mm and max. 11 profiling frames)
- Magnetic forming system 100 kJ
- Equipment to incremental forming
- Hydraulic squaring shears CP 3100 x 13

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