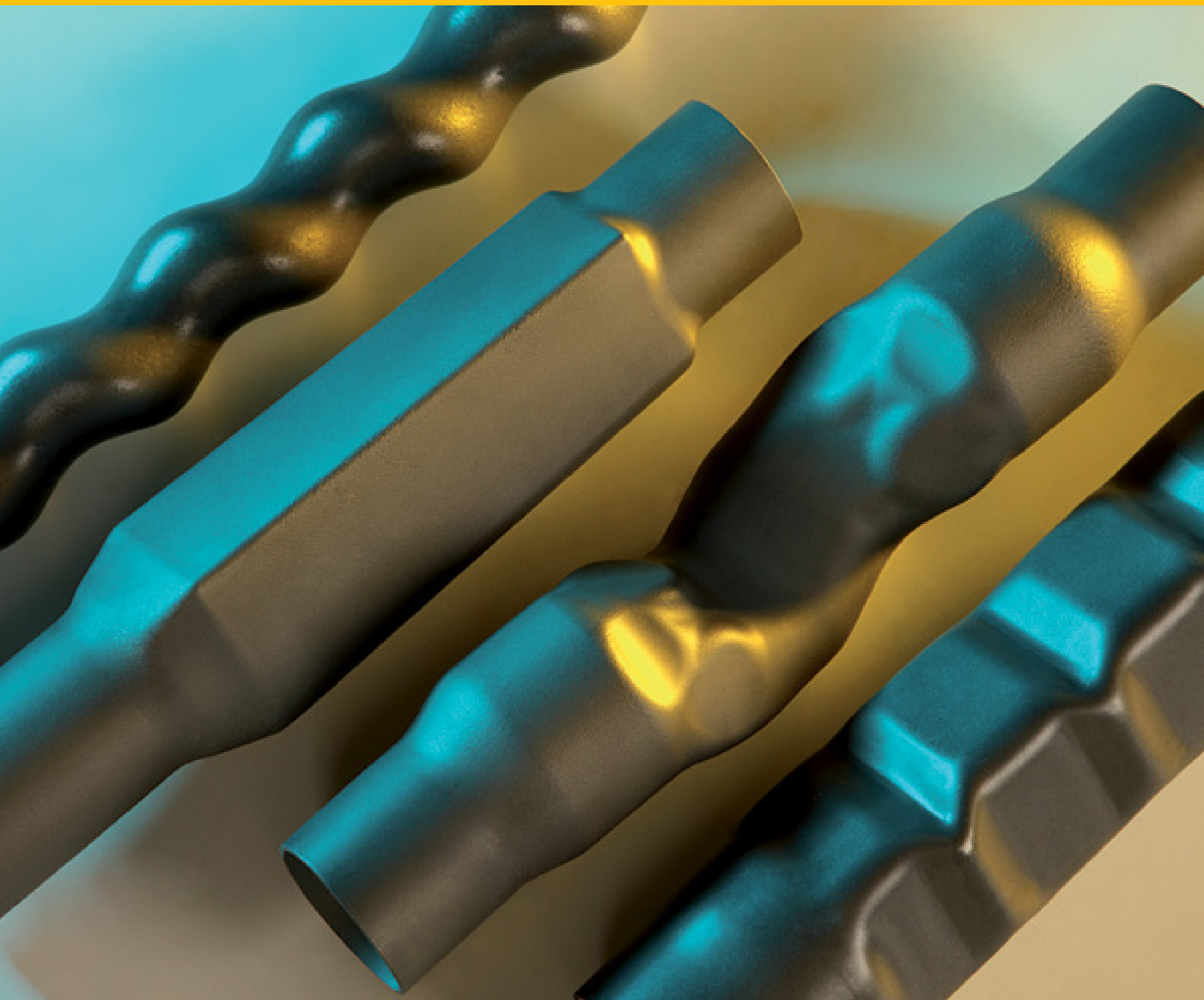
Fraunhofer IWU

FRAUNHOFER INSTITUTE FOR MACHINE TOOLS AND FORMING TECHNOLOGY IWU

PRESS HARDENING
OF SHEET METAL AND CLOSED PROFILES



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PRESS HARDENING OF SHEET METAL AND CLOSED PROFILES

There is a continuing positive trend towards the use of ultra-high-strength materials in innovative vehicle body concepts. Alone the use of ultra-high-strength car body parts can reduce the weight of a midsize vehicle by up to 20 kilograms. This not only reduces the quantity of steel required to manufacture the vehicle, but also saves on fuel consumption and CO_2 emissions during the working life of the vehicle.

Given these advantages during the production and use of a vehicle, forecasts indicate that the demand for ultra-high-strength vehicle body components will increase to approximately 350 million parts per year by 2015. In order to keep pace with this rapid development, we need reliable strategies for mass production in order to satisfy ever more stringent energy and resource-efficiency requirements.

The press hardening technology

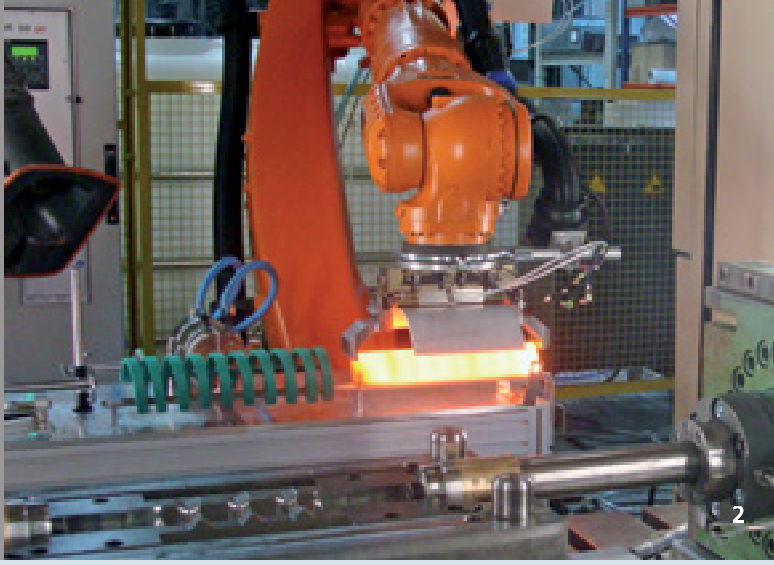
One example of success in the manufacture of ultra-high-strength car body parts is press hardening: a production process for the hot forming of sheet metals. It combines both the shaping and the heat treatment of sheet metal components into one single process step. The process involves inserting sheets or closed profiles, which have been heated beyond the austenitizing temperature, into a cooled forming tool, in which they are then quenched. The thermal integrated processing produces a martensitic structure that gives the press-hardened parts an extremely high tensile strength of up to 1,800 MPa. Components such as this can be used in crash-relevant structures such as A- and B-pillars, bumpers or door sills or, in the power train, for example as camshafts.

However, this combination of forming and thermal processing creates challenges throughout the process:

– During the project planning phase:
  - Thermomechanical process simulation
  - Process monitoring
  - Tool design with integrated cooling system
– During the application phase:
  - Handling of hot components
  - Cutting the press-hardened parts to the final geometry
  - Meeting high energy and resource demands

1 *Press hardening of a B-pillar base*

2 *Media-based press hardening of closed profiles*



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Scientific digression:

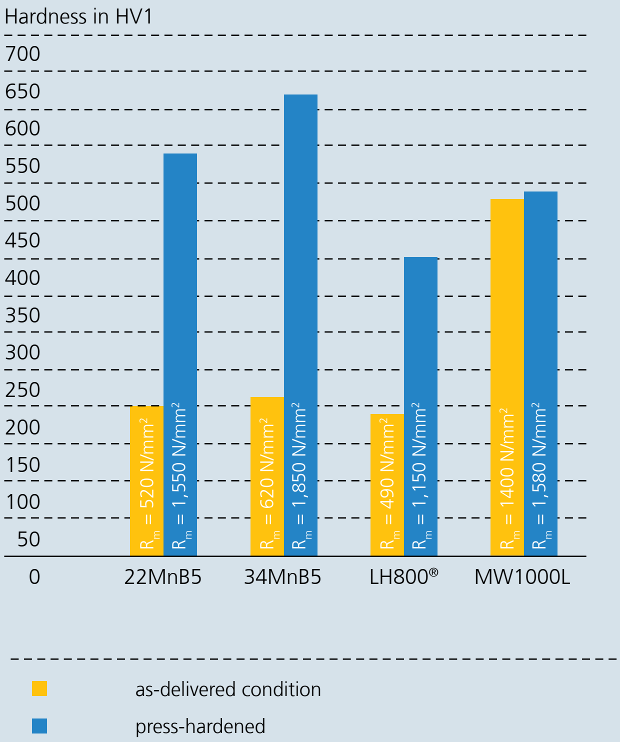
Characterization of a press-hardened closed profile

During Hot Metal Gas Forming (HMGF), the combination of the press hardening and active-media-based forming process, a variety of parameters affect both the process and, as a result, the geometric and mechanical properties of the product being manufactured. In order to determine the impact of these factors, numerical simulations are of great value during process design.

Alongside process variables such as the expected true strain and the thinning of the component, the temperature profile of the component during processing and its resulting mechanical parameters, such as strength and hardness, play a decisive role during HMGF. In order to achieve as accurate a representation of the actual process as possible, thermomechanically coupled simulations are used. During further observations, both the thermal behavior of the tool and the influence of the active medium on the cooling of the component are calculated by means of thermodynamic simulation. As a result, the temperature profile of the component (among other parameters) was determined via this process, which in turn facilitates the assessment of its final mechanical properties.

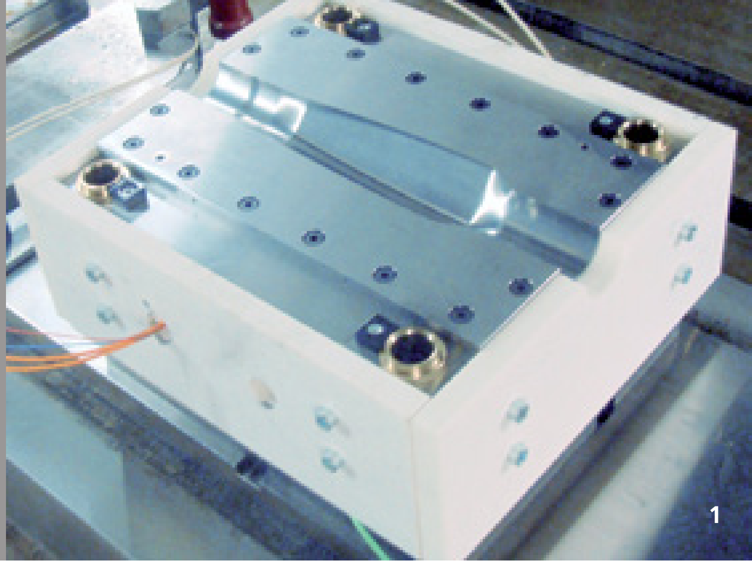
The adjected diagram shows a selection of the materials examined while undergoing active media-based press hardening and the strength and hardness values that were achieved. In order to verify the simulated component and tool temperature profiles, appropriate measuring techniques have to be applied within the tooling systems. At Fraunhofer IWU, both tactile and non-contact sensors have been tested to ensure that they are appropriate for use in HMGF, and modified measuring systems and strategies have been developed on this basis.

Hardness- and strength values of various materials



Test parameters

	Value
Austenitizing time	5 min
Max. temperature of the component	950 °C
Tool temperature	20 °C (water cooled)
Max. medium pressure	70 MPa
Active medium	nitrogen



WHAT WE OFFER

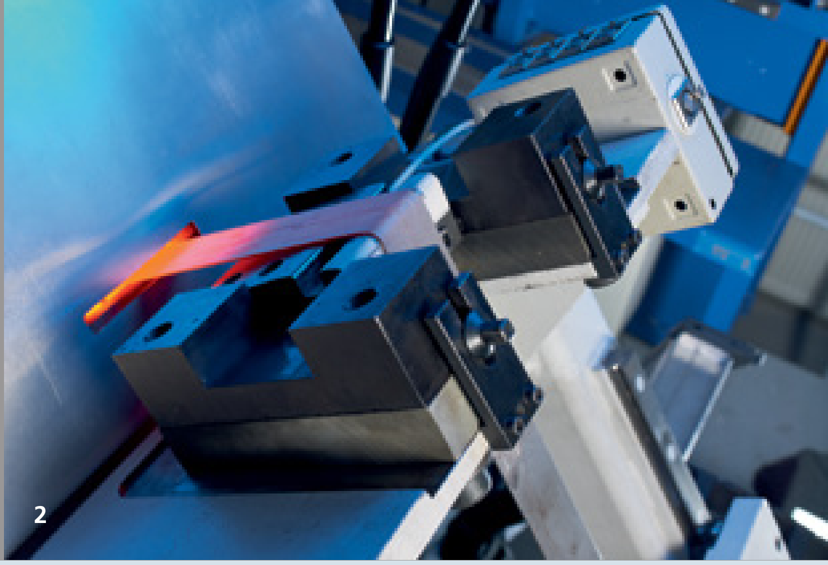
Solution strategy – a holistic approach

The press hardening technology is an interesting and future-oriented research field at the Fraunhofer IWU. We set ourselves apart in this field as a result of our holistic and interdisciplinary concept, which encompasses materials analyses, the specification of technological process parameters through to the manufacture of components using innovative tools. This solution is rounded off by studies into the energy and resource efficiency of the various process steps, while taking cost effectiveness into consideration.

Our range of services

- Production strategies for components with tailored properties (e.g. by means of tailored tempering concepts)
- Process chain and method planning for press hardening (e.g. determination of optimal process parameters, feasibility analyses)
- Studies in the field of materials physics (determination of parameters such as thermal expansion coefficient, thermal conductivity, specific heat capacity)
- Analysis of technological material parameters (e.g. forming limit curve up to a forming temperature of 950 °C, limiting drawing ratio)
- Tribological studies (e.g. tempered strip drawing tests)
- Simulation of the forming process (e.g. thermomechanically coupled forming simulation, microstructure simulation, flow simulation)
- Development of tool concepts and design implementation (e.g. implementation of various tool cooling concepts)
- Press hardening of sheet metal components
- Media based press hardening of tubes and closed profiles (e.g. use of various gaseous active media or inductive heating of semi-finished products outside and inside the tool)
- Evaluation of energy and resource efficiency of processes and process chains

1 *HMGF tool with integrated cooling system*
2 *Tempered strip drawing test*



Scientific digression:

Examination of frictional behavior in press hardening

Tribology is a process parameter with a significant influence on process stability, both in cold and hot forming. In both processes, the coefficient of friction between the tool and the sheet metal has a significant effect on the forming result, thus determining whether the part produced is sound or defective. In contrast to cold forming, however, there are additional wear mechanisms in play during press hardening, which place high demands on the tool surface.

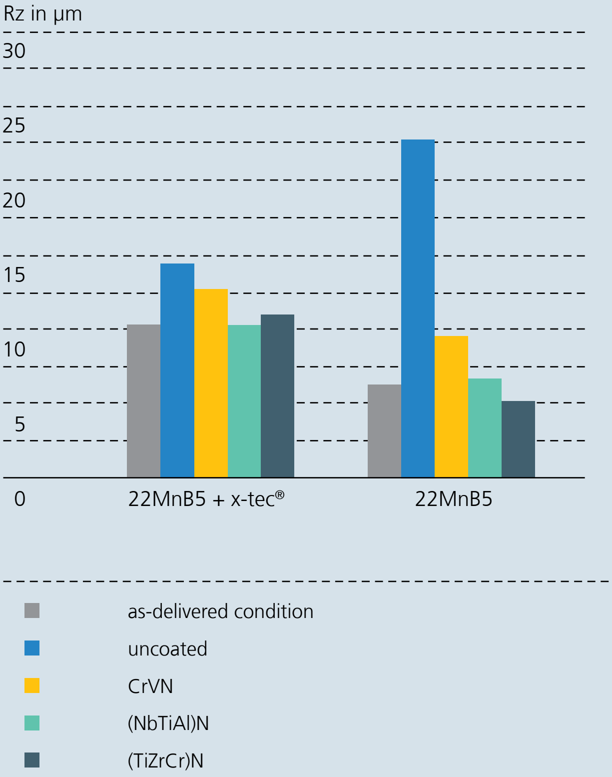
The key wear mechanisms in this case are signs of fatigue due to alternating thermal stress, signs of adhesion and abrasion (depending on the applied sheet metal coating), localized erosion due to the microstructural transformations caused by the high temperatures and diffusion processes on the tool surface.

The service life of tools can be extended and maintenance intervals lengthened by the targeted selection of the tool material, tool coating and, where applicable, the lubricant.

Various hard coatings and an uncoated tool steel were tested for suitability for use in press hardening tools by means of tempered strip drawing tests. During the tests, the press hardening material 22MnB5 was used, in both an x-tec®-coated and uncoated version. Following austenization in the system's integrated furnace, the sheet metal strips were drawn over the coated drawing edges while applying surface pressure. The trials were evaluated with regard to tool wear, the surface condition of the sheet metal and the friction coefficient.

The welding of the uncoated sheet metal to the tool can be avoided by the use of PVD coatings. The friction coefficients for the respective sheet metal materials remain almost unaffected by the tool coating.

Sheet roughness Rz
(Drawing edges with PVD coating)



Test parameters

	Value
Drawing speed	50 mm/s
Drawing distance	300 mm
Drawing radius	8 mm
Tool temperature	23 °C
Furnace temperature	900 °C
Austenitizing time	8 min
Surface pressure	20 N/mm²

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EQUIPMENT

Plant equipment

- MSP4-2000-2.5x1.2-400 multiservopress (with 4 main drives and max. press force of 2,000 kN)
- Hydraulic tryout press EHP4-1600 with multi-point die cushion and high-speed-system
- Hydraulic double-column frame presses and C-stand press
- Roll forming system (11 profiling frames, band with up to 500 mm)
- Hydroforming presses (clamp forces of 15,000 kN and 50,000 kN with gas compression and control unit up to 70 MPa, active medium: nitrogen)
- Induction unit for medium and high frequency, each with 25 kW output power
- Magnetic forming system (105 kJ pulse energy)
- Equipment for high-speed impact cutting (ADIA 7) with speeds up to 15 m/s and 120 lifts/min
- Robot system with grippers for the handling of warm components
- 10 kW recooling system for tool cooling

Measuring- and testing equipment

- Erichsen sheet metal and strip testing machine 145 with 600 kN punch force
- Tensile testing machine Zwick 1475 with position-sensitive strain measurement, high temperature capability up to 1,100 °C and max. force of 100 kN
- Tensile testing machine UTS 20 with vacuum/inert gas furnace up to 1,600 °C
- Biaxial tensile testing machine Zwick (combined force 250 kN)
- Heated strip draw tester with 90 °C bending angle
- CNC micro hardness tester EMCOTEST M1C 010-DR
- InfraTec VarioScan 3021 ST thermo camera with temperature range up to 1,100 °C
- Nikon Epiphot reflected light microscope and Olympus SZX10 stereo microscope
- GOM 3D contour, displacement and strain measurement equipment
- ViALUX (compact mobile and vario system) AutoGrid® deformation analysis equipment
- Optimized equipment to apply electro-chemical or screen printed grids in diverse applications
- Cutting, mounting, grinding and polishing equipment as a basis for metallographic examinations

Software tools available

Design:	Creo Elements/Pro (Pro/ENGINEER), CATIA V5, Autodesk®, Inventor®, AutoCAD®
Simulation:	PAM-STAMP, DEFORM™, LS-DYNA, AutoForm, Abaqus, ANSYS®

REFERENCES

Flagship and reference projects

Cluster of Excellence project "Energy-Efficient Product and Process Innovations in Production Engineering" (eniPROD)

Project runtime: 2009 – 2014

– A vision of self-sufficient, emission-free production with simultaneous reduction of energy requirements and increase in resource efficiency

– Funded by the European Union and the Free State of Saxony

"Determination of Suitable Process Strategies for the Integration of Press Hardening Processes in Active-Media-Based Forming"

Project runtime: 2009 – 2013

– Baseline investigations, strategies for numerical process design, the development of innovative tooling technologies, analysis of contouring accuracy and the adjustment of tailored properties

– Funded by the AiF, through the European Research Association for Sheet Metal Working (EFB) (16182BR and 16961BR)

Joint project "Flexible Heat Treatment"

Project runtime: 2009 – 2012

– Targeted design of component properties and the increase in the energy efficiency of hot forming process chains, tool design, thermomechanically coupled simulation

– Funded by the German Federal Ministry for Education and Research

"Cutting and Joining of Ultra-High-Strength Steels"

Project runtime: 2008 – 2010

– Requirements for reliable series production and the development of new cutting technologies for ultra-high-strength steels

– Funded by the Sächsische Aufbaubank (SAB)

Networks

Network for hydroforming:

Increasing the competitiveness of SMEs through the introduction of new technologies, which contribute to the more efficient manufacture of existing and/or new products (www.netzwerk-ihu.de).

1 *Tensile test to determine flow curves at high temperatures*

2 *Visualization of the energy flow during press hardening*

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