Your Production Technology for Metal Microstructures.

From prototyping and small series up to the individual production line for the forming, cutting and welding.
Graebener® – Machine the difference

Graebener® makes the difference. As family owned company we develop and implement customized solutions worldwide for the core markets of automotive industries, hydroforming, manufacturing of large pipes, shipbuilding, wind tower production and vessel construction – from the Siegerland all around the world.

Based on almost 100 years of experience in the metal processing business it is our commitment to make you better and provide you with the decisive competitive edge. Therefore, a Graebener® solution is no standard solution. A Graebener® solution is your individual solution, tailored and customized to your requirements and needs by highly qualified and experienced engineers. This commitment is based on expert knowledge. More than one third of our employees are highly trained and qualified engineers and technicians with vast knowledge and business experience. The design of your solution is entirely in our hands, including hydraulics, control and feedback control technology and pioneering solutions in the area of intelligent process data analysis and evaluation. It goes without saying that we are certified according to DIN ISO 9001.

We offer more. Since 1921, Graebener® has been standing for family cohesion and teamwork, for a sense of responsibility and for a trusting and long-term partnership. Most of our customers are repeat customers – or, as we call them: partners and friends.

Graebener® is your chance to stand out from the standard.
Machine the difference.

“YOU GET MORE THAN JUST A MACHINE OR A SYSTEM. YOU GET MORE EFFICIENCY AND MORE PRODUCTIVITY. YOU GET THE BEST SERVICE AND A RELIABLE PARTNER WHO UNDERSTANDS YOUR PROCESSES AND DEVELOPS THE OPTIMUM SOLUTION FOR THE MARKET REQUIREMENTS TOGETHER WITH YOU.”

DIETER KARP, Managing Partner

www.graebener.com
**Example for the application of microstructure plates: the fuel cell**

More than enough clean power

Fuel cells are the suitable and environmentally friendly drive system of the future. They are based on a principle which was discovered more than 180 years ago and use the most common element in organic compounds: “Hydrogen”. By means of an electrochemical process, hydrogen and oxygen are turned into electric energy.

The fuel cell stack consisting of joined microstructure plates, the so-called bipolar plates, is the core of a fuel cell drive. The bipolar plates themselves consist of two semi-plates each (anode and cathode). By means of further components, electric current is generated from hydrogen and oxygen in this environment.

Due to their considerable increase in efficiency while at the same time providing a clean and low-noise operation, fuel cells are used in various business areas, e.g.:
- **Automotive and aerospace**: drive unit for emission-free and long-range transport
- **Private and industrial stationary systems**: decentral power and heat generation

**Metal Bipolar Plates**

**Essential for fuel cell and electrolyzer**

Not only is the bipolar plate the basis of the fuel cell drive, it also is an essential component in the electrolysis. Electrolyzers work similarly to fuel cells, but in reverse order. Instead of generating electric current, they convert electric current from e.g. renewable energies in hydrogen to be stored for later usage (Power2Gas).

**Manufacturing**

Today, bipolar plates are mostly made of metal or graphite. In comparison to graphite plates, metal bipolar plates have the following considerable advantages:
- Weight advantages
- Good recycling capability
- Homogeneous electric conductivity
- Good contact material
- High thermal conductivity
- High surface quality
- High forming capacity
- Mechanical stability/elasticity

The manufacturing of metal bipolar plates is mostly carried out by means of hydroforming or by means of mechanical forming methods. Hydroforming offers considerable advantages:
- Forming of thin foils from 50 µm
- Gentle forming of precoated materials
- Realization of most delicate structures
- High repeat accuracy
- Flexible adjustment of production parameters

**Exemplary fields of application**

- **AEROSPACE TECHNOLOGY**
- **UTILITY SYSTEMS**
- **AUTOMOTIVE**
- **ELECTROLYSIS**
- **STATIONARY SYSTEMS**
- **BATTERY TECHNOLOGY**
- **SPECIAL APPLICATIONS**
- **MICRO-REACTORS**
From Hydroforming Pioneer to Trailblazer of New Technologies

As one of the few hydroforming pioneers, we have consistently been developing our hydroforming lines since the mid-1980s. Only this way can we provide our customers worldwide with the most modern high-tech systems which are optimally tailored to their requirements and secure the decisive competitive edge for them.

Graebener® solutions are based on decades of experience in various fields of application. For the forming of most delicate microstructures, we have been developing and enhancing our proven forming method for 15 years and have now made the patented Graebener® hydroforming press ready for series production.

The Graebener® hydroforming press and the Graebener® micro-cutting and welding system combine the know-how of decades of development along the entire value-added chain for the economic production of metal microstructure plates.

The Graebener® technologies have proven reliable in various fields of application.

**Precise and gentle forming —**

Hydroforming — or external high-pressure forming — is an active media forming process. A metal foil is inserted into a tool gravure and expanded into the forming tool with very high pressure by means of a water-oil-emulsion (see sketch).

Thanks to the even force distribution over the entire foil surface, an optimum plate thickness distribution is achieved, and abrupt stress transitions are avoided. Even with small radii, this leads to optimum forming grades and ensures a very low spring back of the material.

**Mechanically produced plate vs. hydroforming plate**

Compared to conventional processes (stamping, deep-drawing), the hydroforming process provides highly precise forming results with increased repeat accuracy — even with foil thicknesses from 50 µm.

In contrast to a tool of a conventional process, the water also protects the material surfaces which is especially important for the promising forming of precoated materials.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Graebener® hydroforming plate</th>
<th>Mechanically produced plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeat accuracy in the process</td>
<td>Very high</td>
<td>Good</td>
</tr>
<tr>
<td>Elasticity after forming</td>
<td>High elasticity due to gentle forming with integrated cooling</td>
<td>Considerably reduced due to strain hardening</td>
</tr>
<tr>
<td>Contact surfaces</td>
<td>Almost ideal forming results for the flat contact surfaces</td>
<td>Good forming results</td>
</tr>
<tr>
<td>Wall thickness variation</td>
<td>Very homogeneous over the entire channel cross section</td>
<td>Heterogeneous (necking)</td>
</tr>
<tr>
<td>Suitability for precoated materials</td>
<td>Ideal no friction on the water side</td>
<td>Limited suitability due to friction in the tool</td>
</tr>
<tr>
<td>Usage of various material thicknesses in one tool</td>
<td>Flexible depending on the tool various material thicknesses can be used</td>
<td>Not possible</td>
</tr>
<tr>
<td>Tool costs</td>
<td>Low: Less wear and fewer tools</td>
<td>High</td>
</tr>
<tr>
<td>Leak tests (also detection of micro cracks for long-term stability against hydrogen permeation)</td>
<td>Integrated in the forming process, 100% test of each plate</td>
<td>Separate process necessary</td>
</tr>
</tbody>
</table>

**Excursus:**

**Hydroforming**

**Precise and gentle forming —**

**Mechanically produced plate vs. hydroforming plate**

Compared to conventional processes (stamping, deep-drawing), the hydroforming process provides highly precise forming results with increased repeat accuracy — even with foil thicknesses from 50 µm.

In contrast to a tool of a conventional process, the water also protects the material surfaces which is especially important for the promising forming of precoated materials.

**Graebener® hydroforming press**

**Graebener® micro-cutting and welding system**
Our Production Technology and Optional Services —

Customized production technology

**HYDROFORMING PRESSES**
- Use the benefits of hydroforming
- Benefit from our individual press concepts
- Economic production – from small to large-scale series

**CUTTING TECHNOLOGY**
- Individual technology for optimum cutting results in 2D and 3D
- Economic production with modern remote technology

**WELDING TECHNOLOGY**
- Individual technology for optimum welding results even for smallest structures
- Economic production with modern remote technology

Customized, scalable series production

**PRODUCTION LINE**
- Realization of your production line, from the coil up to the joined microstructure plate (e.g. bipolar plate or heat exchanger plate)
- Scalable and extendable depending on the increasing production numbers

Optional services

**ENGINEERING**
- We analyze your design and check it for feasibility based on the material data
- We provide advice regarding possible optimizations
- We give you specific proposals for an economic production

**PROTOTYPING**
- Fast results: benefit from our Prototyping Center
- Prototyping starting with a lot size of 1
- Plate dimensions of up to 2,500 cm² with a material thickness from 50 µm

**SMALL SERIES**
- Have us manufacture your first small series
- Transfer the parameters 1:1 to your own Grabener® press
- Production capacities of up to several thousand bipolar plates per year

**PRODUCTION PLANNING**
- Together with you, we analyze the individual production steps and work out a concept for your individual production technology
- We check your infrastructure on site and work out an installation and assembly plan together with you
- Our concept is of modular design and can be extended at any time in case of increased quantities

15 YEARS OF EXPERIENCE

More than 10 government sponsored projects
More than 50 various designs realized
More than 100,000 plates produced
Hydroforming Presses —

We provide you with the most modern production technology for the forming of your metal microstructure plates — with the patented Graebener® hydroforming presses.

Metal microstructures are more sought-after than ever before. However, for forming specialists, that means pushing the limits. Where conventional production processes fail, we are just beginning to leverage the strengths of our production technology.

With the patented Graebener® hydroforming press, a problem-free forming of metal microstructure plates is possible.

The Graebener® hydroforming press is the result of more than 15 years of development along the entire value-added chain of the production of metal microstructure plates based on our decades of know-how in the building of hydraulic presses.

Each of our presses is unique, as individual as your plate design. Based on your design we offer you a hydroforming press which is optimally tailored to your requirements thus providing you with the decisive competitive edge.

Examples of Graebener® hydroforming plates

- Foil thickness: 100 µm
  Material: Sandvik Sanergy® LT (316L)

- Foil thickness: 50 µm
  Material: 304L

- Foil thickness: 127 µm
  Material: Titan Grade 1

For comparison: mechanically produced plate

Your benefits

- Precise and repeatable forming results with a foil thickness from 50 µm
- Gentle forming of precoated or multilayer materials (e.g. Sandvik Sanergy®)
- Integrated process control incl. 100% leak test
- Considerably lower tool costs
- Very long tool life
- Resource-friendly capacity expansion of production lines
Economic Cutting and Welding

We reach optimum cutting and welding results for you

We not only form your microstructures, we also support you with the subsequent processes of cutting and welding as experienced technology and system partner – from prototyping to series production.

With us, you do not receive a standard solution. As technology partner, we develop the optimum solution for your individual plate design together with you. Initial trials with our cutting and welding system will quickly give you significant results – from possibilities and limits of the process and clamping technology, ideal gassing up to the customized automation solution for your own production.

Based on our long-time know-how regarding the economic production of metal microstructure plates we recommend relying on the most modern remote technology. This will ensure highly precise, economic and absolutely dependable results for you either in 2D planar cuts or in more sophisticated 3D cutting solutions, even with smallest foil thicknesses. A main advantage of the remote technology in contrast to the conventional laser optics is the increased process speed. This way, speeds of up to 1 meter per second can be realized reliably when lap welding stainless steel foils with a thickness of 100 µm.

To ensure a reliable result even with smallest structures we apply spot diameters of below 70 µm. In addition to this, we also put great value on positioning accuracy, repeat accuracy and long-term stability of your system.

As a result, we provide you with a progressive and economic solution for your cutting and welding process which is ideally tailored to your requirements.

Cut of a welding bipolar plate with a thickness of 50 µm

15x magnification

50x magnification

200x magnification
Engineering, Prototyping and Small Series Production

We help you push the limits of feasibility and achieve optimum results for your individual design – in the Graebener® Prototyping Center.

For the prototyping, we have developed a patented machine concept – ideally suited for a wide range of plate dimensions and materials. We realize very narrow radii with a foil thickness from 50 µm.

The experience gained in our Prototyping Center are an integral part of your individual solution, from the initial consultation, the feasibility study and the tool manufacturing up to the optimum forming process.

These experiences are also consistently used for a later design and manufacturing of your series production line by transferring the process parameters of the prototyping to your Graebener® machine. This will provide you with the decisive competitive edge.

We produce your small series

Before taking the next step and investing into your own Graebener® production system, we gladly support you with your first small series.

We can effortlessly handle lot sizes of up to 50,000 parts per year for you. We also support you as reliable partner in case of later production peaks and help you with our own production systems. This way, we keep your risk to a minimum while at the same time paving the way for your maximum profit.

Our range of services, from initial sample to small series

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Analysis of your design regarding feasibility and, if necessary, engineering for optimization</td>
</tr>
<tr>
<td>Material</td>
<td>Stainless steel, titanium, copper, plated materials, even precoated materials (e.g. Sandvik Sanergy®)</td>
</tr>
<tr>
<td>Forming</td>
<td>Plates with a size of up to 2,500 cm² with a foil thickness from 50 µm</td>
</tr>
<tr>
<td>Cutting</td>
<td>Rough and final cutting by means of laser</td>
</tr>
<tr>
<td>Measuring/testing</td>
<td>Detailed measuring of the forming results by means of micrograph generation and microscopic measuring</td>
</tr>
<tr>
<td>Joining</td>
<td>Laser welding</td>
</tr>
<tr>
<td>Leak test</td>
<td>100% leak test of the formed individual plate directly integrated into the process; leak test of all media areas of the joined microstructure plates</td>
</tr>
<tr>
<td>Coating</td>
<td>Usage of precoated material, alternatively, post-coating carried out by our partners if requested</td>
</tr>
</tbody>
</table>
Series Production from the Coil 
up to the Joined Microstructure Plate —

We realize your individual production line – expandable at any time for larger lot sizes

Whether you require the planning of a complete production line or the extension of your existing line, for us, the main focus of our planning will always be your individual component – your microstructure plate.

In close cooperation with you, we realize your individual production line from the coil up to the joined microstructure plate.

We provide you with more efficiency and more productivity. You get the best service and a reliable partner who understands your processes and develops the optimum solution for the market requirements together with you.

Benefit from our decades of experience as special machine builder. Not only are we hydroforming pioneers, we are also among the trailblazers in the area of microstructure plates.

Make our experience your strength.

Future option:
extension of your line

You are facing increasing requirements regarding output quantity or component geometry? Our concept will safely accompany you into the future.

The modular structure of your line guarantees a cost-efficient extension of your production line. In the best case scenario, we will not even have to interrupt your operation for this purpose. All necessary process parameters of the extension modules will be determined beforehand in our Graebener® Prototyping Center.

Our all-inclusive package:

• Design analysis
• Tool engineering
• Prototyping in the Graebener® Prototyping Center
• Planning of the production sequence
• Demand assessment of individual machines and production systems
• Definition of the necessary handling and automation systems
• Generation of the technical specification
• Generation of the 2D/3D line layout with all necessary units and systems
• Generation of the machine installation plan
• Analysis of the interfaces between the respective line parts and to the primary control
• Preplanning of the foundations
• Assembly and start-up
• After-Sales-Service

Exemplary illustration of a production line
Project MetaBPP
Combination of metal bipolar plate and seal
Elaboration of the technological boundary conditions for the integration of a fuel cell suitable seal. Successful realization with an industrial partner.

Project Ekolyser
New economic, sustainable materials for PEM electrolysis
Extension of the competence for forming, cutting and welding of a microstructure plate for the application of highly dynamic PEM electrolysis.

Project PreCoat
Precoated materials for bipolar plates
Elaboration of the boundary conditions for tool, machine and devices for the processing of precoated fuel cell suitable pre-material.

Project RoBiPo
Metal bipolar plate for high-temperature fuel cell
Extension of the competence for forming, cutting and welding of a microstructure plate for the application of a high-temperature fuel cell.

Project BREEZE! Graebener® proves marketability

Graebener® inside: With the successful completion of the project BREEZE! we proved the marketability of our system technology already in 2014. Together with further project partners we realized a 30 kw Range Extender for a Fiat 500.

Within the scope of the project we supplied the metal bipolar plates as proof of concept of our patented production technology and also contributed to the project with our many years of experience in the area of further value-added chain steps. Today, we have vast experience along the entire value-added chain, from the coil up to the functional fuel cell system.