Production Technologies for Hydrogen and Electric Flying

Fraunhofer IWU in Chemnitz

Prof. Dr.-Ing. Martin Dix

Fraunhofer IWU

Profile of Fraunhofer IWU

Characteristics

Partner for Innovations in Production Engineering

From the material level to the factory level.
From idea to realization.

- Foundation: July 1, 1991
- Employees: approx. 700 persons
- Research volume: over 50 M Euros
- Locations: <u>Chemnitz</u>, Dresden, Zittau, Wolfsburg
- 3 scientific fields – 3 directors

Functional Integration and Systems Integration	– Prof. Drossel
Process Technology	– Prof. Dix
Production Systems and Factory Automation	– Prof. Ihlenfeldt

Dresden

Wolfsburg

Zittau

Chemnitz

VALUE CREATION COMMUNITY

HYDROGEN-SYSTEM – PRODUCTION

AREAS OF ACTION

- Industry and science form the hydrogen system production value creation community, are
- pacemaker for the industrial mass production of electrolysers and fuel cells and
- are working on the rapid ramp-up of their efficient, unit-scalable production, for the
- production of cost-effective systems for mass use!

TECHNOLOGY-

MALL

INDUSTRY

- SOLUTIONS AND EXPERTISE
- INFRASTRUCTURES
- REFERENCE PRODUCTS

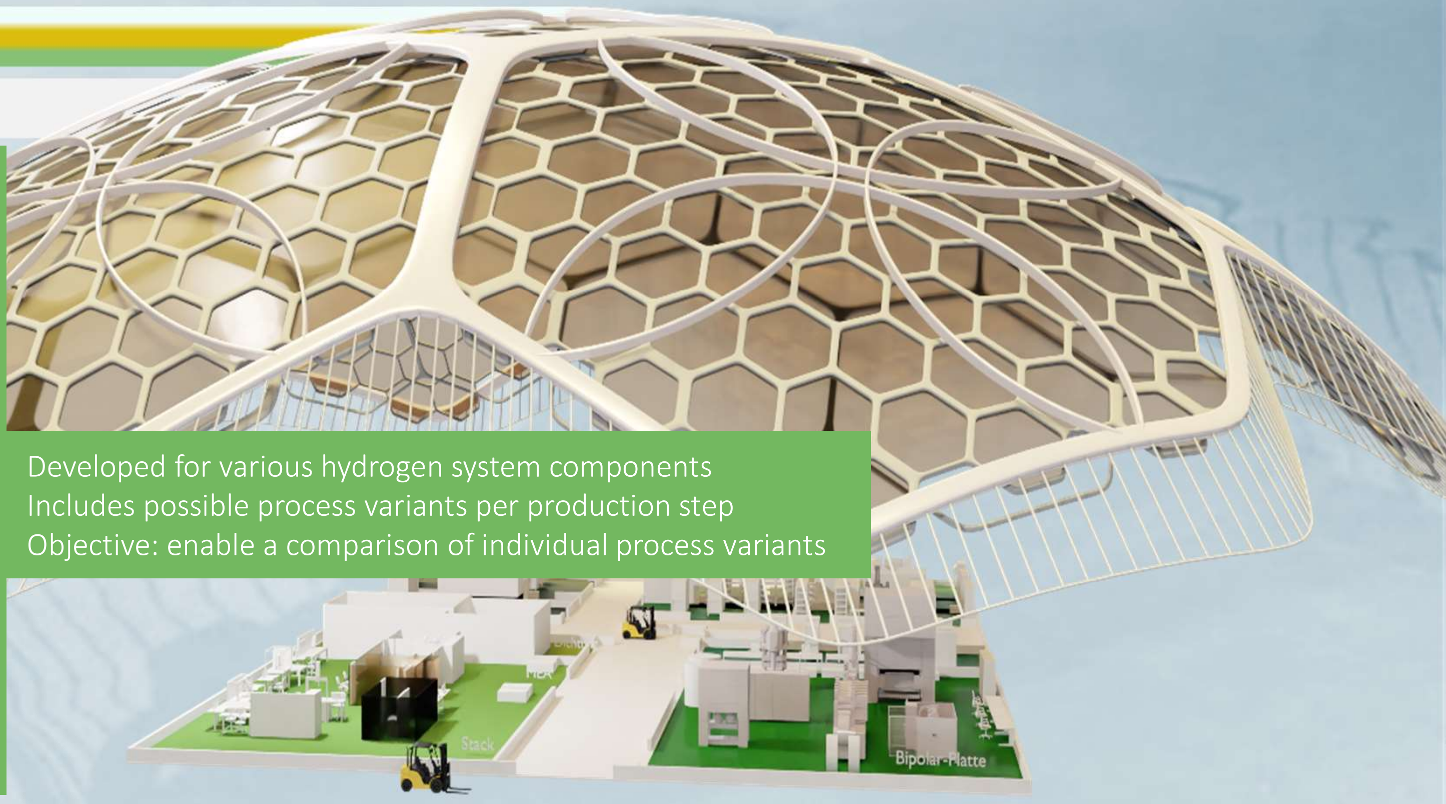
SERVICES

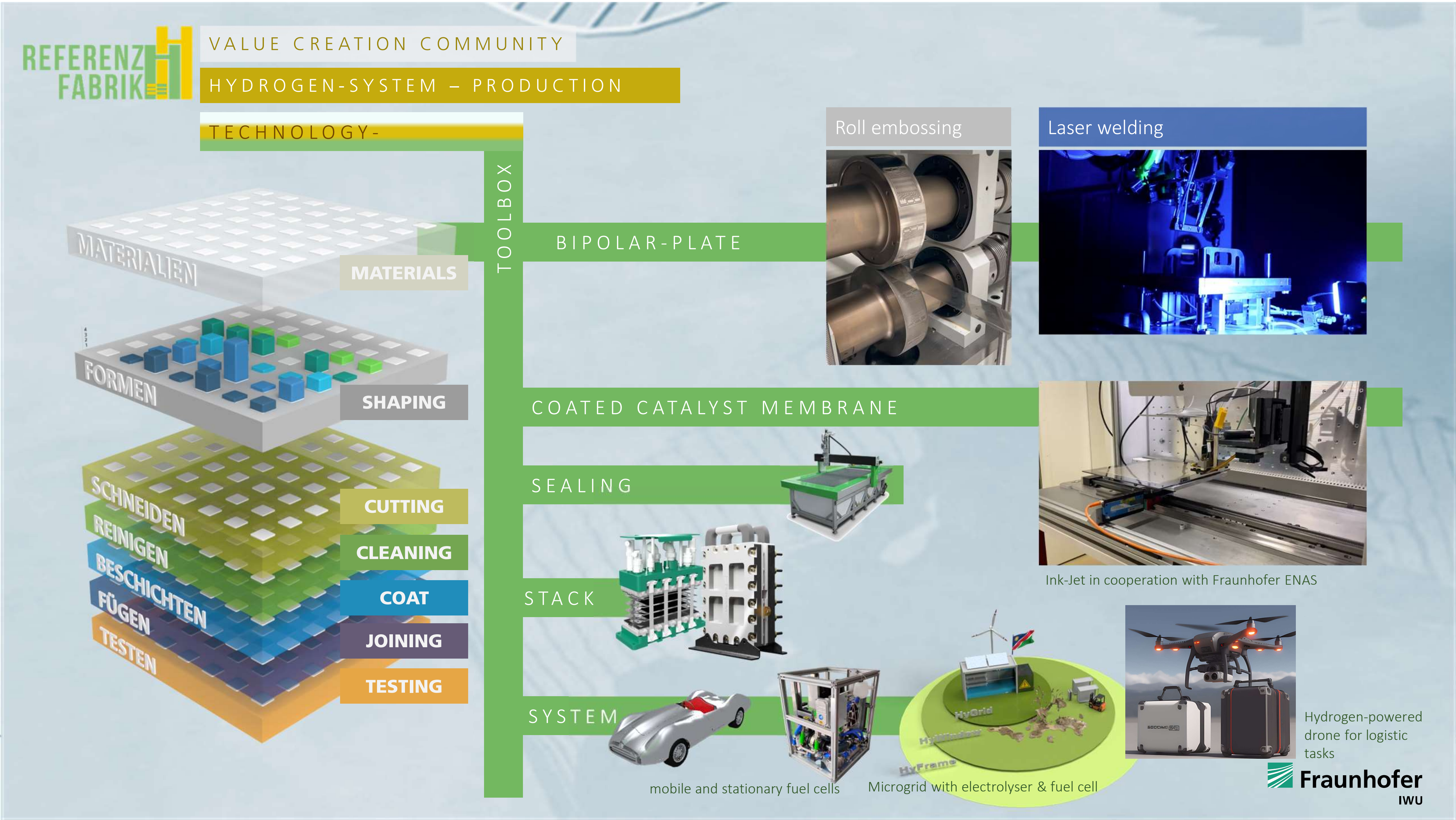
FRAUNHOFER

- DUSWAP [STACKING]
- HYTRA [TRYOUT AREAL]
- HYGO [TRYOUT AREAL]
- FRHY [ELEKTROLYSEUR]
- H2GO [BRENNSTOFFZELLE]
- HOKOME [ROLLE ZU ROLLE]
- H2WIND [ZELL-DESIGN]

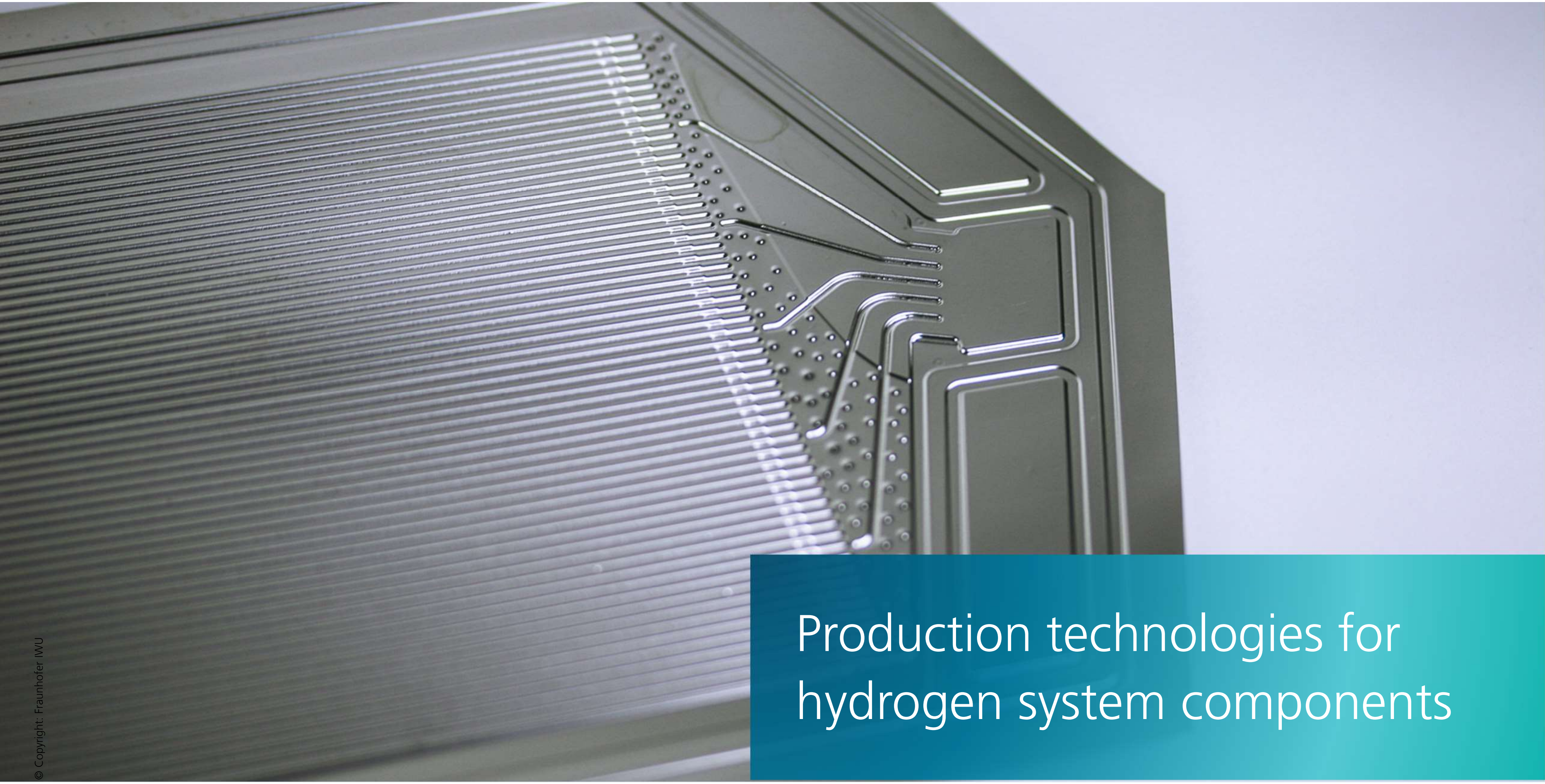
TOOLBOX

- Developed for various hydrogen system components
- Includes possible process variants per production step
- Objective: enable a comparison of individual process variants





REFERENZ FABRIK H
VALUE CREATION COMMUNITY
HYDROGEN-SYSTEM – PRODUCTION
TECHNOLOGY-
TOOLBOX
MATERIALIEN
MATERIALS
FORMEN
SHAPING
SCHNEIDEN
CUTTING
REINIGEN
CLEANING
BESCHICHTEN
COAT
FÜGEN
JOINING
TESTEN
TESTING
BIPOLAR-PLATE
Roll embossing
Laser welding
COATED CATALYST MEMBRANE
Ink-Jet in cooperation with Fraunhofer ENAS
SEALING
STACK
SYSTEM
mobile and stationary fuel cells
Microgrid with electrolyser & fuel cell
Hydrogen-powered drone for logistic tasks
Fraunhofer IWU



Production technologies for hydrogen system components

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1. Production technologies for fuel cells and electrolyzers

Innovative cell designs for fuel cells and electrolyzers

Our reference solutions for fuel cells and electrolyzers

- Adapted geometry in the port area and flow field to avoid wrinkling during rolling and for optimum weld seam guidance during joining
- Sealing concept adapted to the continuous manufacturing process

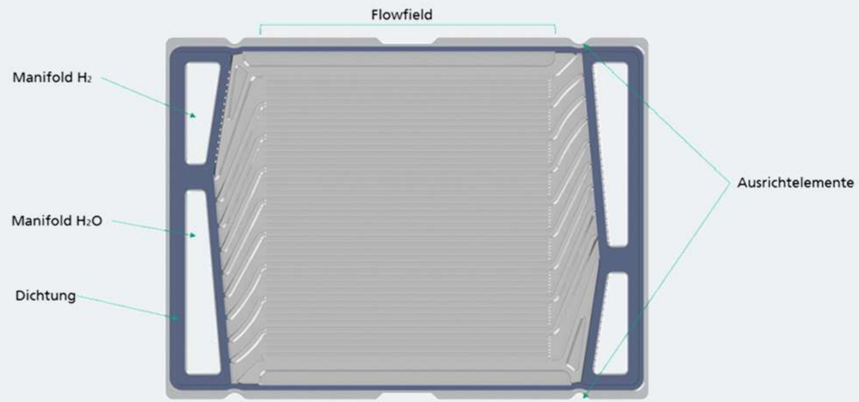
HyVictus V03

for fuel cells with sheet thicknesses of 50 to 100 µm

Dimensions: (380 x 150 x 1.3) mm³; Material: 1.4404 (316L); $_{s0}$ = 100 µm; Plates per stack: 400 pcs.

HyVentus V04

for electrolyzers with sheet thicknesses from 200 to 1000 µm



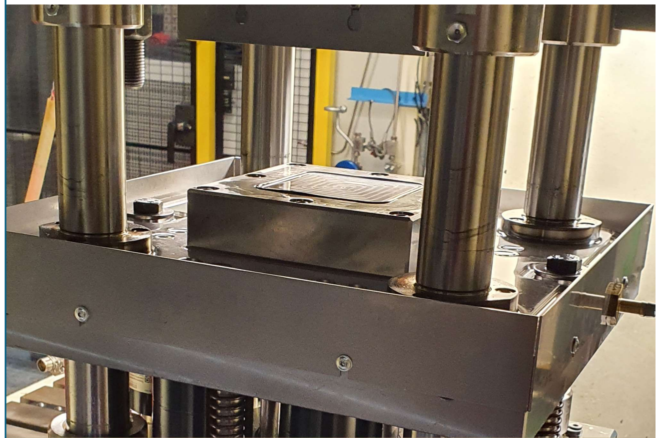
Dimensions: (350 x 250 x 1.7) mm³; Titanium Grade 1; $_{s0}$ = 500 µm; Plates per stack: 12 pcs.

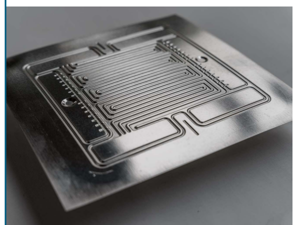
1. Production technologies for fuel cells and electrolyzers

Forming technologies for bipolar plates at the Fraunhofer IWU

Hydroforming

~6,7 BP-HP/min



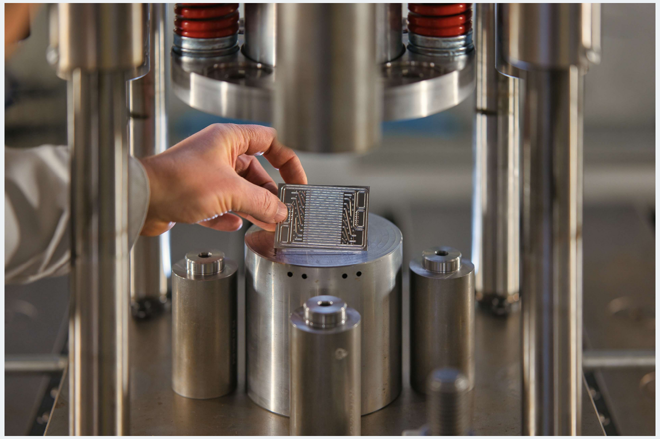


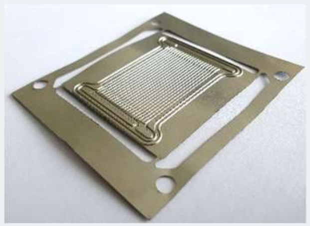
- Only one die set
- High BP-HP quality
- Potentials by passive hydroforming

Small batch size

Hollow-Embossing

60 BP-HP/min



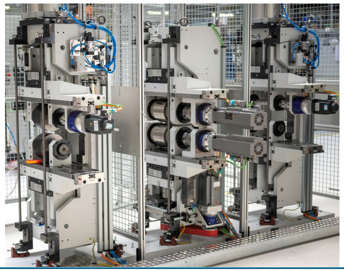


- Higher production rate
- Most established industrial forming technology

Medium batch size

Hollow-Embossing-Rolling

> 120 BP-HP/min



- Lowest process forces and energy consumption
- Currently low TRL

Mass production

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1. Production technologies for fuel cells and electrolyzers

Our high-rate forming technology

HOLLOW EMBOSSING ROLLING AS HIGH-RATE TECHNOLOGY FOR THE PRODUCTION OF BIPOLAR PLATES

Process advantages

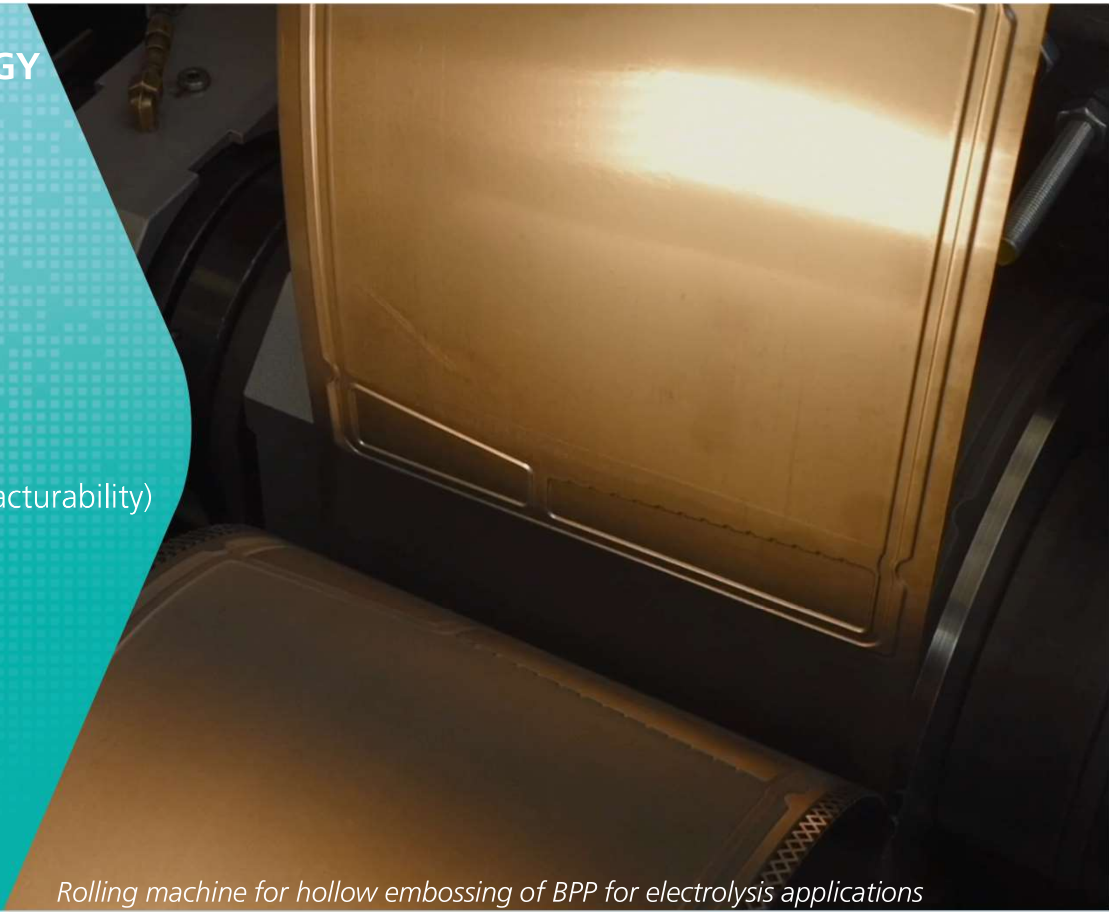
- **high-rate capability** (continuous strip feed)
- comparatively **low process forces** (incremental forming)

Service portfolio

- FE based **feasibility analysis**
- **Component and process design** (related to application and manufacturability)
- **Manufacturing of demonstrators**
  → from postage stamp to DIN-A4 format

Development approaches

- Robustness of the forming process
- increase of sheet quality (flatness)
- Synchronization with subsequent processes



Rolling machine for hollow embossing of BPP for electrolysis applications

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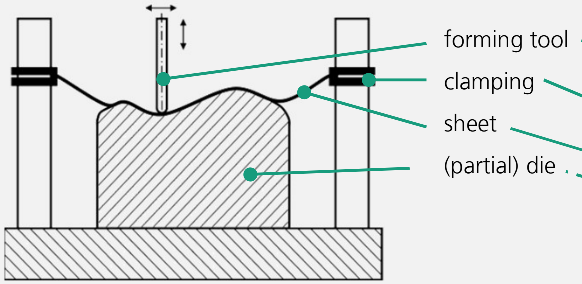
2. Production technology with highest material efficiency

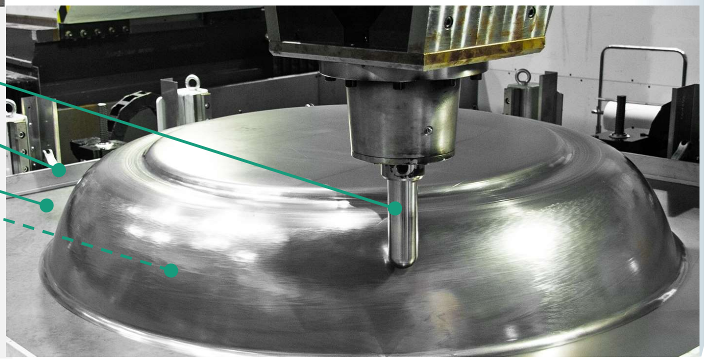
Incremental sheet metal forming

Maximum flexibility through the use of (reconfigurable) counter tools with a very low degree of mold storage

- Tool-free production of free-form sheet metal components
- Integration into machine tools or NC-based robot cells



Procedural principle using a (partial) die



*example

Available at Fraunhofer IWU

- Working area: **approx. 4 m x 2 m x 1 m**
- Max. press force (z-direction): approx. 20 kN

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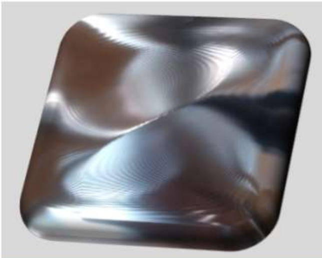
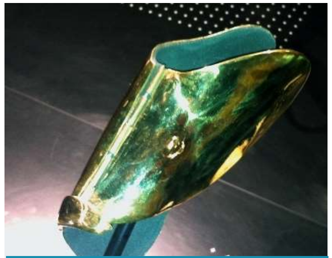
2. Production technology with highest material efficiency

Possible range of components – any size, any material

Part dimensions from 1 up to 4000 mm and material like Magnesium and Titanium

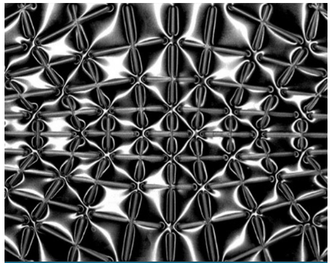

Facade elements


Car spare parts

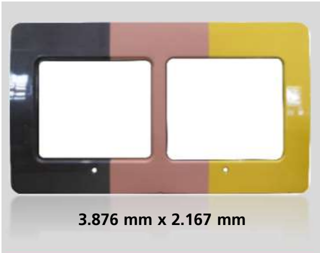

Titanium implants


Extractor hood


Wind turbine housing

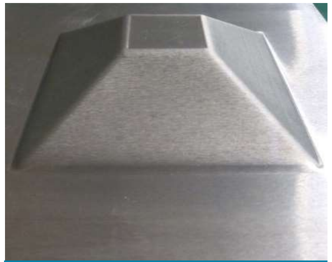

Art

Signs & Advertisment

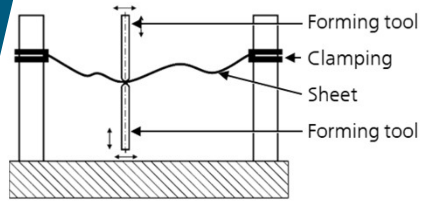


Train side wall


Heat exchanger


Magnesium part

Future focus
dieless forming



Note: All components shown here were manufactured at Fraunhofer IWU or in cooperation with partners from industry and science

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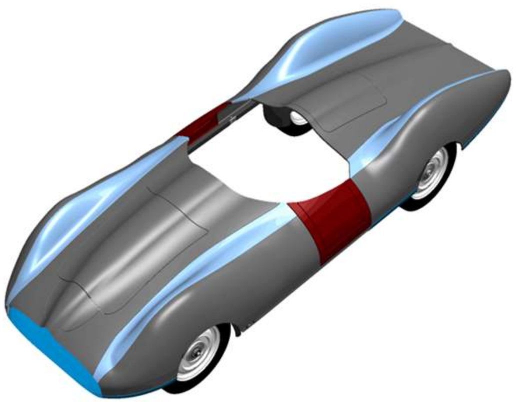
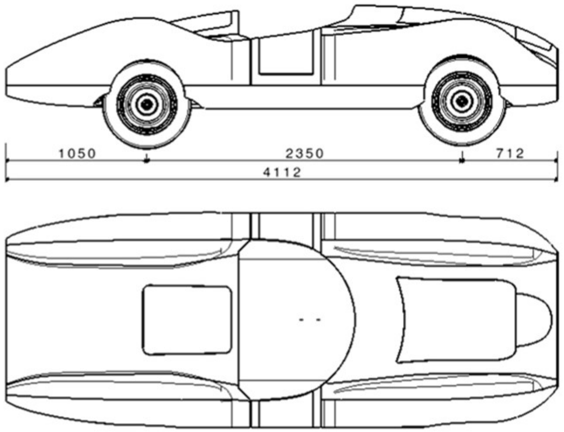
2. Production technology with highest material efficiency

Technology Demonstrator Silver Bumblebee®

Reconstruction of the outer panel of an Auto Union racing car in cooperation with the Vehicle Museum Chemnitz

- Cost-efficient and fast forming technology for small quantities
  - ➢ Cycle time **from CAD data set to first part within 1 week**





Production technologies for hydrogen tanks

3. Production technologies for H_2 tanks

Current challenges in their industrialization

Material

- Tank must be able to withstand all operating loads at cryogenic temperatures (-253 °C) under the influence of corrosive LH_2 → preferred material: EN AW 2219

Manufacturing Process

- Detailed characterization of process parameters and limits necessary
- Efficient manufacturing and testing processes for components and modules up to the assembly of the complete tank system

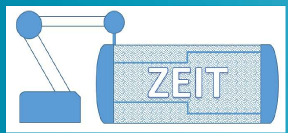
Safety

- Avoid leakage of highly flammable LH_2 by means of suitable design measures, safety systems and systematic non-destructive testing of all components and assemblies

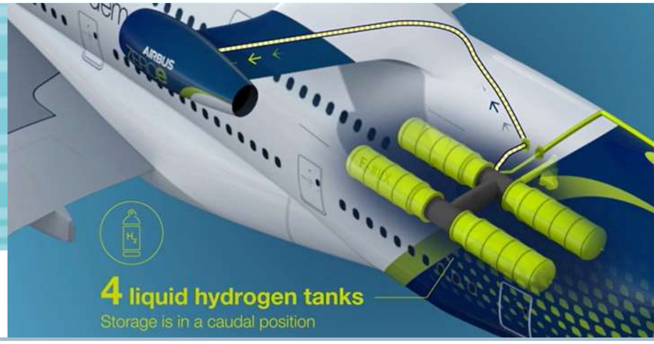

Concept1: Turbofan


Concept2: Turboprop

Our Solution: The "ZEIT" Project (Zero Emission Industrial Technologies)



Duration: 09/2022-02/2026
Total project amount : 10 Mio. €



Partner: AIRBUS, CORIOLIS, hereon, TEIJIN, HUTCHINSON PFW Aerospace GmbH, FIBRE Faserinstitut Bremen

Funding: Bundesministerium für Wirtschaft und Klimaschutz, DLR

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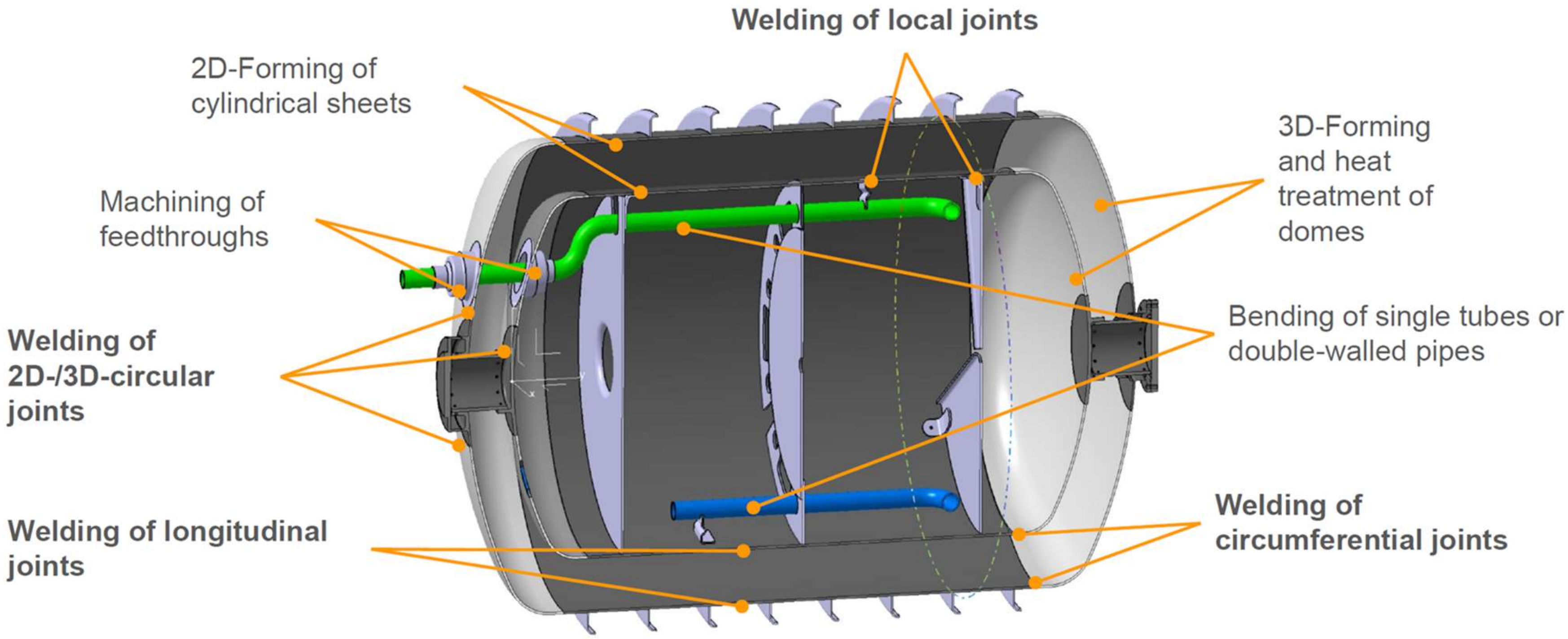
  Image references: Airbus

3. Production technologies for H_2 tanks

Main processes in LH_2 tank production

Simplified technology demonstrator for process validation



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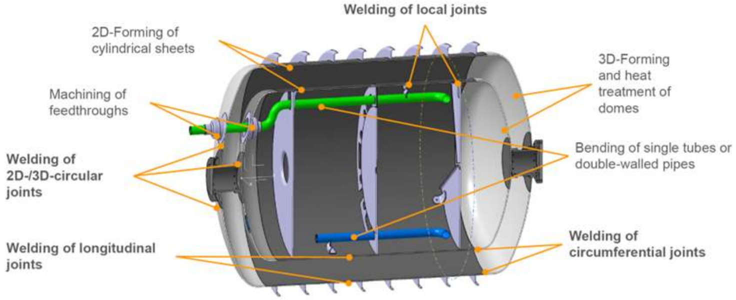
3. Production technologies for H_2 tanks

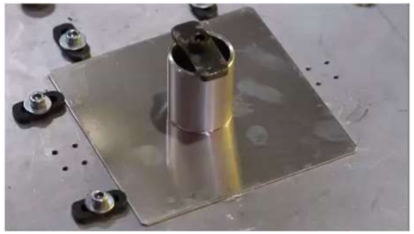
Joining processes for LH_2 tank production

Range of possible joining technologies for aircraft components



Robot-Based TIG Welding

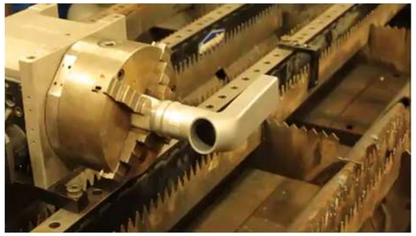
Fillet Weld
EN AW-6061



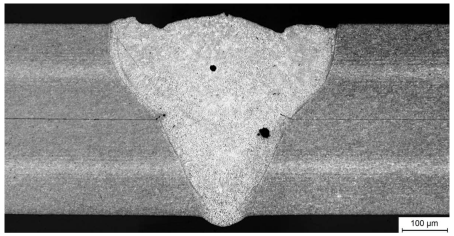
Butt Weld
EN AW-6061

Laser Beam Welding

AlSi10Mg
(3D-printed)

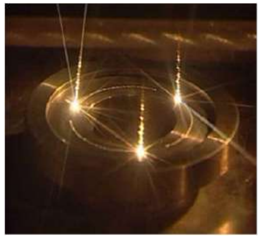


EN AW-7021
(high strength with high copper content)

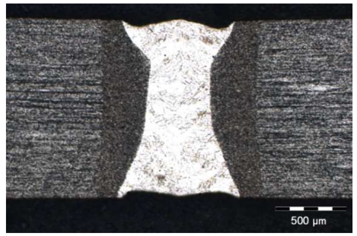


Electron Beam Welding

Multi Focus Technology



Ti-6Al-4V (Ti64)



Machining technologies for aerospace components

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4. Production technologies for aerospace components

Digital twin of the machining process – Software **TwinProCut**

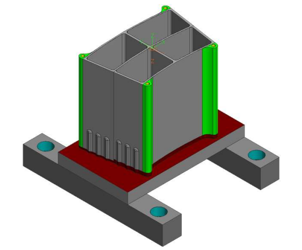
- **Process optimization**
  - Time optimization of the run-in process
  - Minimization of the production scrap rate
  - Minimization of the rework rate
- **Production-ready digital image** with all production-relevant information
- Directly from the first manufactured component, which **replaces the qualification model**

Benefits

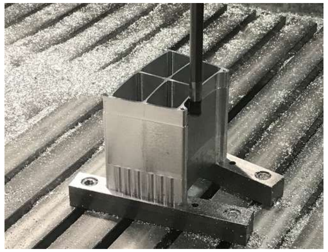
- Complete representation of the machining process
- Representation of all relevant process parameters
- Process data-based optimisation, process control and documentation

Application for work preparation, quality assurance, process analysis

Planning Data

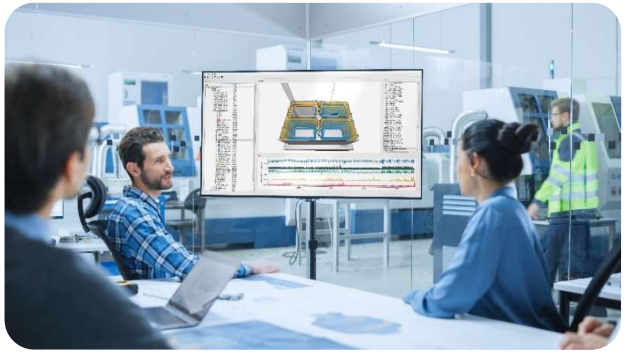


Process Data



Digital (Process-) Twin

Software **TwinProCut**



19.04.2024

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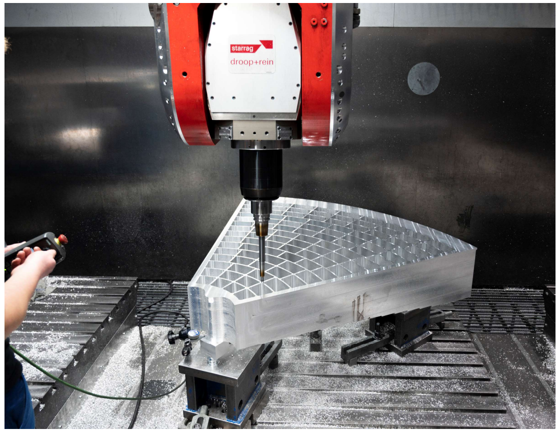
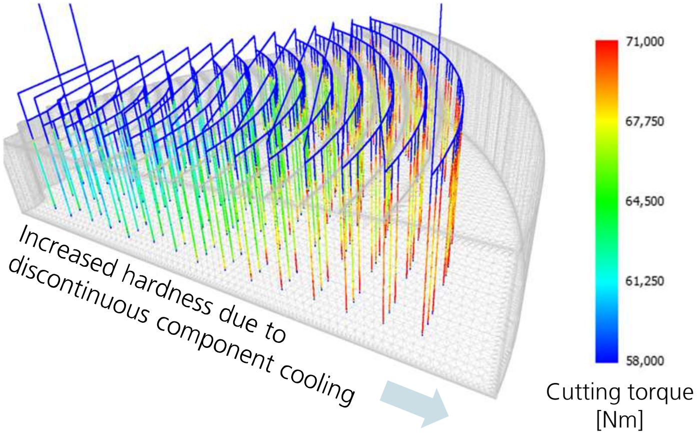
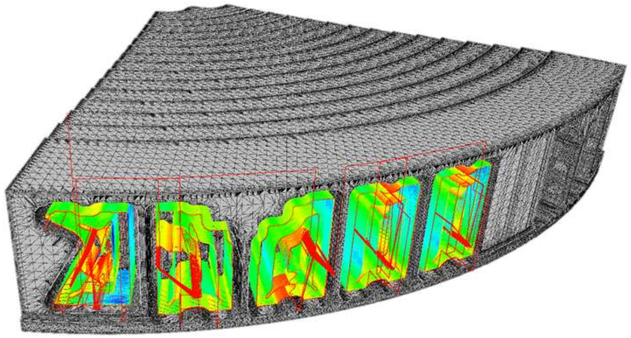
4. Production technologies for aerospace components

Application possibilities and Benefits of **TwinProCut**

Machining process and process data acquisition	Calculation of process parameters and visualization	Output of a solid model based on process data
		

Process development, validation and documentation

Optimization, quality assurance and analysis

 19.04.2024

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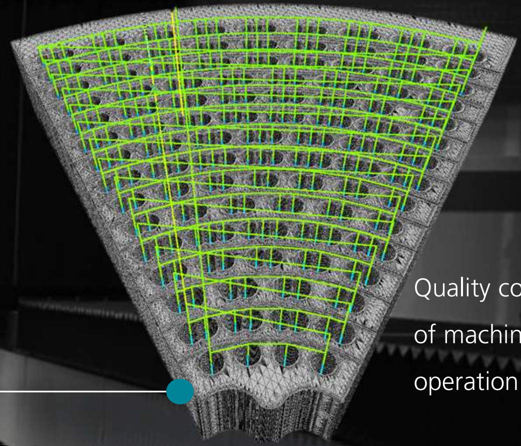
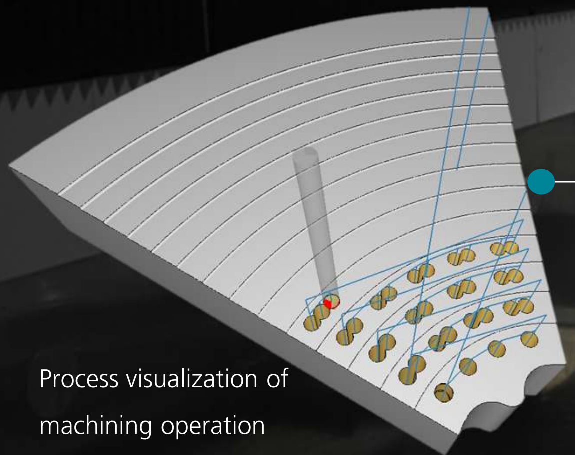
4. Production technologies for aerospace components

Example – Large integral component for ATHENA telescope

- Main structure of the ATHENA telescope, biggest ESA spacecraft project (~2 Bil. €), planned Launch: **2034**
- Dimensions: ~Ø3000mm ; Height: H=350mm → machined from one part
- Full machining time 2-3 month, Raw Data~ **540GB**
- **Visualization** of the complete **process steps**
- Evaluation of the **interoperability** of the process characteristics
- Spatially resolved **failure analysis**, e. g. material defect or tool defect
- Process data based **quality control** and **process documentation**



Quality control of machined operation



Process visualization of machining operation

Future Missions – Mission Future

5. Future Missions – Mission Future

H_2 into Sky

Logistics drone with integrated fuel cell system

Transportation of heavy loads (max. 25 kg) and with a flight duration of at least 1 hour compared to existing systems

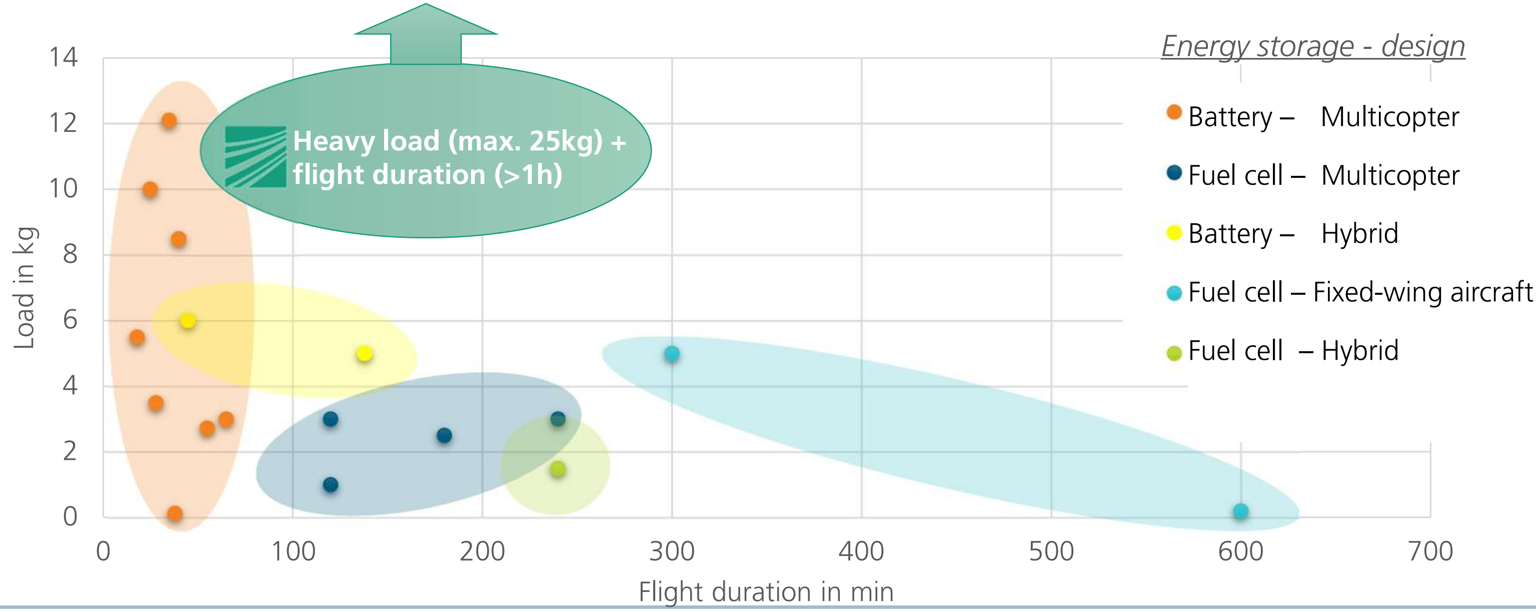


  Image reference (bottom right): Drone industry insights: https://droneii.com/how-drone-use-optimizes-industries, 2023

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Thank you for your attention

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