FormTech Activities

- Key technology:
  SPF*, SPF/DB, DB** (hot)
  Sheet metal forming (cold)

- SME cluster ’Supply Chain’ for details and assemblies

- Representation
  EMFCO, USA
  ACB, F
  IMSP, GUS

- Aircraft
- Aerospace
- Engines
- Automotive
- Medical
- General Ind.

* SPF = Super Plastic Forming, ** DB = Diffusion Bonding
SPF History

- SPF phenomenon under investigation since about 1912
- SPF community: \( \approx 200 \) experts world-wide

<table>
<thead>
<tr>
<th>Authors</th>
<th>Alloys</th>
<th>Year, source</th>
</tr>
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<tbody>
<tr>
<td>Bengough</td>
<td>((\alpha+\beta) ) brass</td>
<td>1912</td>
</tr>
<tr>
<td>Rosenhain et al.</td>
<td>Zn-Al-Cu</td>
<td>1920</td>
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<tr>
<td>Hargreaves and Hills</td>
<td>Pb-Sn</td>
<td>1928</td>
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<tr>
<td>Jenkins</td>
<td>Cd-Sn, Pb-Sn</td>
<td>1928</td>
</tr>
<tr>
<td>Pearson</td>
<td>Pb-Sn, Bi-Sn</td>
<td>1934</td>
</tr>
<tr>
<td>Chaston</td>
<td>Pure Pb</td>
<td>1935</td>
</tr>
<tr>
<td>Bochvar and Sviderskaja</td>
<td>Zn-Al</td>
<td>1945</td>
</tr>
<tr>
<td>Presniakov and Chervjakova</td>
<td>Al-Cu</td>
<td>1958</td>
</tr>
<tr>
<td>Underwood</td>
<td>Review of Soviet works</td>
<td>1962</td>
</tr>
<tr>
<td>Backofen et al.</td>
<td>ZN-22% Al Blowing of hemisphere</td>
<td>1964</td>
</tr>
</tbody>
</table>

Information burst in the field of superplasticity since the end of sixties
SPF – Process Scheme

- **Phase 1: Start of SPF process**
  - Gas pressure and/or vacuum
  - SPF is pneumoforming under isothermal conditions

- **Phase 2: Membrane forming**
  - \( p_{\text{SPF}} \)

- **Phase 3: Final detail-forming**
  - \( p_{\text{SPF}} \)

- **Phase 4: Finished part removed from die**
SPF - Technology, Parts and Materials

Magnesium ~AZ 31, MA 2-2
Aluminium ~AA 5083, 7475
Titanium ~Ti 6-4, BT6, Ti6-2-4-2, β 21 S, SP 700, Ti 6-22-22
Ti-Al ~gamma TiAl
Steel ~1.4462
Nickel ~IN 718
SPF Sample Parts „Magnesium“

- Certain SPF Mg-alloys show extraordinary SPF properties
- Very high weight saving potential
- SPF-properties better than AA 5083 etc.
Sample SPF-parts* for Aston Martin Vanquish manufactured from Al today.

Possible in Magnesium-alloy

* Photographies of sample parts by courtesy of Superform Ltd.
SPF Sample Parts ´Aluminium´*

* Photographies of parts by courtesy of Superform Ltd.

03.04.14 Company Presentation_FT Products
SPF Sample Parts ´Titanium´

• „Elbow“, Ti SP 700
⇒ Integration,
⇒ Weight and cost reduction

Advantage SPF-Process:
• Cost Reduction
• Weight Reduction
• Short Schedule
• Complex design possible

• „Hemispheres“, Ti 6-4
⇒ Cost reduction

• Housing, Ti 6-4, CRES, etc
⇒ Rapid Prototyping
SPF Sample Parts „Gamma TiAl“

• TiAl offers significant weight reduction potential
• TiAl maintains hi-strength and oxidation resistance up to high temperatures
• TiAl can replace Ni–alloys in hi-temperature applications
SPF Sample Parts „Steel“

Sample geometry to create new design approaches

Possible with very thin material

Characterisation SPF – Design:
Part geometry not possible with cold forming
Strain more than ≈ 300%
SPF Technology, Advantages

- Single sheet structures with high complexity due to high SPF strain
- Sheet forming verified for thickness range between 0.1 and 22mm
- One – step forming process
- Stress relieving and/or aging heat treatment included in the SPF process
- Forming die inexpensive. Only one cavity and a flat top die necessary
- Ceramic die concept for rapid prototyping verified
- Short lead time for feasibility studies, prototypes and small volume production
- SPF-Production cost effective up to ~20 000 parts per year

**Advantage SPF-Process:**

- Cost reduction
- Weight reduction
- Rapid prototyping
- Integral design of complex shapes

**Cost savings up to 40 %**
- Better material utilisation
- Low assembly cost
- Reduced part number
- Lower die cost
SPF/DB*- Technology

Hollow blades for fans and compressors
⇒ *Weight reduction*

Integrally stiffened fuselage panel (SST***)
⇒ *Weight reduction*
⇒ *Performance optimisation*

Cooler outlet duct (Fighter aircraft)
⇒ *Cost reduction*
⇒ *Weight reduction*

Laminar Flow Panel (RaWid**)
⇒ *Integration of different functions*
⇒ *Cost reduction for future production*

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* SPF/DB = Super Plastic Forming / Diffusion Bonding, *RaWid = Reduction of Aerodynamic Drag, *** SST = Supersonic Transport
Sandwich Components in Reference to borit® Design

Materials: Metal-alloys, (also plastics, textiles possible)

Production steps: Hydroforming or SPF, etc. of single core sheets
Bonding or soldering etc. of two core sheets forming inner sandwich structure

Application: Flat, metallic, lightweight panels in big dimensions

Branches: Aircraft-, automotive-, van-, motorhome, train-system-, shipbuilding industry

Advantages: Low weight
Low cost
Variable strength given by different core geometry
High rigidity of sandwich-core
Smooth surface possible with face sheets
Sandwich Design Technology
Summary

• Integrally stiffened, light weight sandwich design
• 2-, 3-, 4-, n-sheet technology increases design flexibility
• Several industrial process alternatives for sandwich parts:
  • Mg, Al, Ti, SS and Ni-alloys possible by SPF combined with:
    • Welding, e.g.. TIG, LBW, FSW, Roll spot, Roll seam
    • Brazing or bonding
  • Ti- and steel alloys by SPF and Diffusion Bonding
  • Cold forming combined with bonding
• Repeatable process with NC-driven-production steps:
  - DB-Parameters: Temperature, pressure, time, clean atmosphere
  - Silk - screen printing for stop-off pattern

Cost and weight savings in the range of 40 % and more
Sandwich design with:
  High-corrosion resistant and/or hi-strength alloys and/or low-weight metals
DB of Plates e.g. Heat Exchangers

First Step: Preparation of surfaces
Second Step: DB-process

Design and verification of “Inside Channel System” much simpler as with machining of solid block
Hot Presses

- SPF, SPF/DB and Hot forming
- Temperature up to: 1080 °C
- Table size up to: 1800 x 1600 mm
- Daylight up to: 800 mm

- FormTech has own SPF and SPF/DB workshop
- FormTech owns presses 100, 300 and 800 to
SPF School

Package 1: SPF “crash course” 4 days
Package 2: Planning, spec’s and documentation, SPF demonstration 3 days
Package 3: SPF work including pre- and post processing 3 days

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<thead>
<tr>
<th></th>
<th>Package 1</th>
<th>Package 2</th>
<th>Package 3</th>
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<td>Designer</td>
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<td>Methods engineer</td>
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<td>Quality assurance</td>
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<td>Shop floor</td>
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</table>
SPF Cone Cup Material Test and Database

New alloy
- Nickel
- Titanium
- Aluminium
- Magnesium

<table>
<thead>
<tr>
<th>Temperature / Flowstress</th>
<th>$\sigma_1$</th>
<th>...</th>
<th>$\sigma_m$</th>
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<td>$T_1$</td>
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<tr>
<td>$T_n$</td>
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Cone Cup Test

Transfer of optimised SPF-Parameters on SPF Verification sample

Cones

CRES - Sample

Detailed definition and verification of SPF properties
Key Activities Cold Forming

- Deep drawing
- Elastomeric forming
- Bending
- Welding
- Materials: Stainless steel, CpTi, Al

Cost effective production of sheet metal parts
Batch size typical for aerospace industry and niche products
NC-controlled machines
**Supply Chain Europe**  
**Sheet Metal Structures**

<table>
<thead>
<tr>
<th>Processes</th>
<th>Materials</th>
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<tbody>
<tr>
<td>Forming of sheet metal and extrusions</td>
<td>Aluminium 2xxx, 5xxx, 6xxx, 7xxx, etc.</td>
</tr>
<tr>
<td>- Deep drawing</td>
<td>Titanium</td>
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<tr>
<td>- Rubber pad- / Fluid-cell forming</td>
<td>- Commercially pure Titanium (CpTi):</td>
</tr>
<tr>
<td>- Stretch forming</td>
<td>- Grade 1, 2, 3, 4</td>
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<tr>
<td>- Brake forming</td>
<td>- Ti 6-4, Ti 6-2-4-2, β 21 S, Ti 15-3-3-3</td>
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<tr>
<td>- Roll forming</td>
<td>Superalloys: Inconel, Haynes</td>
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<td>- Spin forming (hot and cold)</td>
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<tr>
<td>Machining</td>
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<td>Surface treatment</td>
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<tr>
<td>- Chemical machining</td>
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<tr>
<td>- Anodising</td>
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<td>- Paint</td>
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<td>Assembly</td>
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<tr>
<td>- TIG</td>
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<tr>
<td>- Brazing</td>
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<td>- Riveting</td>
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</table>
EMFCO-Representation in EUROPE

EXOTIC METALS FORMING COMPANY

Hi-temperature/ Hi-pressure Ducting Systems
EMFCO Products
Engine/ Bleed Air Ducts

A-340 Duct, Inconel 625

Duct System designed and manufactured

Engine Bleed Ducting System

Engine Bleed Air Ducts
Inconel 625

ECS Ducting, CpTi
EMFCO Products
Duct Systems, Ti- and Ni-alloys parts

´Scuff plate`, Ti 6-4

KIT of engine ducts
Inconel 625/ 718

´APU Mufflers´,
CpTi and Ti 15-3-3-3
EMFCO Products
A 380 supplier

A 380 Workshare Breakdown

• EMFCO will supply the APU Ducting System ATA 36 for Airbus Deutschland
• Ducts in Section 18, 19.0 and 19.1 will be made from Ti 15-3-3-3
• Ti-alloy Ti 15-3-3-3 results in significant weight reduction
ALTAÏR Group

| ACB, F and Cyril Bath, USA | • Machines/ presses for metal forming  
  • stretch forming  
  • elastoforming  
  • SPF  
  • Parts manufacturing |
|---------------------------|---------------------------------------------------------------------|
| SITIA, F                  | • Simulation of forming processes  
  • Simulated dies for elastoforming with compensated springback |

Leading supplier for aeronautical industry
ALTAÏR/ACB

Competences:
- forming simulation
- prototyping
- tool design and manufacturing
- technology transfer
- small batches and series production
- process training

Products:
Presses for
- Stretch forming
- Elastoforming
- Super Plastic Forming

Part supplier:
Production of
- Stretch form of extrusions
- Elastomeric parts
- SPF parts
ALTAÏR/ ACB Products
Stretch forming presses

Profile stretch forming

- Forces from 100 to 800 kN
- Table dimensions up to 2130 x 1270 mm

Sheet stretch forming

curvable jaws
- max. Jaw distance 12000 mm
- Jaw length up to 2500 mm
- Forces between 1000 and 5000 kN

rigid jaws
- max. Jaw distance 6200 mm
- Jaw length up to 6000 mm
- Forces between 2000 and 7500 kN
ALTAÏR/ ACB Products
Elastoform and SPF Presses

Elastoforming

- max. pad dimensions 2850 x 1100 mm
- max. tool height 200 mm
- pressure up to 1000 bar

Super plastic forming

Platen dimension up to 2280 x 5300 mm
Max. opening from 700 to 2000 mm
Force between 2500 and 28000 kN
<table>
<thead>
<tr>
<th>Simulation of profile stretch forming</th>
<th><img src="image1.png" alt="Profile Stretch Forming Simulation" /> <img src="image2.png" alt="Profile Stretch Forming Simulation" /> <img src="image3.png" alt="Profile Stretch Forming Simulation" /></th>
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</thead>
<tbody>
<tr>
<td>Simulation of sheet stretch forming</td>
<td><img src="image4.png" alt="Sheet Stretch Forming Simulation" /> <img src="image5.png" alt="Sheet Stretch Forming Simulation" /> <img src="image6.png" alt="Sheet Stretch Forming Simulation" /></td>
</tr>
<tr>
<td>Simulation of elastoforming parts</td>
<td><img src="image7.png" alt="Elastoforming Parts Simulation" /> <img src="image8.png" alt="Elastoforming Parts Simulation" /> <img src="image9.png" alt="Elastoforming Parts Simulation" /></td>
</tr>
</tbody>
</table>
ALTAÏR/ Cyril Bath
Reconfigurable die for stretch forming

- Replacement of 45% to 75% of existing dies
- Reduction of capital investment
- Reduction of storage costs
- Optimisation of production time: ~15 min to create new geometry
- Rapid and inexpensive prototyping: Verification of parts with new geometry from the drawing board in less than 5 days.

Cost reduction for fuselage panels
IMSP*
Representation in Western Europe

*Institute of Metals Superplasticity Problems - Ufa
IMSP Key Activities

Grain refinement processes for nano- to submicron alloys

Special materials: High damping, Hard alloys, Composites, Permanent magnets

SPF and SPF/DB processes

Isothermal forging

Liquid forging, e.g. wheels

Isothermal spinning, e.g. engine disks

Modelling for a.m. processes

Materials Development up to material sample production

Process Development up to verified processes
FormTech Services

Engineering and consulting for design, materials and process development departments

• Feasibility studies, prototyping and production of sheet metal parts

• Manufacturing cells, presses, etc. for sheet metal forming