



Hot Forming



Diffusion Bonding

Re-launch of Ti-based DB-SPF sandwich parts?

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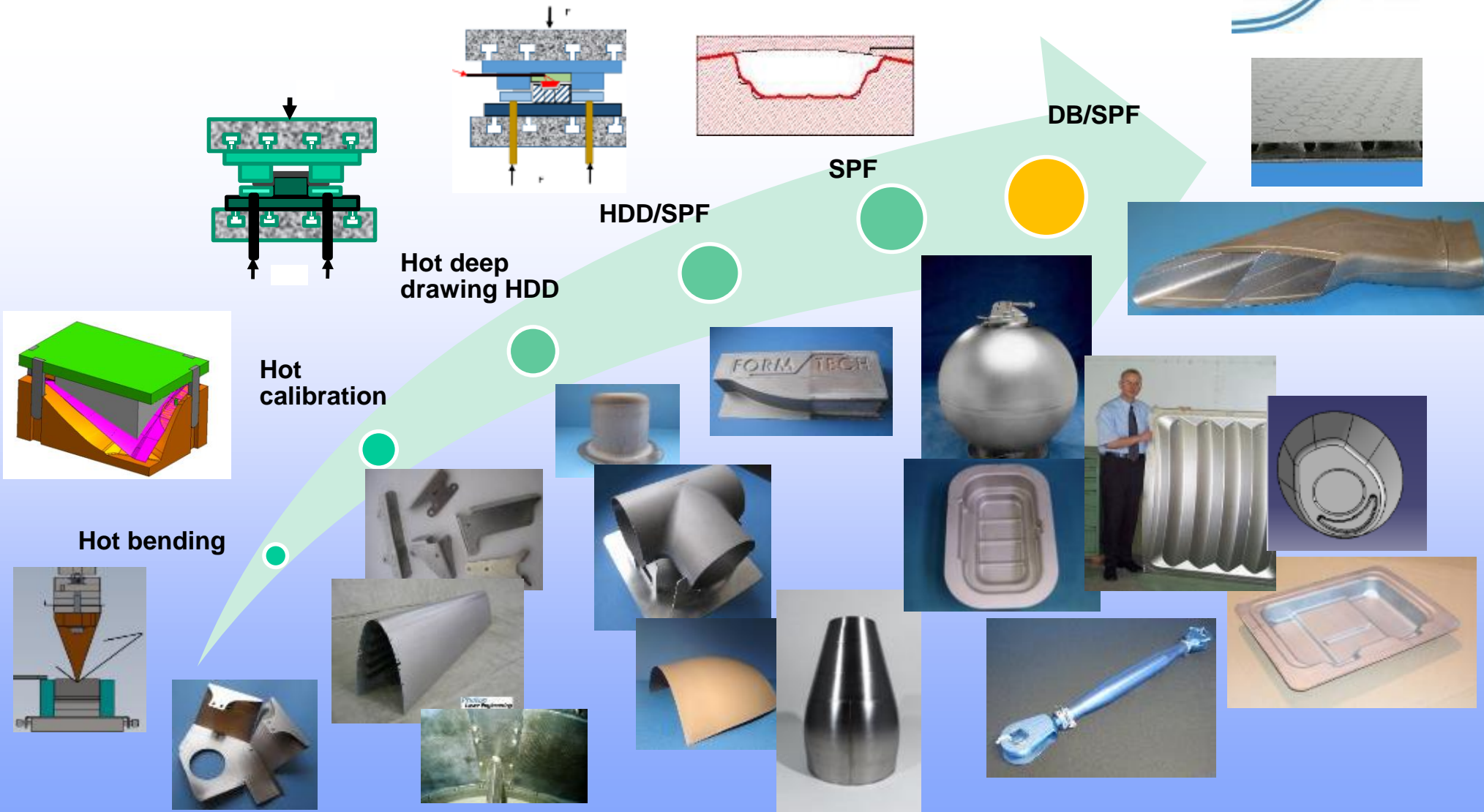
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Hot forming of „hard metals“



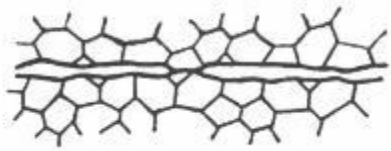
- **sheet metal and tubes**
- **shortest possible cycle time** for forming and relaxation
- validated **process parameter window**
- **as-formed material properties** for the full range of suitable forming temperatures
- **cost efficient production presses**
- **single and double** action
- **tool design/** -material experience up to 1100°C

Industrial hot forming processes

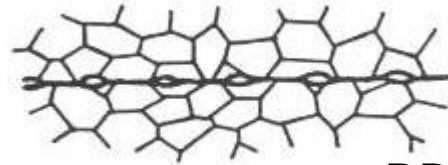


Diffusion Bonding

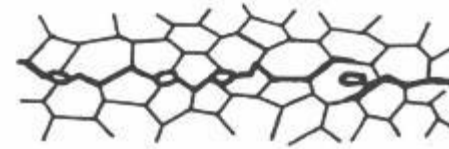
Contact



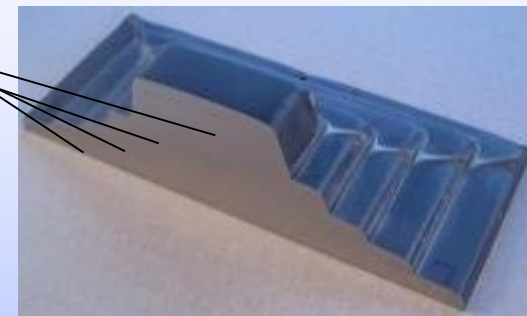
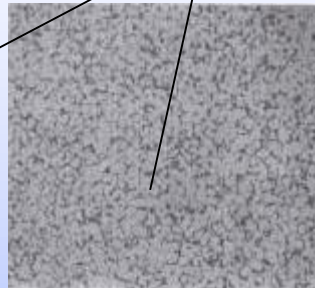
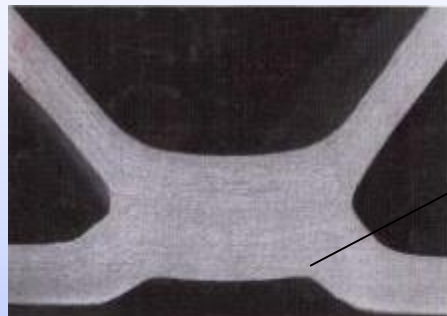
Deformation



Start of Diffusion



Volume diffusion



DB-bondline

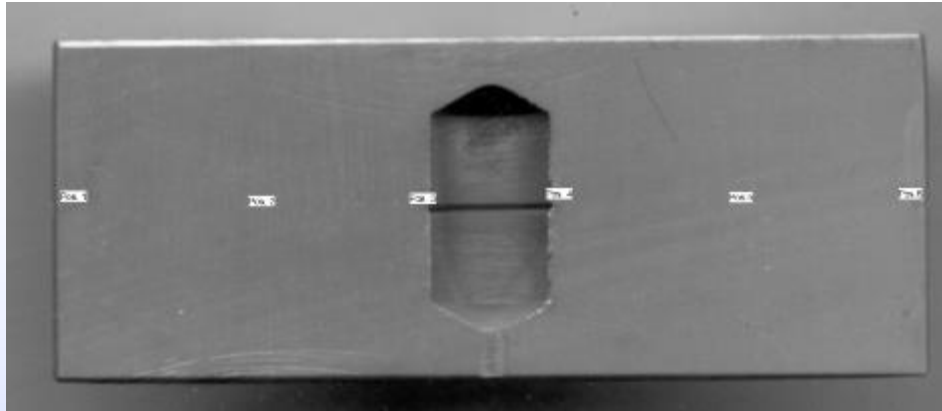
- **Base metal strength throughout.**
- **Bonding surface is large compared to fusion welding → big safety factor with DB!!**
 - **Saving of large machining volume**
 - **Integral heat exchangers with thermal improvement**
 - **“Sandwich-type” structures for lightweight, rigid, perforated, heat shielding panels**
 - **DB of dissimilar alloys → erosion resistance, thermal exposure**

R&D and process validation approach



- Titanium and steel alloys
- DB investigations
 - Special DB test device
 - Metallography
 - NDT methods
 - Process control
- Validated range of DB parameters for sheet metal and plates
- FT-production specification

Testpart DB



Test matrix:

Pressure, time, temperature

Results:

Applicable process window

- Ti and CRES alloys
- Systematic research to define suitable set of parameters
- Special geometry of test part considering unavoidable but detrimental gas volume

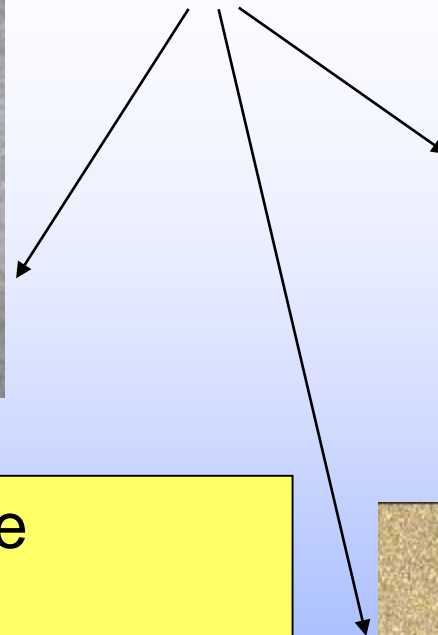
Validated DB-quality under defined DB parameters and specified/ acceptable qty of H_2, O_2, N_2

DB-quality with micrographs

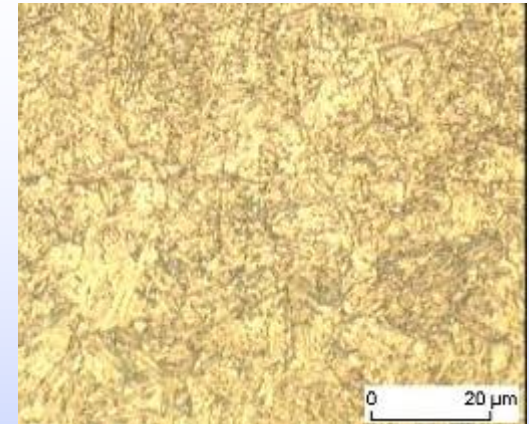
Titanium Ti6-4



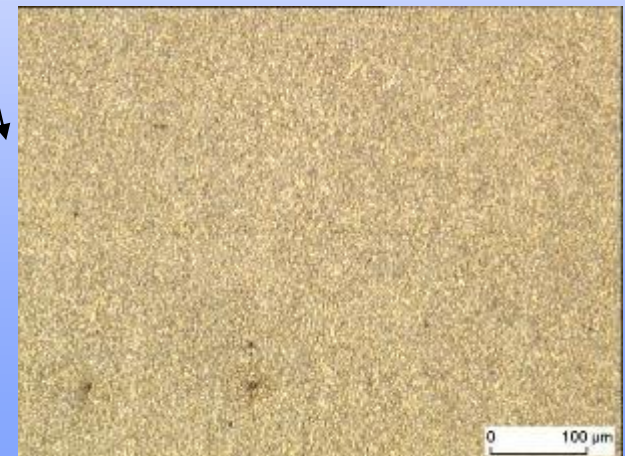
DB -zone



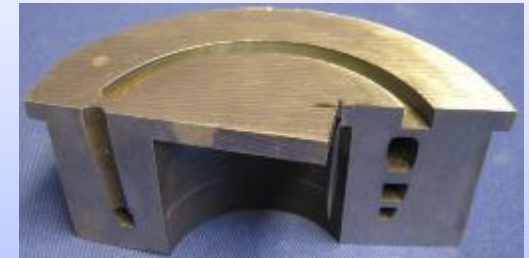
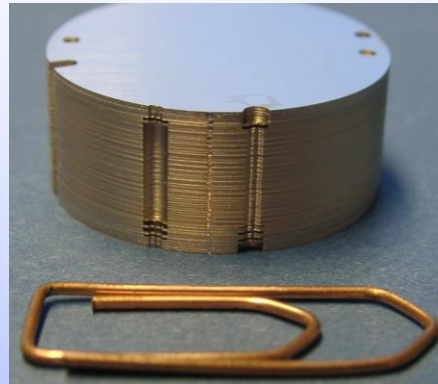
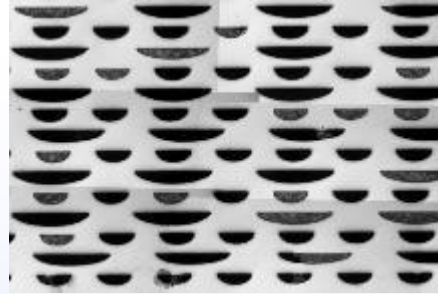
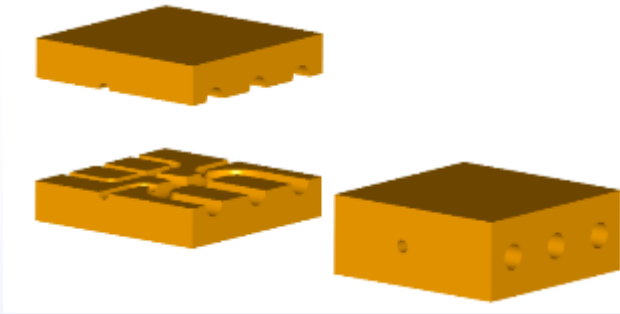
Steel 1.2344



- DB with zero-void is possible
- **Reasonable/ economic production approach: Given targeted void formation by process control**



Heat exchangers (HE)



With kind permission of KE Technologie

Macro-HE
e.g. ITER, $t \sim 14\text{mm}$

Micro-HE from single foils
 $t \sim 0,4\text{mm}$

Heated/ cooled injectors

- **Complex/ integral channel structures**
- **HE's show much better thermal efficiency**
- **Design only feasible with DB from separate layers**

Leading edge for hybrid fan blade



Hybrid fan blades

- body from CFRP,
- erosion shields from Ti 6-4

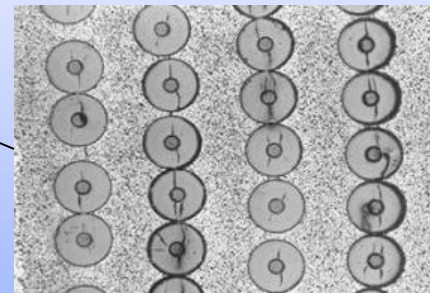
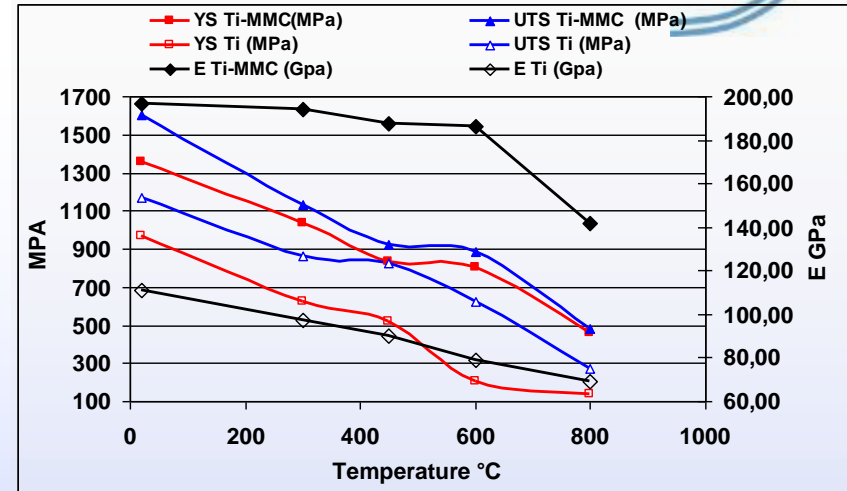


Test sample FT

LE by DB built-up from layers
Layers are from different alloys
Erosion resistant Ti-alloy embedded
→ Prolongation of service interval

R&D:

DB/SPF of Ti-based Metal-Matrix Composites (MMC)



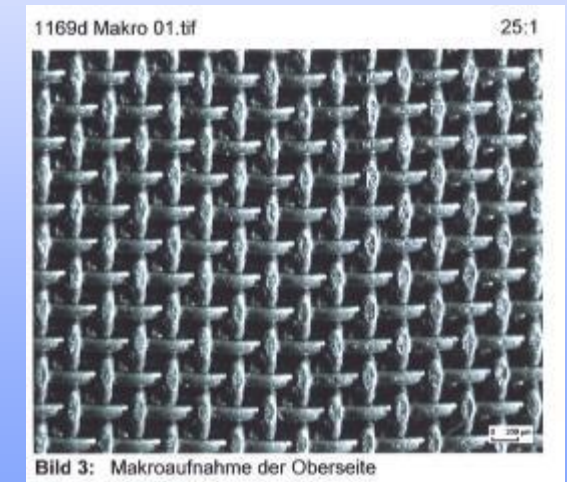
MMC have higher Young's modulus

Benefit: MMC show textured strength properties

Noise attenuation

Steel 1.4301

Titanium exhaust
Noise abatement with perforated sheet and
Ti-meshes

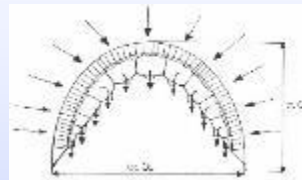


Combined DB and SPF

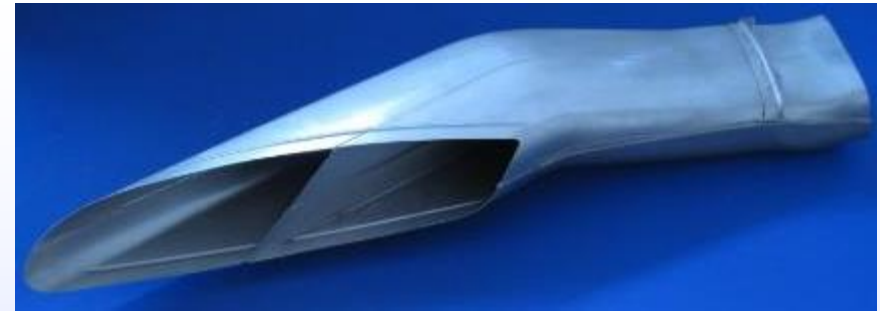
DB → joining of flat or preformed sheets in specifies areas

SPF → inflation, creation of inner core structure, final shape

- Laminar Flow Control
- Noise abatement
- Integrally stiffened ducts
- Hollow blades
- Inner core housing
- Thermal shielding
- Engine fire wall



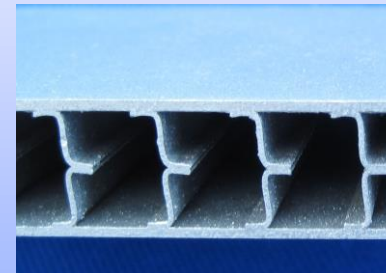
LFC for VTP



Cooler outlet duct



Wide chord fan blades RR-TRENT



Structural heat shields, diff core patterns

Design of lightweight DB/SPF panels



- Material combination: Similar or dissimilar alloys (Ti or CRES)
 - Wall thickness: Foil to plate
 - Max dimensions:
 - Currently at FT 1600x1400mm
 - „Any“ dimension with new equipment
 - Shape: Flat/ cylindrical/ curved
 - Part thickness:
 - Thin to thick with different DB/ SPF processes
 - Thickness uniform or varying
 - Core stiffening structure: Square, rectangular, conical, double-cone, hexagonal, etc.
- Many designers' ideas can be transferred to production
- Integrated DB/SPF parts save cost (as long as no scrap occur)

Production issues with sandwich panels



- Material choice:
 - Big benefit from low temp alloys
- Modifications:
 - Quick and simple production change of inner core if required from stress analysis/ full scale testing
- Cost of SPF/DB parts drastically reduced with high quantity projects
- Special equipment investment results in significant production cost cut

Summary DB/SPF



- SPF/DB structures offer huge benefits in terms of cost, weight and design freedom
- SPF/DB panels can replace CFRP products if temperature is beyond CFRP limits
- Product realization is possible on the existing, validated technology basis
- Significant rise of Ti-applications assumed

Thank you very much for your attention

History



1979 start of activity Ti with SPF and SPF/DB in R&D

Build-up of lab HFD 200t with platen size ~400x400mm. First SPF parts, boxes, spar with sinoidal web, combination of SPF+DB

ICSAM San Diego → Infos Rockwell B1 et al

Design and re-build of 200t HFD with platens ~1400x600mm

Qualification SPF/DB cooler outlet for Tornado fighter

Qualification „end cap“ A320, several housings, pressure bulkhead edge angle for A310 ff,

Design and build of 1200t HFD with 2400x1200mm. Full qualification of hemispheres D=748mm and 485mm for satellites and rockets

Transfer of HFD 1200t to Toulouse

1999 start of activity FormTech

Installation of HFD100t 700x700mm. Several mod's of HFD 100t: e.g. max. platen temp 1200°C, heated platen re-design, gas pressure management, outer insulation, double action, etc

Acquisition of HFD 800t and HFD 280t

Production and R&D in very many projects.

Internal test procedures for SPF of sheet metal and tubes., HDD and DB