Cost-effective sheet metal forming Titanium alloys for new types of aircraft

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• Key technology:
  • hot: Super Plastic Forming, Diffusion Bonding, combined SPF/DB, Hot forming, Hot drawing
  • cold: Deep drawing, Bending, etc.

• Branches:
  • Aircraft
  • Aerospace
  • Engines
  • Automotive
  • Medical
  • General Ind.

• Products:
  • Production of sheet metal products from very small to very big lots
  • R & D: Bilateral industrial for feasibility & prototyping, national and EC FP’s

• Materials:
  • Titanium alloys e.g. Ti 6Al4V, Ti15-3-3-3, β 21 S, Ti-Al, CRES e.g. 1.4462, Nickel based alloys, e.g. IN625, 718(Magnesium, Aluminium)

• R & D Projects:

References, e.g.:
• Rolls Royce D and UK
• AIRBUS Defence, Space, Aircraft, Helicoptres D
• Turbomeca
• HEGGEMANN
• GMT
• PFW

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General market situation

• FT´s mission:
  • Provide the market with sheet metal products from „hard“ metals, e.g. Titanium-, Nickel based alloys and corrosion resistant steel (CRES)
• Benefit/ added value for the client
  • Functionality
  • Weight reduction
  • Cost reduction

• SME´s got under pressure from OEM´s global purchase strategy
• Clusters are suitable instruments for networking, fund-raising and creation of international contacts
Processes, applications, current highlights

Hot forming/ calibration
→ brackets, clips etc., Ti6-2-4-2, Ti15-3³, TiAl

Hot drawing
→ duct halves, hybrid parts/door surrounding etc., CpTi, Ti3-2.5, Ti6-4, Ti6-2-4-2

Gas pressure forming/ SPF
→ Struts, hemispheres, thermal shields

Diffusion Bonding
→ Leading edge with erosion-retardant inlay, near-net shape parts, etc.

DB / SPF
→ noise reduction, laminar flow, etc
Hot calibration and hot forming

Hot calibration starts from preformed parts → reducting of residual stresses and calibration of final geometry
Hot forming starts from flat blank. Forming and calibration is done in one cycle.
Geometry not possible with ambient temperature forming
Titanium alloys are hot-formable at T > 650°C
No/ very little surface degradation → Possible to avoid chem-mill/acid flash pickling
Hot forming of e.g. Mg-, Al- and Steel alloys possible as well

Advantages

• Near-net-shape parts with constant wall thickness
• ~ no residual stress
• ~ no distortion during trimming
• Cycle time much shorter as with SPF
• Cost savings for small to big quantities
Hot deep drawing

Hot deep drawing starts from flat blank

Parts have constant wall thickness

Important cost-reduction by material saving.
  → Better buy-to-fly ratio

Process cycle time short

Tool more expansive → blankholder

Titanium alloys are hot-formable at $T > 650^\circ\text{C}$

Surface degradation can be about ~nil

Hot deep drawing of e.g. Mg-, Al- and Steel alloys possible as well

Advantages

• Near-net-shape parts
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Hot Gas Pressure Forming/ SPF

Hot process at ~750 to 900°C and controlled strain rate allow some x00% of strain
Complex geometry. One-step operation
Relatively simple tooling
Forming is done with a shielding gas, e.g Ar for Titanium
Parts are net-shape
Just trimming and usually no further machining required

Advantages

• SPF and HGPF processes are good for complex shape with hi-strength alloys
• Initial wall thickness with very thin gauge, e.g. 0,1mm up to very thick gauge, e.g. >20mm possible
• No residual stress → no spring back
• Relatively low tooling cost
• No final machining in 3D necessary

• SPF/HGPF for complex shape with Hi-strength alloys

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Typical SPF/ HGPF-Sample Geometries

- Stützstange, Ti 6-4, t = 7 mm
- Aircraft housing, Ti 6-4 and CRES
- Fuel cell anode plate: 1.4462, 0.1 mm
- Bleed Air Duct, Ti SP 700
- Wave structure for heat exchanger 1.4462, 0.15 mm
- Helicopter cover, Ti 6-4
- ARIANE V, Hemispheres Ti 6-4
- Functional duct, Steel or Titanium
- Hemisphere Submarine, Ø = 400 mm, Ti6-4, s₀ = 20 mm
- Medical Implant Ti 6-4 ELI, t = 0.2-0.4 mm
- Racing car: Heat shield Ti6-4, S=1.0 mm; 600 mmx 450 mm

### Materials

- **Titanium** ~Ti 6-4, BT6, BT6-S, Ti6-2-4-2, β 21 S, SP 700
  - Ti 6-22-22, Ti15333, Ti-MMC, CpTi, etc
- **Ti-Al** ~gamma TiAl, TMB
- **Nickel** ~IN 718
- **Steel** ~1.4462, Lean duplex, etc.
- **Aluminium** ~AA 5083, 7475, etc.
- **Magnesium** ~AZ 31, MA 2-1, etc.
Diffusion Bonding (DB)

DB is an established process to join metallic materials in solid state with resulting base materials’ strength and integrity. Single parts are pressed together under elevated temperature and the specified cycle time. The matching surfaces join by diffusion of solids. DB is applicable both for Titanium and Steel.

Advantages
- Creation of complex channel structures, e.g. heat exchangers made from micro-etched foils.
- Near-net-shape parts built up from solid details.
- Scrap significantly reduced.

DB-weld seam

Macro-heat exchanger, z.B. ITER, t ~14mm

Micro-heat exchanger made of single foils, t ~0,4mm

Contact  Deformation  Start of Diffusion  Volume diffusion

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SPF / DB - Lightweight structures

SPF-DB parts are built from single sheets joined by DB and inflated by SPF. SPF-DB parts offer lightweight, sandwich-like construction.

Advantages
• Weight reduction and performance optimisation
• Cost reduction

Applications
• Hollow fan blades or stators
• Integrally stiffened ducts
• Panels for noise abatement
• Thermal insulation
• Laminar Flow Control

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Current hi-potential applications

Noise reduction for new engines

- Laminar flow control

- TiAl in hot sections

- Tie-rods

Noise reduction and NOx pollution → Clean Sky and Horizon 2020
Hybrid structures

„Door surrounding“
• Hot formed, near-net-shape Ti6-4 part
• Rib and doublers assembly by LBW
• CFRP spar
• Novel hybrid joint CFK-Titan
• Better load transfer
• Increased fatigue live
• Ti-saving ~ 80%
• Cost saving ~40%

„Hybrid fan blade“
• Composite body by new approach
• Ti leading edge
  • DB-ed multi layer LE body
  • Increased erosion resistance from „hard“ Ti-alloy
  • Hot forming of final near-net-shape
• Ti erosion shields suction and pressure sides
  • Hot forming/ hot calibration

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Forming production process evolution

Cost / process optimisation:
- Reduction of material cost
  → Waste
  → Alternative Ti alloys
- Reduction of preparation cost
- Reduction of SPF cycle time

Industrialisation with production cell

Joint approach SCHULER/ FT:
Delivery of machine, tool, technology
Summary

- Titanium alloys offer considerable advantages for new engines and aircraft
- Hot forming and diffusion bonding guarantee for cost saving and technical benefit
- FormTech is deeply involved and offers co-operation

Thank you very much for your attention

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