Benefit of hot forming processes for Ti-alloy sheet metal part production

Werner Beck, Sabine Wagner
FormTech GmbH, Weyhe, Germany

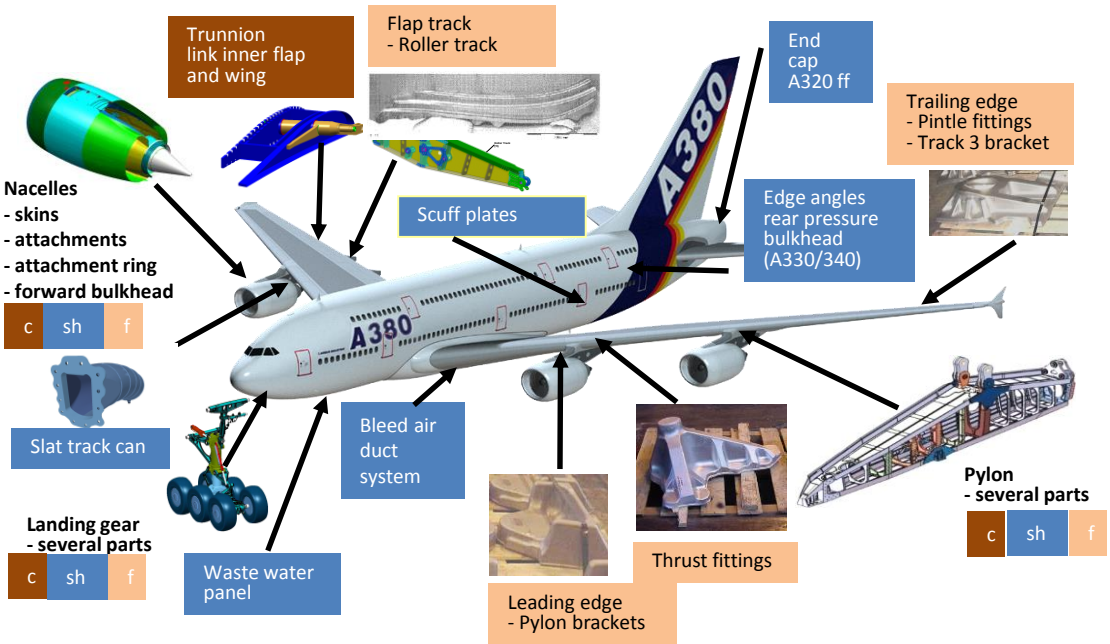
Outline

- Motivation for titanium alloys in sheet metal part production
- Titanium parts in aircraft
- Disadvantages of cold forming
- Hot forming techniques
- Start of hot forming production. Early samples of Ti 6-4 parts
- Improvement of SPF competitiveness
- Process development hot deep drawing
- Schuler hot forming presses
- Validated examples for hot deep drawing
- Combined process HDD and SPF
- Summary

Motivation for titanium alloys in sheet metal part production

- High strength material
- Low specific weight
- Splendid corrosion resistance
- Favorable specific young´s modulus
- High service temperature possible
- Big technical advantage with replacement of steel parts
- Welding properties superior
- Low scrap rate in comparison to machining

Titanium parts in aircraft



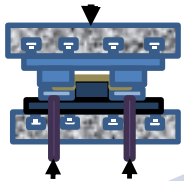
c=cast | Sh=sheet | f=forged → **Not to forget Bolts/ rivets/ axles**

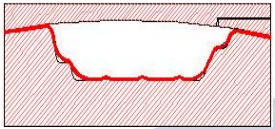
Disadvantages of cold forming

- Drawbacks from material properties
  - Low ductile strain
  - High Young´s modulus
  - Yield strength Rp0,2 high → heavy presses necessary
- Difficulties
  - Springback
  - Poor formability → multiple draws with intermediate annealing
  - Biaxial forming/deep drawing not possible
- Cold forming limitations
  - straight bends
  - r/t ~5 → weight penalty from large flanges
  - Considerable rework or large tolerance band

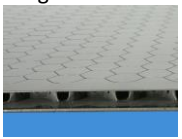
Hot forming techniques

ITA presentation





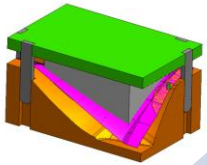
Engine fire wall



SPF/DB

SPF

Fan blade

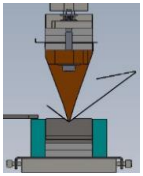


Hot deep drawing HDD

Tie-rod

Outlet duct

Hot calibration



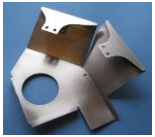
Fuel tank

TiAl Exhaust patch

Brackets/clips

Hot bending

Fitting shields



Leading edge
LFC, HTP, VTP
L>4,5m

TiAl Exhaust panel

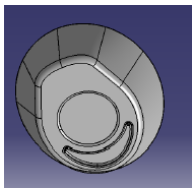
Start of hot forming production

Early samples of Ti 6-4 parts

- Hot bending/forming with „baking“-process in furnace
  - Sealing straps Ti6-4 with slight curvature for air intake Tornado et.al.
    - Low quantity
    - Low precision

- Superplastic forming (SPF)
  - A300 freighter, Waste water panel, Ti 6-4

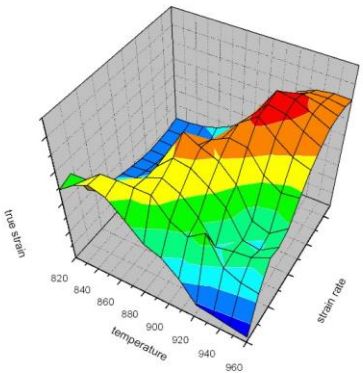
  - A320 Endcap, Ti 6-4



→ Big advantage
- Complex geometries possible

→ Disadvantages
- Titanium et al SPF materials are expensive
- Long cycle time due to relative low SPF strain rate
- Wall thickness not constant
- Removal of thick α-stabilized layer expensive
- Distortion from handling/cooling
- Automated LBC/LBW difficult
  - varying wall thickness

Improvement of SPF competitiveness



Approaches

- Reduction of cycle time
- Reduction of surface cleaning expenses
- Reduction of cost/kg

Tests

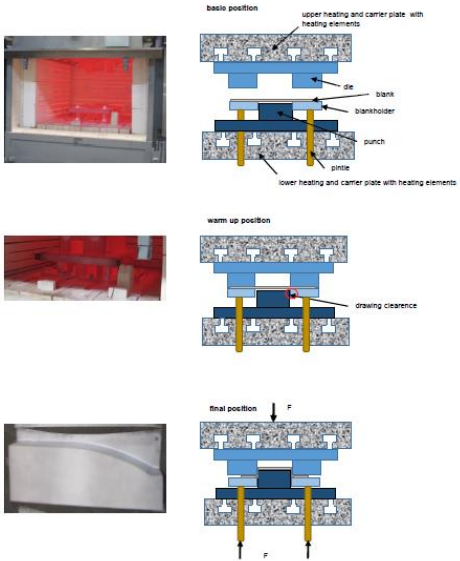
- SPF parameters = f(geometry, „non-optimal“ SPF)
- Micrograin Ti6-4 material → T ↓, strain rate ↑
- Alternative alloys → cost/kg, T ↓, strain rate ↑
- Process cycle time reduction from part handling, tool change hot/hot, etc. etc.

Result

- Cycle time shorter but parts still expensive from material cost, SPF cycle and chem-mill

Way forward → Hot deep drawing

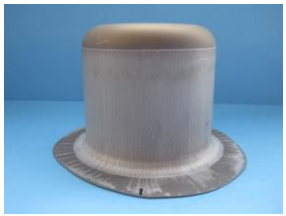
Hot deep drawing process



- Cycle time not depending on strain rate sensitivity
- Temperature low
- Surface layer thin and easily removed
- Controlled material flow with t= const
- Low material waste
- No residual stress

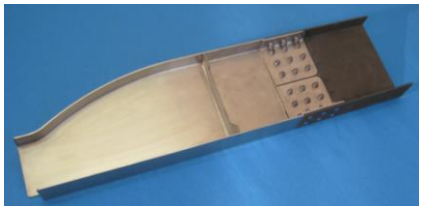
Different to SPF: Presses have to be „double-action“

Process development – Hot deep drawing



Swift-test:
Accepted test to demonstrate deep drawing properties of sheet metal in one draw
Drawing ratio β: Blank dia/punch dia
β_{Steel} → 1,8 to 2,1
$\beta_{Ti\ 6\text{-}4}$ =2,4 validated

→ Good Ti-6-4 drawability at elevated temperature



Test sample "Door surrounding"
Target: Hybrid structure with better load transfer CFRP segment
Ti 6-4 segment: Hot deep drawing. First application

→ Transfer of SWIFT data successful

Bundesministerium für Bildung und Forschung

CoolTiTech OPTiSTRUCT

SCHULER Hot Forming Presses

SPF, DB, Hot Forming and Hot Deep Drawing

The sheet metal hot forming press has a built-in furnace capable of heating tools and parts up to 950°C (1750°F).

Single action presses are used for:

- **Super Plastic Forming (SPF)**
- **Diffusion Bonding (DB)**
- **Hot Forming (HF)**

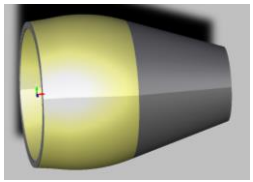
Schuler has developed a **double action** press for faster cycle time, constant wall thickness and reduced forming temperature, thus reducing alpha-case build-up. A **drawing cushion** is installed in the table to supply the blankholder force:

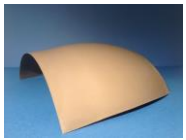
- **Hot Deep Drawing (HDD)**

SCHULER
Member of the ANDRITZ GROUP

Validated examples for hot deep drawing

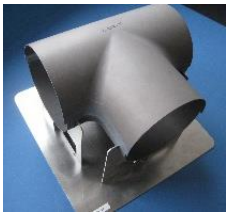
Engine Exhaust Cone 120°-segment





Flange for “hybrid bracket” Ti 6-4

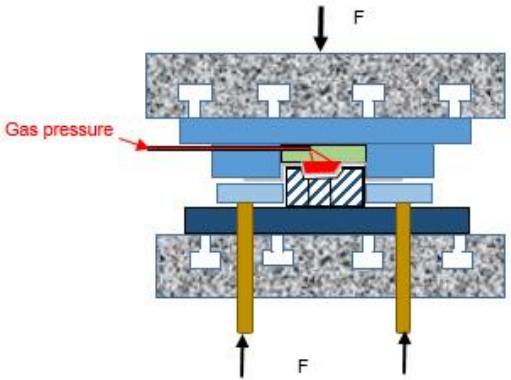
Bleed Air “T- Duct”
e.g. CpTi, Ti3-2,5 or Ti6-4



- Perforated sheets
  - Noise reduction of exhaust systems with Helmholtz resonator
  - Laminar Flow Control for leading edge
- Hybrid parts
- High quantity production

→ One draw
→ No intermediate annealing
→ Reduction of cycle time
→ No spring-back
→ High precision
→ Suitable for automated follow-on processes, e.g. LBC and LBW

Combined process HDD and SPF



Double action press with integrated gas pressure unit

Sample part “Door surrounding”
Ti 6-4, t=1,0mm
Different surface cleaning tests

- Short cycle time
- Mostly constant wall thickness
- Complex detail geometry

Summary

Status regarding titanium sheet metal forming with hot deep drawing

- Industrialization potential validated
- Short cycle time & high quantity output
- Tight tolerances
- No manual rework
- No heat treatment
- Just slight surface cleaning
- Repeatability proven