Advanced Production Technologies for High Performance FML Parts

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Overview

• Motivation

• Aluminium lay-up
  • 2D-trials
  • 3D-trials
  • Inline QS

• Glasprepreg lay-up
  • 2D-trials on vertical plate
  • 3D-trials on 2x2 m tool (TRL3)
  • 3D-trials on 2x5 m tool (TRL4)

• Summary and outlook
Motivation – Status Quo

Status Quo in serial production
• Manual lay up of
  o aluminium foils
  o glasprepreg
  o adhesive film
• Multi Shot Bonding
• Subsequent part inspection

Source: PAG
Motivation – Project goals

Project goals in AutoGlare (LuFo V2)
• Automated handling and layup of
  o aluminium sheets
  o glasprepreg
  o adhesive film
• One-Shot-Bonding
• Integration of Inline-QS
Motivation – DLR sites in project AutoGlare

Augsburg               Stade               Braunschweig               Köln
Automated layup of aluminium
2D layup

• Strategy:
  o Use of two cooperating robots
  o Plain gripping
  o Transport in a funicular curve

• Results:
  o Handling and layup perfectly possible
  o Transport without damage
  o No air inclusions
  o Bottom layers not damaged

• Challenge:
  o Fixiation of the first layer
  o Wrinkle development in spherical contour
Automated layup of aluminium
3D layup

• Strategy:
  o Use of two cooperated robots
  o Gripping in curved configuration
  o Transport with constant distance between the grippers
  o Layup from one end to the other

• Results:
  o Handling and layup perfectly possible
  o Transport without damage
  o No air inclusions

• Challenges:
  o Transport concept dependent from the stability of the sheets
Inline QS in aluminium lay-up
Edge detection

- Examination of laid up sheets in terms of positioning accuracy
- Integration in running process possible
- Resolution sufficient for aluminium, glass prepreg and adhesive film
Automated layup of glass prepreg material
Material analysis

- Tack behaviour:
  - Release of backing paper
  - On aluminium foils
  - On glass prepreg
  - Variation compaction pressure
  - Change during shop life time

- Wrinkles:
  - Curvature-dependent
  - Steering-dependent

- Process parameter:
  - Necessary heating power
  - Necessary compaction pressure
  - Maximal layup speeds

- Process ability:
  - Cut at course ends
2D layup trials
Process parameter

Analysis of material behaviour on 2D flat plate
• Hexcel DLS 1611 material with 150 mm width
• 0.4 mm aluminium sheets (w/o primer)

Results 2D – Glass prepreg on Aluminium
• Heating supports tack
• Compaction pressure of 1.200 N shows best results
• Cutting at end of course successful
  • Cutting speed = 10 m/min (US-knife)
• Layup speed at 1 m course length = 12 m/min

• Layup of glass prepreg onto glass prepreg
  • tack is much better

✓ Successful analysis of process parameters
2D layup trials
Steering trials and accuracy measurements

- **Steering analysis**
  - Aim: 12 m Radius for CoFu²-tool (TRL4)
  - Wrinkles due to movements between prepreg and backing paper

  No steering possible!

- **Analysis of layup accuracy (defined gaps)**
  - Measurements with a microscope
  - $\sigma$ for 90°-Ply = 0.56 mm
  - $\sigma$ for 0°-Ply = 0.21 mm
  - High controllability of course layup

  **Accuracy within tolerances!**
3D-trials on 2x2m tool (TRL3) 
Analysis of accuracy and repeatability

- For each ply, 4 courses were laid up five-times each and position measured at 14 measurement points
- Measuring device: tactile measurement with Leica AT960 and T-Probe

Good 3D repeatability was demonstrated (<= 1,1 mm)
Manufacturing / technology demonstrator
Overlap measurements

0° plies:
• Defined overlap at start/end of 0° plies = 12,1 mm (simulation result)
• Measured overlaps = 12 ± 1mm

90° plies:
• Defined overlap at start/end of 0° plies = 2,2 mm (simulation result)
• Measured overlaps = 2 ± 1mm
Summary and outlook

- Tack behaviour:
  - Release of backing paper
  - On aluminium foils
  - On glass prepreg
  - Variation compaction pressure
  - Change during shop life time

- Wrinkles:
  - Curvature-dependent
  - Steering-dependent

- Process parameter:
  - Necessary heating power
  - Necessary compaction pressure
  - Maximal layup speeds

- Process ability:
  - Cut at course ends
Summary and outlook

• Successful handling of aluminium, layup of glass prepreg
• Continuation of the works concerning the aluminium handling and aluminium layup
• Tests with automated fiber placement technology to enable layup without overlap
• Integration of a sensor system for quality assurance
• Analysis of measured and simulated process induced deformations / stresses from layup to curing
Thank you for your attention!