Costs and trends in modern rotor blade manufacturing

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Wind Energy Denmark, Herning, 01.10.2019
Fraunhofer IWES sites

Rotor blade department

Composite technology

Manufacturing

Virtual test rig

Blade testing
Manufacturing cost analysis
IWES blade IB40-1.5

- 40 m long blade for a 1.5 MW wind turbine
- IWES flatback airfoils
- T-bolt connection
- Materials:
  - Glass fiber NCFs + epoxy resin
  - Balsa wood + PET foam
  - Epoxy adhesive, ...
- Blade mass: 5530 kg
- Structural shell concept
Manufacturing cost analysis

Production steps

- Prefabs: Main spar caps, root flange inserts, root platform, shear webs (vacuum infusion)
- 2 shells (vacuum infusion)
- Shear web bonding
- Shell bonding
- Machining
- Surface activation and coating
Manufacturing cost analysis

- Scenario: 40 m blade series produced in one mold set in western Europe
- 24h main mold cycle time (+ repair time), 226 blades per year
- 10 €/kg plus 2000 € logistic costs (depending on wind farm location)

Costs by category

Material Costs
Material costs for sandwich parts

- Cheaper non-crimp fabrics, resin systems, core materials, consumables?
- New foam core kitting processes
- Re-useable infusion and vacuum materials to replace consumables
- Waste reduction

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Material costs for spar caps

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Material costs for spar caps

Pultruded profiles

- High fiber volume content, high stiffness & strength
- Reproducible impregnation & curing process while fibers are under tension
  - Very good fiber orientation, low scatter
  - Potential (especially of carbon fibers) useable
- Higher pultrusion speed to reduce process costs
  (Resin injection simulation for tool design)
Lay-up effort

- Textile handling jigs for fast & reproducible lay-up
- Patented handling solution for textile stacks & sandwich cores

1% mold occupation costs for lay-up

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Main mold occupation costs (times)

∑ 5,6%
Main mold occupation costs (times)

- **Assumption:** More blades can be sold per year if they can be produced faster.
  - Saving 1h main mold occupation time is worth 170 000 €.
    (Scenario: 40 m blades, 3 years x 226 blades per year)

- **Preforming:** Stacking of textiles (and cores) outside of the main molds + transfer into the main mold

- **Prefabbing:** Pre-fabrication of shell-components
  - Established for spar caps & root insert
  - Faster infusion and curing possible
  - Lowers repair effort (dry-spots, wrinkles)

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Main mold occupation costs (times)

- Low viscosity infusion resins for faster infusion
- Faster curing of infusion resins and adhesives
  - Cure monitoring: Measure temperature time series
    → Curing model: Earliest demolding time
  - Curing at higher temperatures
    → Trade-off between cycle time & composite/bond line strength due to higher residual stresses!
- New infusion resins/adhesives, higher reactive curing agent
  → Reduction in pot life. Fast resin infusion / adhesive application necessary!
Adhesive application and curing

∑ 2,4% mold occupation costs for adhesive application & curing
∑ 2% for adhesive
Adhesive application and curing

- Reproducibly fast adhesive application
  - Lower main mold occupation times
  - Faster curing adhesives applicable
  - Reduced risk to loose a blade in production or in service
- 1st solution: Automated application of a triangular bead
- 2nd solution: Semi-automated application of beads with variable cross-sections
  - Actuators deform a nozzle’s cross section
  - Quick and easy change of profiles without material waste and cleaning effort
- Patent pending
Surface finish effort

- General
- Main spar cap production
- Root insert production
- Shear web production
- Root platform production
- Shell production
- Shear web bonding
- Shell bonding
- Machining and surface finish
- Final check and blade delivery

Materials: Orange
Labor: Blue
Invest: Red
Energy: Green
Logistics: Tan

7.7%
Surface finish effort
(Semi-)automated surface activation

- Higher material removal rate at lower cost
- 6-axis CNC-controlled gantry used as test rig for reproducible grinding tests
  → Aims at measuring the removal rate
- Belt grinder from Jöst Abrasives tested:
  - Removes dust from blade instead of rubbing it in
  - Belt cleaning station removes dust from belt to keep it sharp
  - Long tool life with constant grinding properties
Surface finish effort

**Surface scanning**

- Scanning system to measure actual blade shape before grinding
- Patented optimization process to find optimum blade shape
- Projection system to inform workers (add/remove material?)
- Controlling the grinder to create that blade shape
- Flexible system: can be integrated into automation, but does not require automation equipment
Costs of bad quality?

- High costs in case of a blade failure:
  - Repairs or blade replacement with crane
  - Downtime / AEP loss
  - Root cause analysis
  - Increased inspection effort for similar blades?
  - Reinforcement of similar blades on site?
  - Challenging for sales team?
- Very seldom, has happened to almost every company though.

→ Avoidance costs difficult to quantify
→ Robust processes for reproducibly high quality!
Conclusion & outlook

- Highly competitive market → Reduce blade manufacturing (& service) costs!
- Robust processes for reproducibly high quality and utilization of material potential (pultrusion, adhesive application)
- Processes that reduce work effort and mold/machine occupation times (preforming, prefabbing, faster infusion & curing, grinding)
- Cheap high performance materials
- How much may a new material/machine cost? → Cost model can give answers.
- Outlook:
  - Modularization & standardization
  - Suppliers not only for materials, but also for (standardized) blade components
Acknowledgements
Fraunhofer IWES is funded by:

Federal Republic of Germany
Federal Ministry for Economic Affairs and Energy
Federal Ministry of Education and Research
European Regional Development Fund (ERDF):

Federal State of Bremen
- Senator of Civil Engineering, Environment and Transportation
- Senator of Economy, Labor and Ports
- Senator of Science, Health and Consumer Protection
- Bremerhaven Gesellschaft für Investitionsförderung und Stadtentwicklung mbH

Federal State of Lower Saxony
Free and Hanseatic City of Hamburg
Thanks a lot for your attention!