Costs and trends in modern rotor blade manufacturing

Roman Braun, H. Rosemann, M. Lindermann, O. Bagemiel

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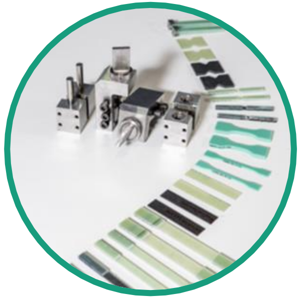
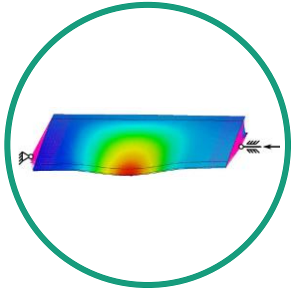
Rotor blade department



Composite technology

Manufacturing



Virtual test rig

Blade testing

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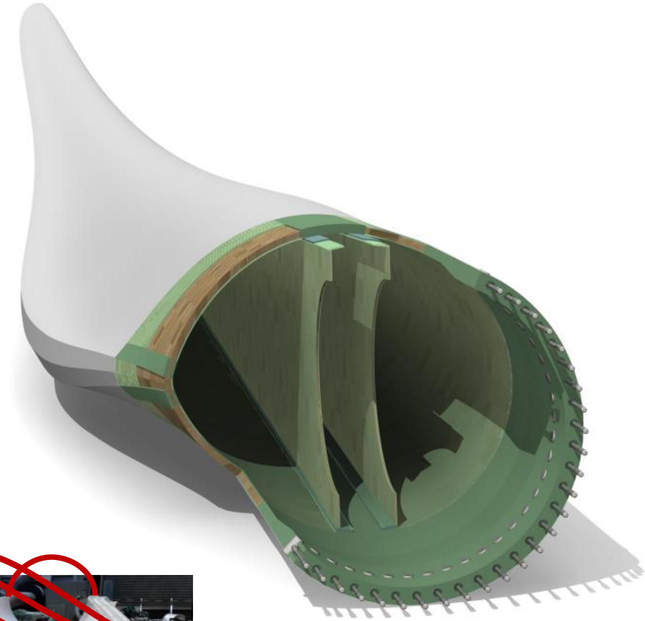
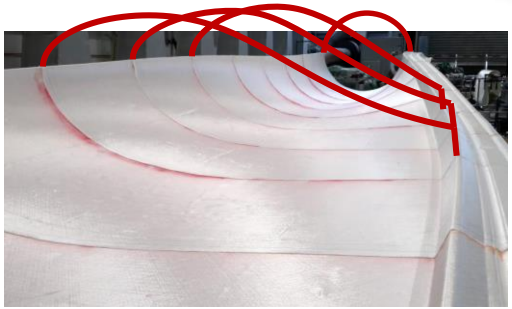
Manufacturing cost analysis

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





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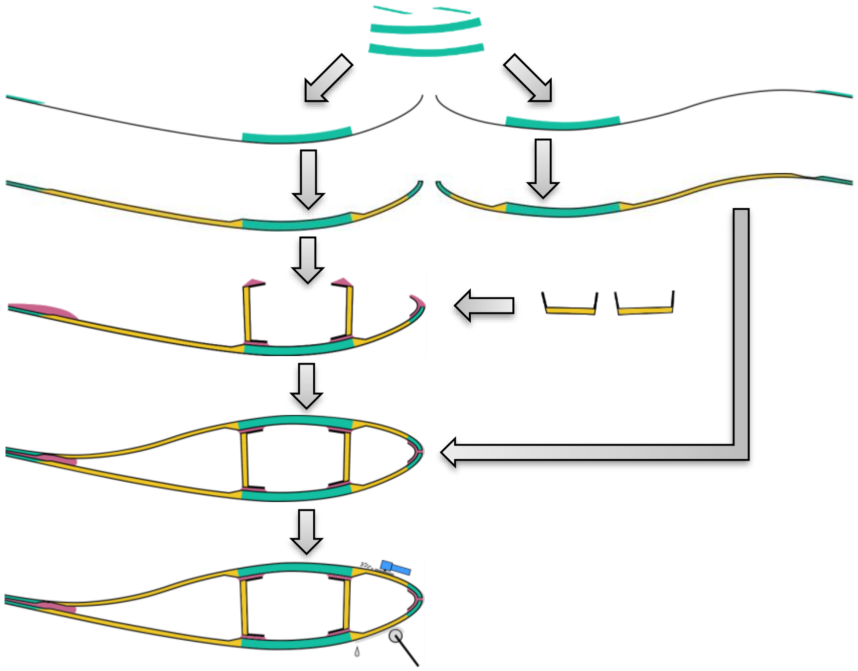
Manufacturing cost analysis

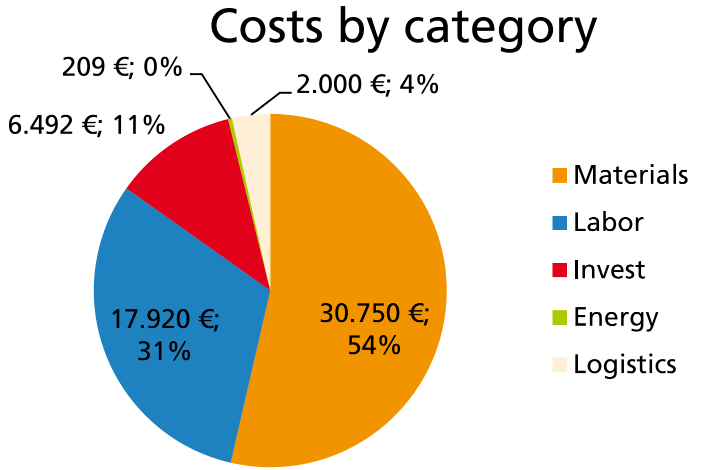
Production steps

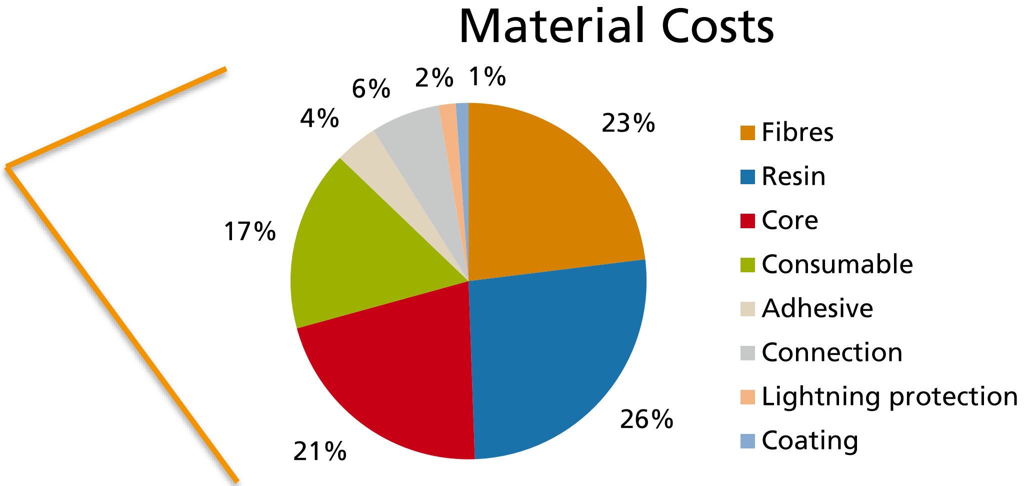
- Prefabs: Main spar caps, root flange inserts, root platform, shear webs (vacuum infusion)
- 2 shells (vacuum infusion)
- Shear web bonding
- Shell bonding
- Machining
- Surface activation and coating



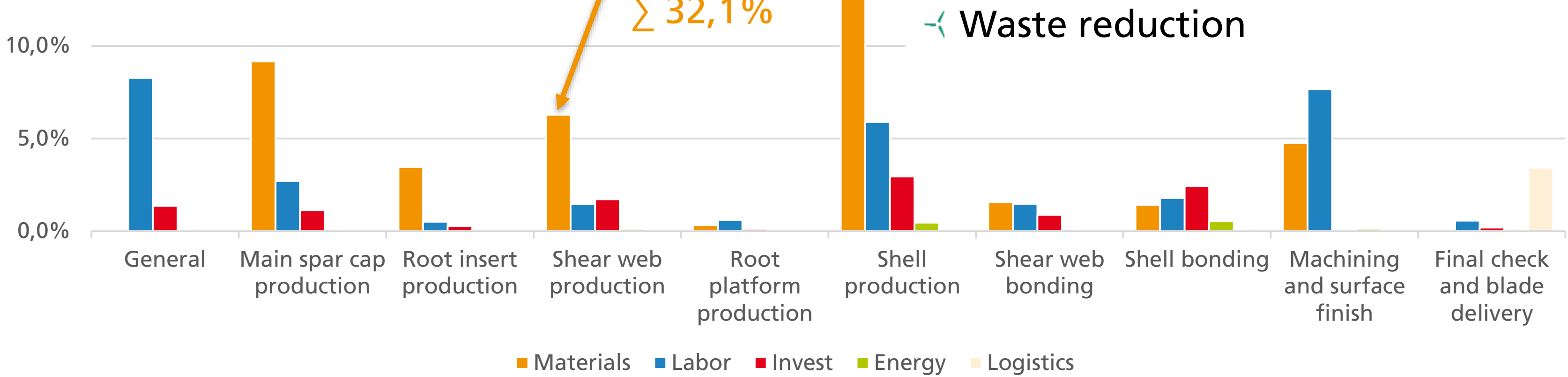
Manufacturing cost analysis

- 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)



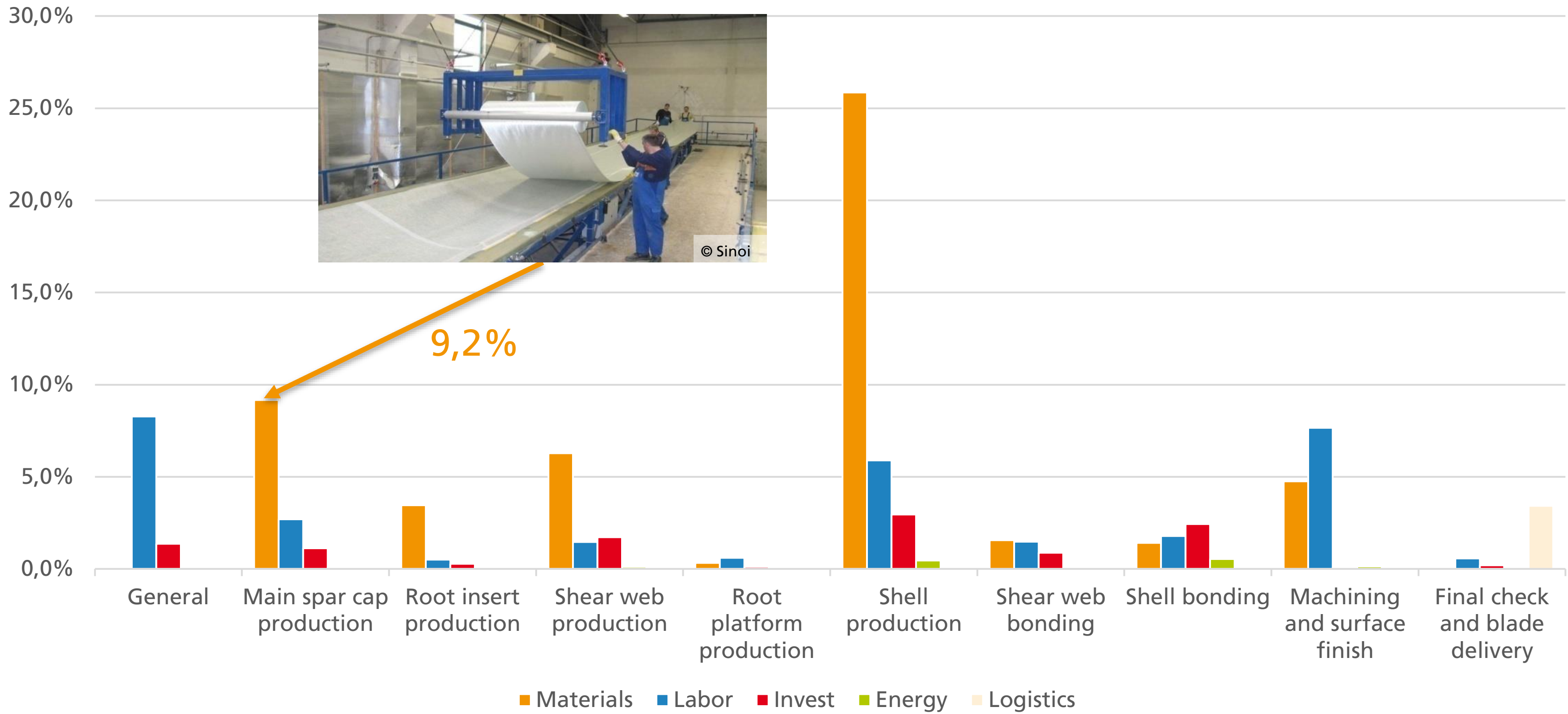


Material costs for sandwich parts



- 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

Material costs for spar caps



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)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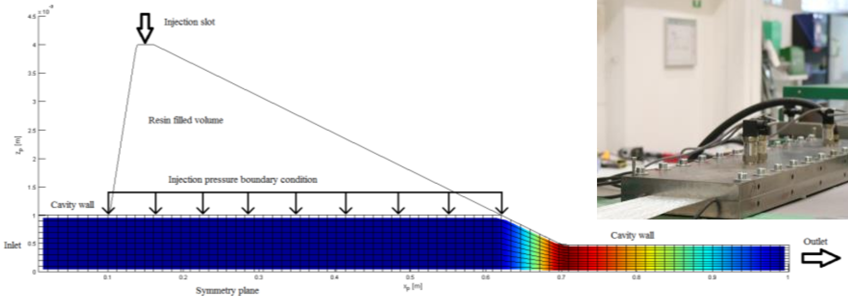

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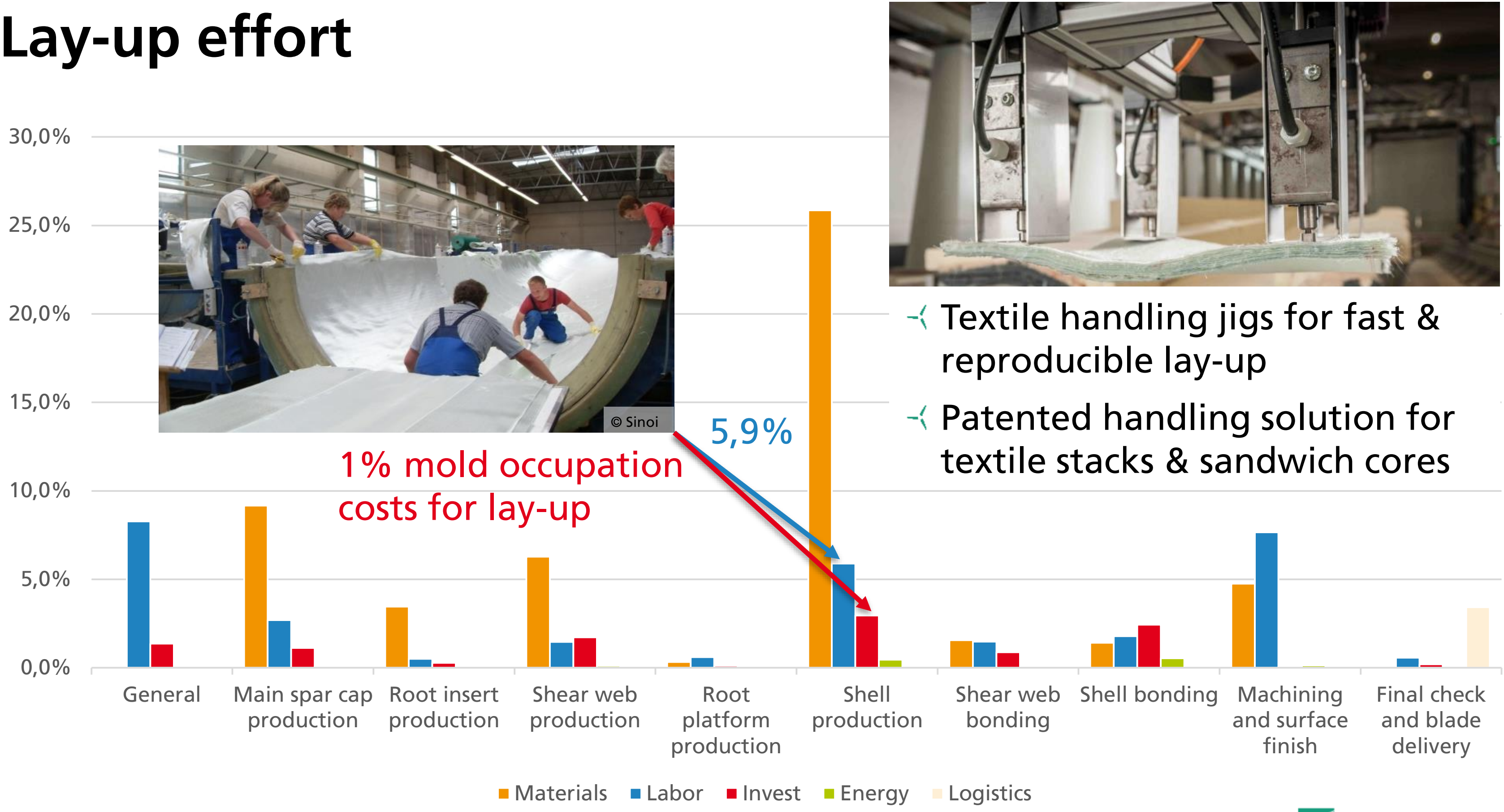
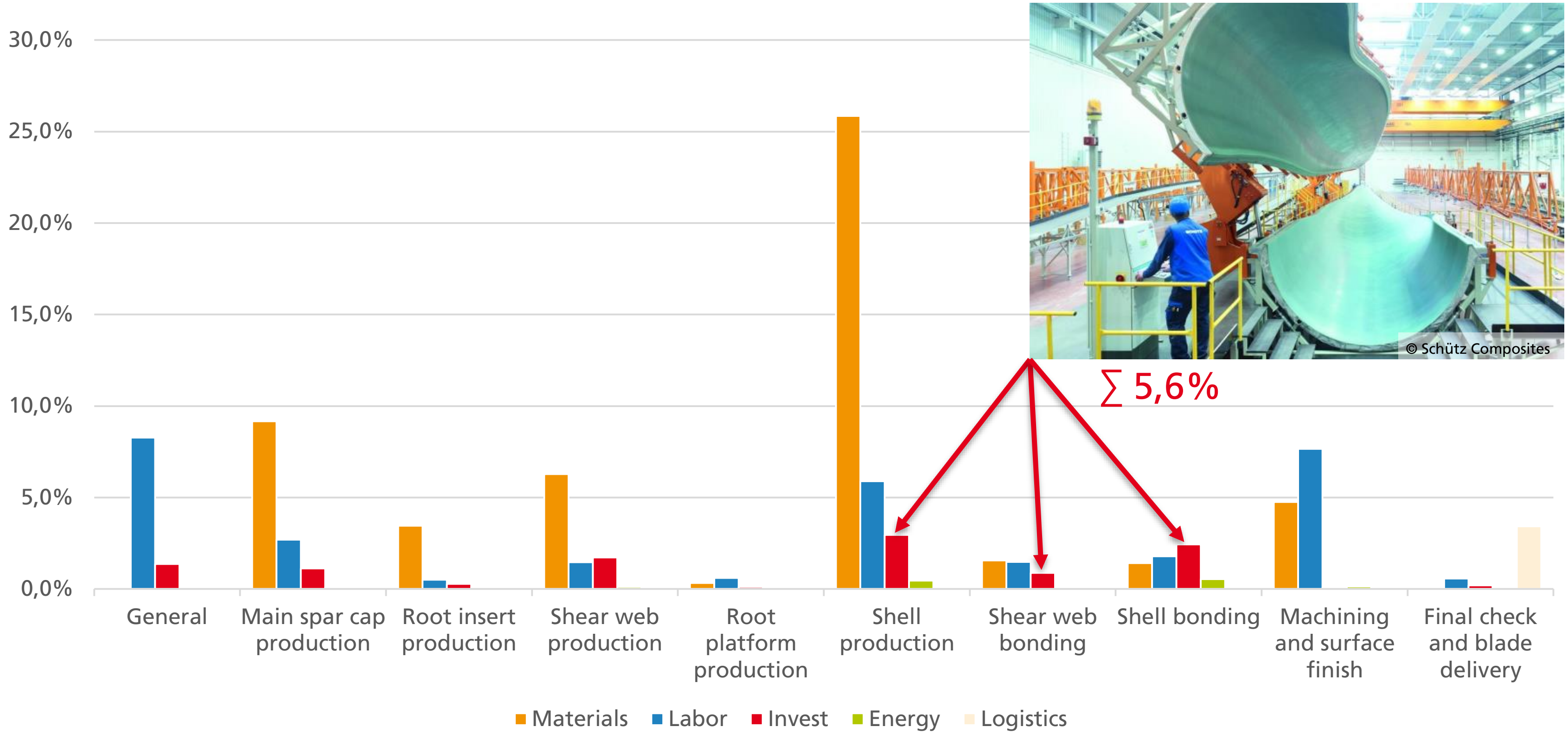
Lay-up effort



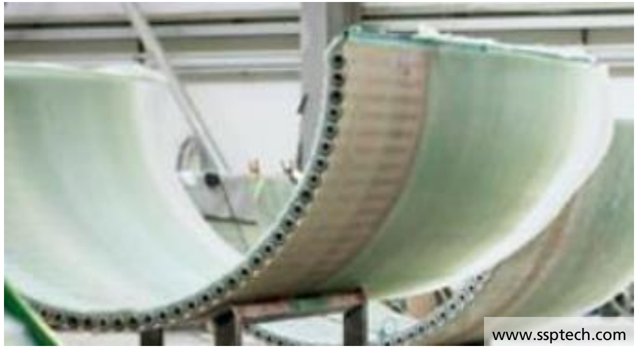
- Textile handling jigs for fast & reproducible lay-up
- Patented handling solution for textile stacks & sandwich cores

Main mold occupation costs (times)



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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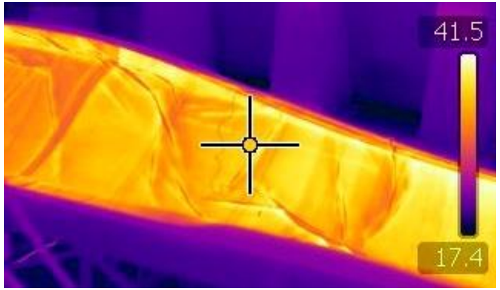
Main mold occupation costs (times)

- 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!



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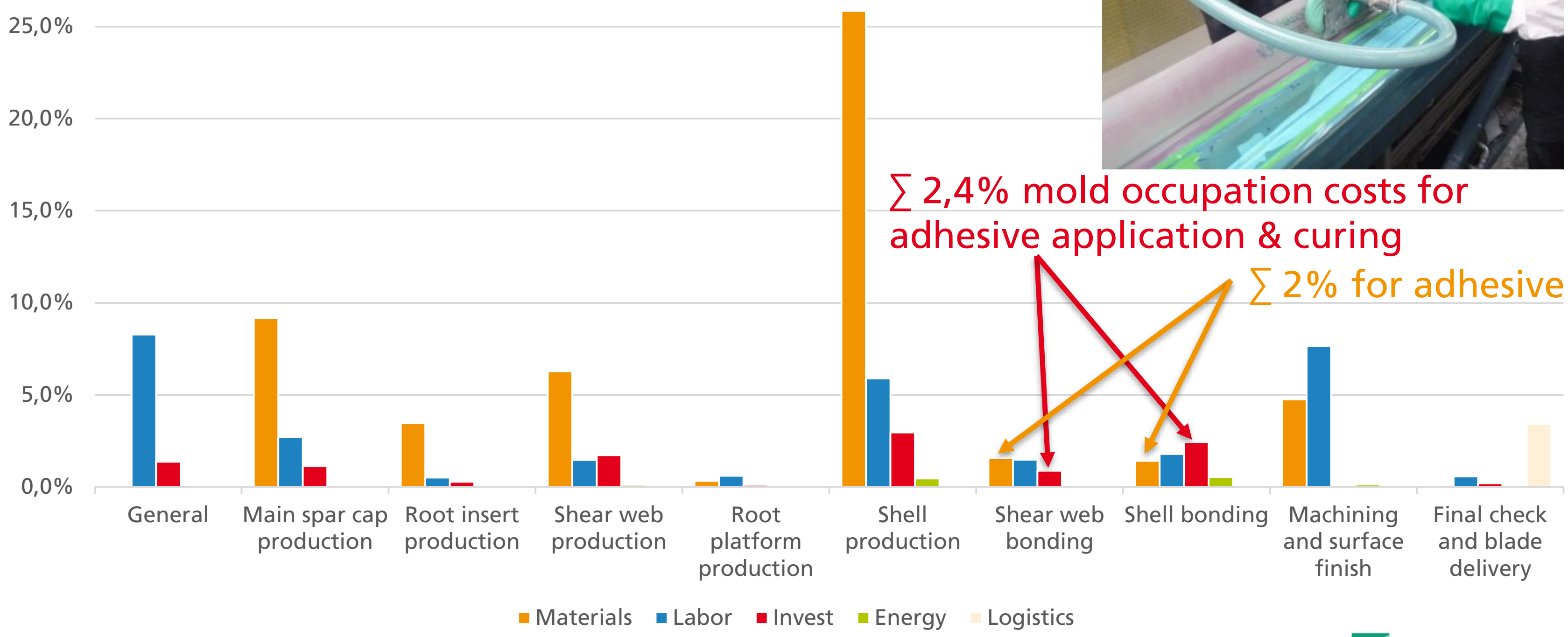
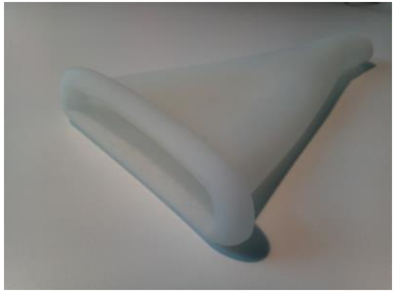
Adhesive application and curing



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



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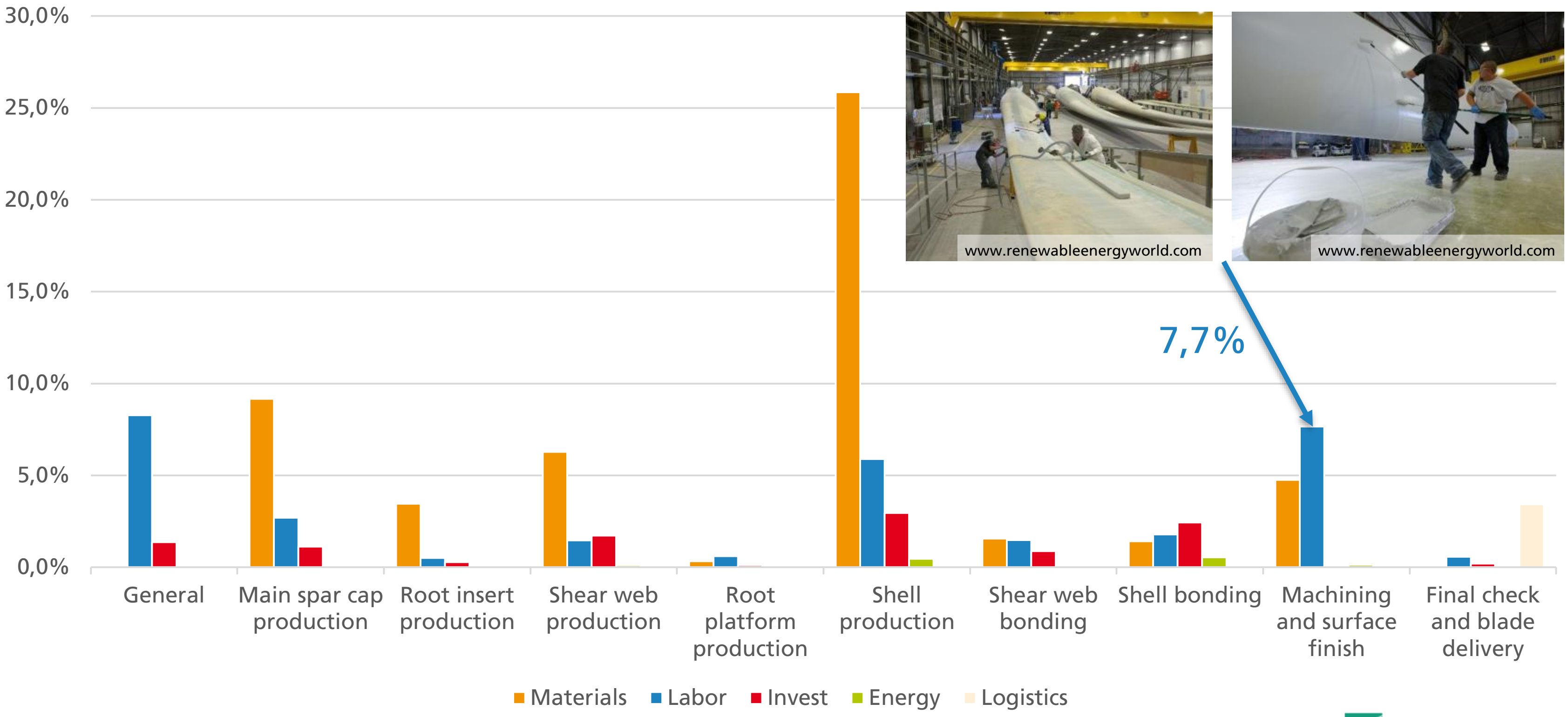
Surface finish effort



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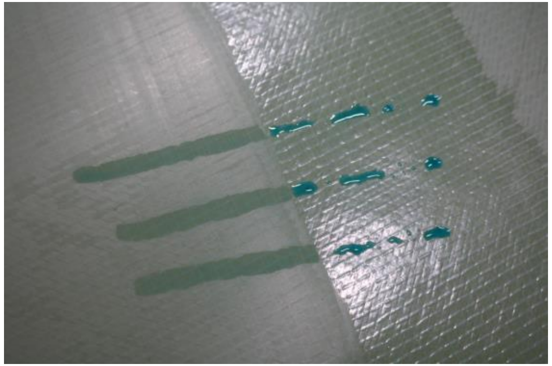
Surface finish effort

(Semi-)automated surface activation

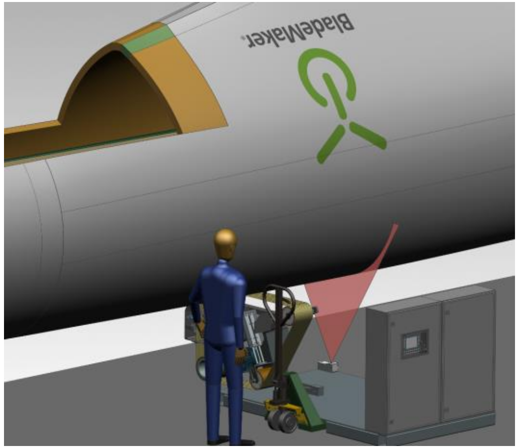
- Higher material removal rate at lower cost
- 6-axis CNC-controlled gantry used as test rig for reproducible grinding tests
  → Aims at measuring the removal rate
- Belt grinder from Jöst Abrasives tested:
  - Removes dust from blade instead of rubbing it in
  - Belt cleaning station removes dust from 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



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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

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Thanks a lot for your attention!

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