CHALLENGES IN THE DESIGN AND MANUFACTURING OF LARGE WIND TURBINE BLADES

Pim de Laat

Specialist in development of advanced composite products
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PONTIS ENGINEERING: INTRODUCTION

» Founded in 2007

» 25 Specialists in Composite Engineering Six Sigma trained

» Offices in Netherlands (Amsterdam), USA (Boston, Ma) and Asia (Beijing)

» Global customer base incl 7 stock market listed companies.

» Pontis focusses globally on growing markets for innovative composite solutions.

» Expertise in wind:

  • Blades ranging from 6 to 89 meter
  • 6+ offshore blades built
  • More transfers done
## BRIDGING DESIGN & MANUFACTURING

### Design Requirements
- Lowest loads (Lowest weight)
- Smooth blade
- Accurate profile tolerances
- Slender blade design

### Manufacturing Requirements
- Fast production
- Lowest cost
- Six sigma quality, no rejects
- Robust and simple process
DESIGN CHALLENGES

DESIGN OF BIG BLADES LEADS TO MULTIPLE CHALLENGES:

CONFLICTING REQUIREMENTS:

- Aerodynamics
- Blade stiffness
- Blade mass -> Loads
- Blade stability (e.g. TE buckling)
- Logistics
BLADE MASS

KEEPING THE MASS AT AN ACCEPTABLE LEVEL

» What is this level?

» Balance between mass, loads, costs and aerodynamics

POWER IS LENGTH^2 (SWEPT AREA)

MASS IS LENGTH^~2.6*

DUE TO THIS, WE ARE FORCED TO CONSIDER NEW TECHNOLOGY/OPTIONS

» Superior material selection

» Adapt loads to structure e.g. 3rd webs

» Root connection technology

*depends on blade family.
BLADE STABILITY/BUCKLING

NEW BLADE DESIGN DRIVERS

- Higher Loads
- Larger panel spans --> TE buckling
- Thinner Spar-Caps* --> Spar cap buckling

* use of different materials
MATERIALS

MATERIAL PROPERTIES

» mech. prop. no longer sufficient -> requirement for **higher** material properties
  E-glass → HM Glass → Carbon

» Polyester --> Epoxy --> PU and MMA?

MATERIAL PROCESSING

» Prepreg, Infusion, Pultrusion and root connection

» Location, logistics experience (skill set) HSE etc.
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MANUFACTURING GENERAL

“Typical” mould cycle time for serial production rotor blade

» Focus Material lay-up.
» Full automation still too expensive
» Average ROI 3 – 5 yrs
» Need for more flexible dedicated solutions
» Manufacturing of smaller parts may increase the supply chain.
PRACTICAL CHALLENGES

» DIMENSIONS (MAX CHORD) BECOME EXCEPTIONALLY LARGE

» TE THICKNESS, TOLERANCES STILL BASED ON 45M BLADE

» BONDING PASTE POT LIFE APPLICATION TIME

» MANAGING OVERALL MFG PROCESS RANGING FROM LOGISTICS TO DOWNTIME
TECHNOLOGY

» PRODUCTION STATUS COMMUNICATION INCREASINGLY CRITICAL FOR LARGER BLADES (JIT)

» LOADING MATERIALS, MASS INCREASE LENGTH \( \sim 2.6^* \) \rightarrow \) INCREASE LAY-UP TIME POTENTIAL \( \sim 2.6^* \)

» BLADE INFUSION, INCREASING COMPLEXITY

» COMPONENT HANDLING, TOOLING, PARTS

*depends on blade family.
QUALITY

» COST OF DEVIATIONS GROW EXPONENTIAL WITH LENGTH OF THE BLADE (MATERIAL AFFECTED)
» CONSISTENT QUALITY (PROCESS STABILITY/CAP.
» CONTROL/PROCESS DRIVEN QUALITY ISSUES
» WHAT IS ACCEPTABLE?
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TREND TO CONSIDER MODULAR BLADE CONCEPTS AS WELL AS BLADE EXTENSIONS

IN GENERAL ALL CONNECTIONS ADD MASS, BUT COULD BE A GAME CHANGER WHEN THE FOLLOWING IS CONSIDERED:

» Logistics
» Increase supply chain
» Ease of repair
» Accuracy
» Blade family extension
PONTIS PATENT APPLICATION

- Damage tolerant edge.
- Low modulus TE that can not buckle.
- Move the load carrying material inwards, however overall change in mass is neutral when increased stability is considered.
## SOLUTIONS: MATERIAL LAY-UP

### Preforms
- **Manufacturing Benefit**
  - Reduce in-mould cycle time
  - More consistent high quality product
- **Design Impact**
  - More time spent optimizing laminate layout for preforming purposes.
  - Additional moulds

### Prefabs
- **Manufacturing Benefit**
  - Reduce in-mould cycle time
  - More consistent high quality product
- **Design Impact**
  - Neutral

### Ready for Automation
- **Manufacturing Benefit**
  - Less man hours
  - Quicker cycle time
- **Design Impact**
  - Less intricate parts that can be made by machine

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35% inmould cycle time reduction achieved.

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**PONTIS ENGINEERING**

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CHALLENGES IN THE DESIGN AND MANUFACTURING OF LARGE WIND TURBINE BLADES NOVEMBER 2016
SOLUTIONS: PROCESS AUTOMIZATION

ADVANCE KITTING OF CONSUMABLES

» Sensing technology (in mould??)
» Improved resin quality

AUTOMATION INFUSION

CURE OPTIMIZATION THRU SENSING

» Insulation optimization
» Automated cure cycle thru sensing

Photo: Hedrich
SOLUTIONS: CONTINUOUS IMPROVEMENT

GOAL TO CONSTANTLY IMPROVE MFG PROCESS;

» Time,

» Quality,

» Costs

» How:
- Standardization of process,
- Kaizen events (small task groups)
- Involvement of personal
- 5S --> lean journey
SUMMARY

» CONTRADICTION BETWEEN DESIGN AND MANUFACTURING INEVITABLE

» EXPONENTIAL MASS INCREASE WILL REQUIRE SUPERIOR MATERIALS AND BLADE ARCHITECTURE

» DESIGN CHALLENGES ON BLADE STABILITY/BUCKLING

» INCREASED MANUFACTURING CHALLENGES FOR BIG BLADES

» MANAGE BLADE QUALITY --> SIX SIGMA

» ADAPT /TAILOR PROCESSES TO SPECIFIC PRODUCT DEMANDS

» TREND TOWARDS OPTIMIZATION PROGRAMS
QUESTIONS?

THANK YOU

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