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Struzziero, Giacomo; Teuwen, Julie

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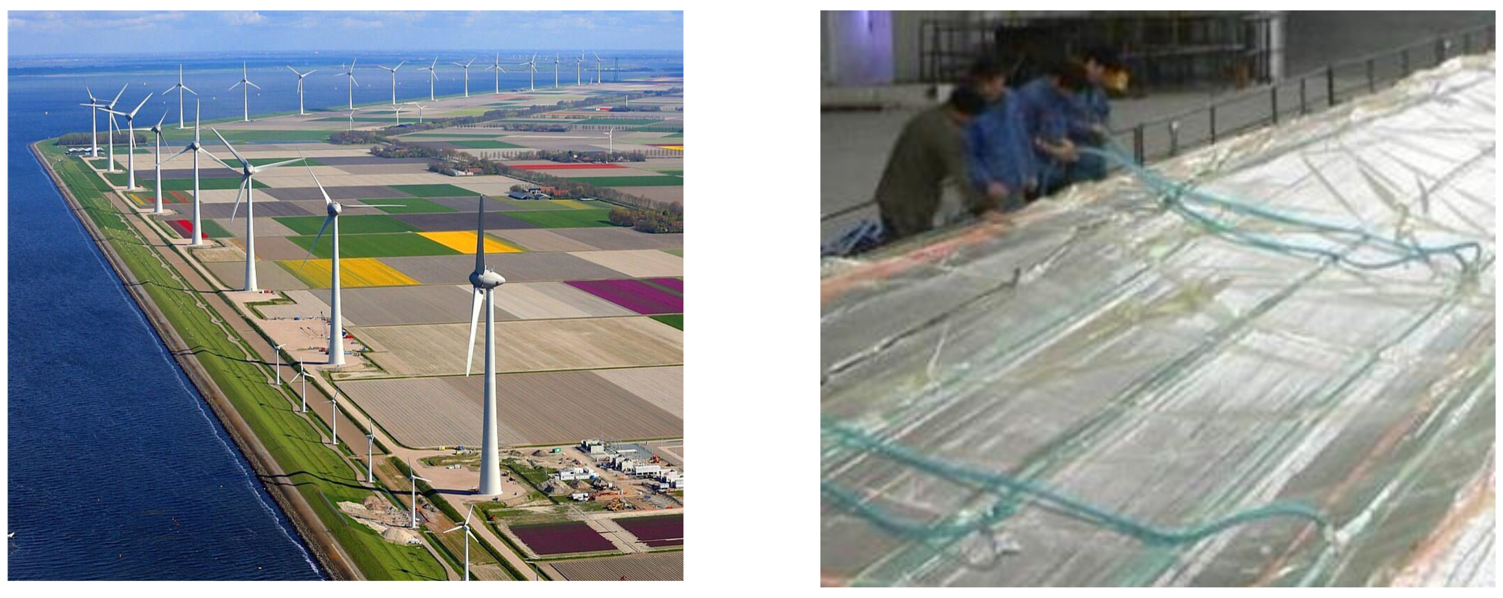
Quantifying the relevant time-quality trade-off of the curing process for wind turbine blades manufacturing

Giacomo Struzziero, Julie Teuwen
Department of Aerospace Structures & Materials, Faculty of Aerospace Engineering
Delft University of Technology, Kluyverweg 3 2629 HS, Delft (The Netherlands)

Introduction

- **Challenges in composite manufacturing:**
  - **Quality compliance due to unexpected process induced defects**
  - **Reducing cost due to long process time and failures**
  - **Sustainability due to large amount of scrapped materials**
- **Wind industry current solution**
  - **Overdesigning**
- **Issues:**
  - **Process cost**
  - **Blades efficiency**
  - **Sustainability**

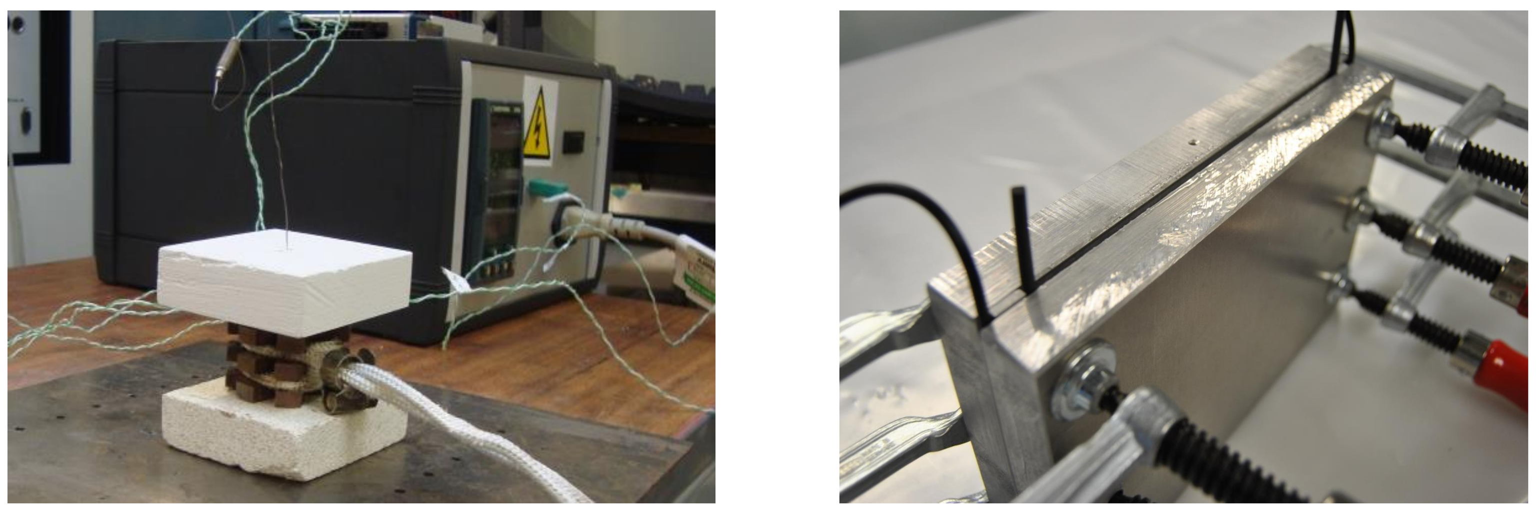


a) b)
Figure 1: a) Wind turbine farm in Netherlands b) Manufacturing of wind turbine blades

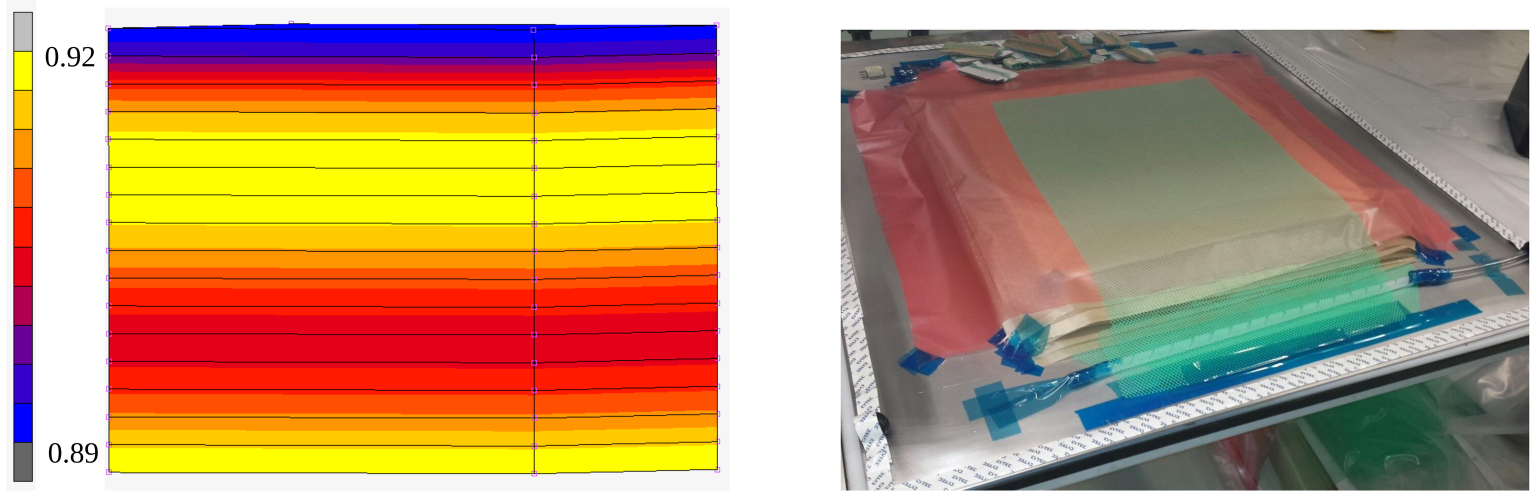
Research methodology

Three threads of research can be identified to generate the necessary science based background allowing optimisation of the process:

- **New material characterisation methodology**
  - **Chemical-thermal properties**
    - Cure kinetics
    - Specific heat
    - Thermal conductivity
  - **Mechanical properties**
    - Mechanical modulus
  - **Thermomechanical properties**
    - Coefficient of thermal expansion
    - Shrinkage
- **Cure process simulation**
  - **Heat transfer model**
    - Degree of cure evolution
    - Overshoot temperature
  - **Coupled thermo-mechanical model**
    - Residual stresses generation
  - **Model validation**
    - Temperature measurements
    - Residual stresses measurements
- **Multi-Objective optimisation methodology**
  - **Quality/Cost Pareto front**
    - Set of optimal design points
    - Significant reduction in process time (78%)
    - Overshoot temperature (60%)



a) b)
Figure 2: a) Thermal conductivity test set-up b) Mechanical modulus samples manufacturing



a) b)
Figure 3: a) Degree of cure results for a 47 mm thick laminate b) Sampled manufacturing for mechanical performances and validation

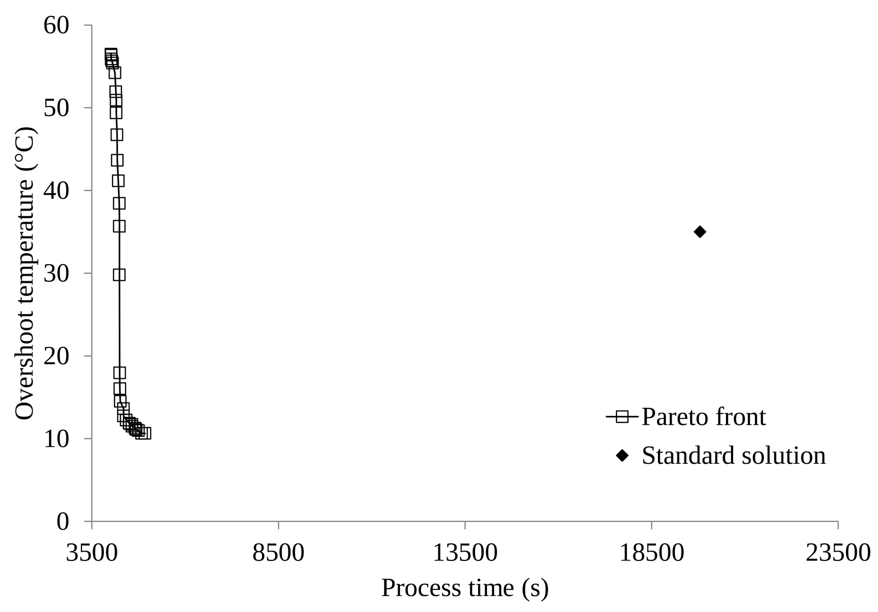


Figure 4: Comparison between standard results and Pareto front

Conclusions

- **The optimisation methodology is able to unveil relevant quality/cost trade-off**
- **The material characterisation will provide accurate material properties evolution due to novelties in characterisation**
- **Infrastructure for measuring temperature and residual stresses will validate models predictions.**

References

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[2] Standard DNVLG-ST-0376. Rotor blades for wind turbines. December 2015

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