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Increasing efficiency of rotor blades – a permanent challenge

Harald Bersee
20 Sept. 2016

Suzlon wind farm in Utah, USA

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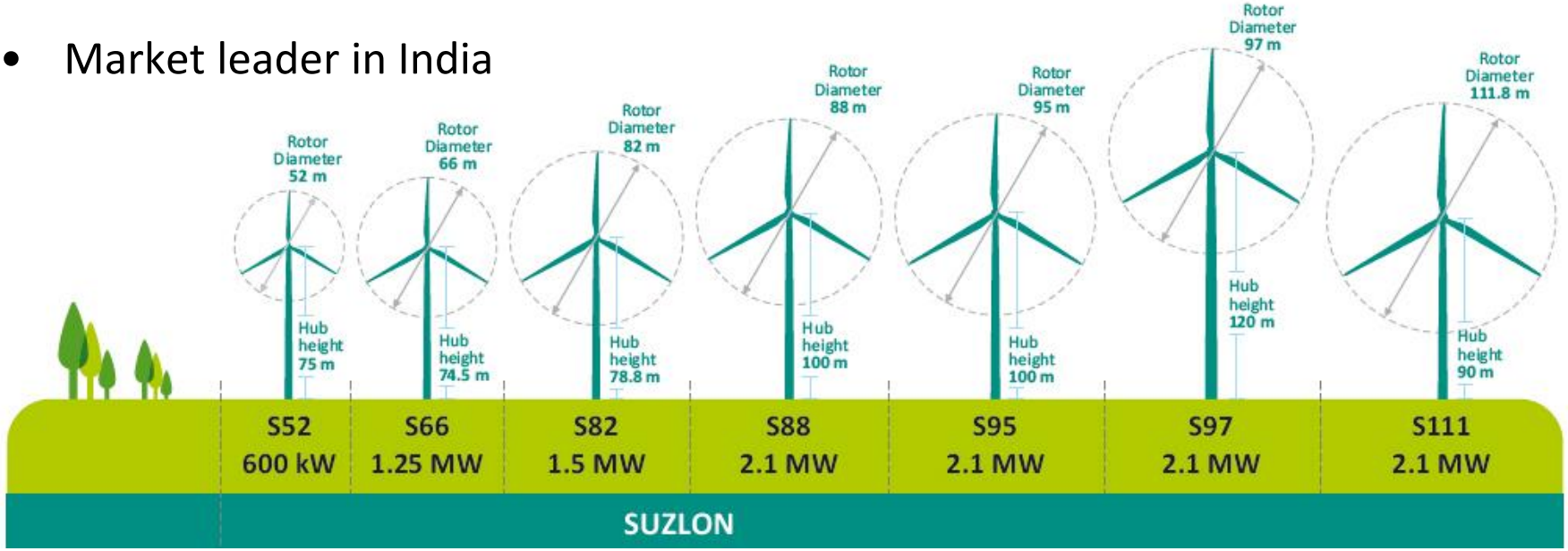
- Founded in 1995 by Tulsi Tanti
- A workforce of over 8000 people
- A presence in 19 countries of Asia, Australia, Europe, Africa and North and South America
- Installed capacity ~ 15GW across 17 countries
- Market leader in India



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Suzlon Energy Blades

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Foundation
SE Composites 2001 - SE Blades in 2011

Employees
App. 5.500

HQ
Pune, One Earth

R&D
The Netherlands: Hengelo
Denmark: Vejle
India: Pune, Vadodara

Blade Testing Centre
BTCG, Baroda

Manufacturing
India: Padubidri, Bhuj, Daman, Dhule, Vadodara, Jaisalmer, Ratlam, Anantpur
Ex-North America: Pipestone

Service
India (Pune & Baroda)

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Rotor Blade Manufacturing across India

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RBU	Blade model
Padu	SB 46, 47, 54
Jaisalmer	SB 54
Dhule	SB 47, 54
Bhuj	SB 47, 54
Ratlam	SB 54
Pondy	SB 54
Anantapur	SB 54

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Driver for Wind Turbine Blade Design

- Efficiency of wind turbines is measured by:
  - Levelized Cost of Energy (LCoE) = Cost of Product / Produced Energy in MWh (for total product life cycle)

- Contribution of wind turbine blade to lowest LCoE:
  - Increasing power output of the blade
    - Attributes 100% to energy production of wind turbine
  - Lowering the blade weight & Loads
    - Has an effect on. 80% of the turbine costs
  - Lowering the costs of the blade
    - Contributes appr. 20% of the turbine costs

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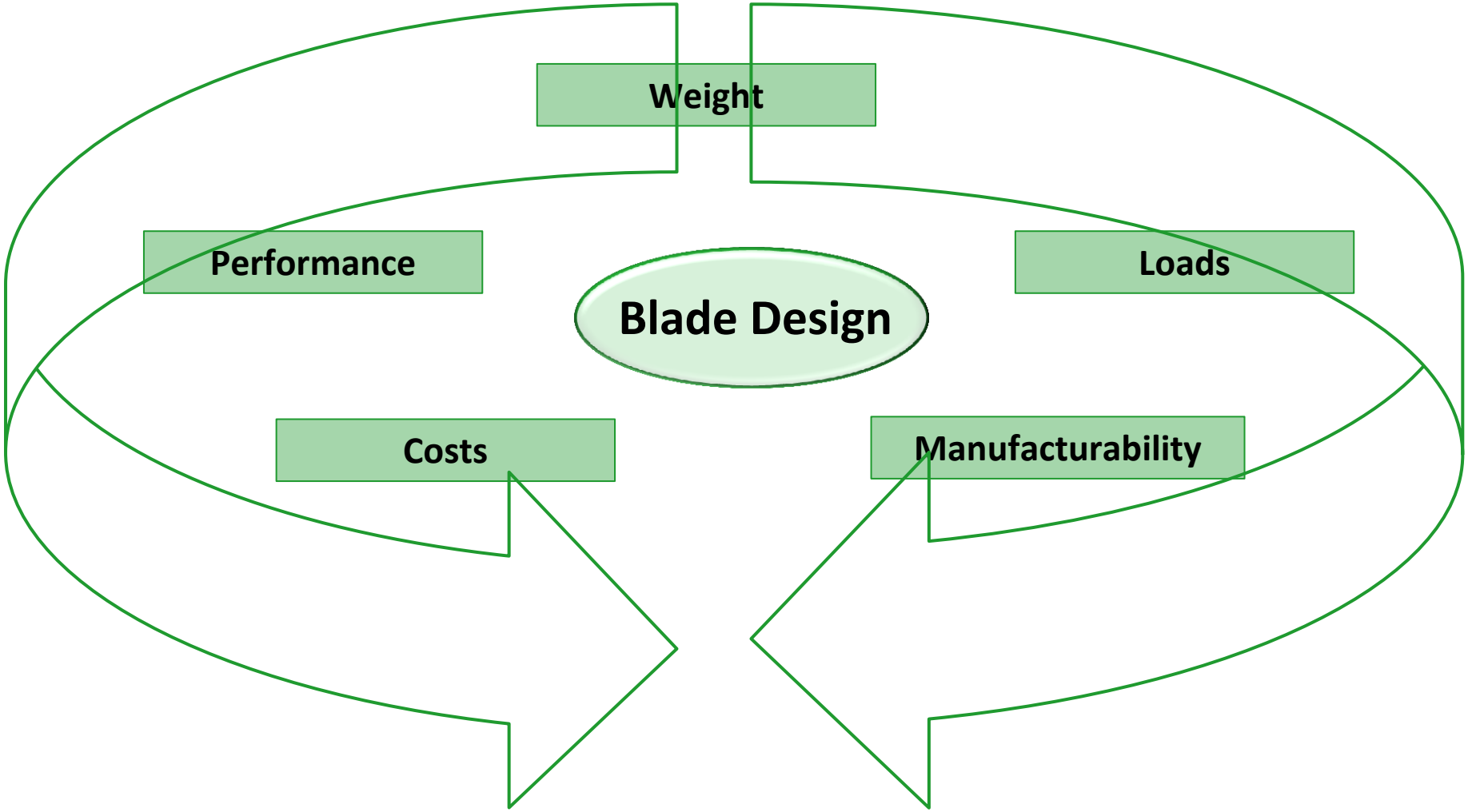
Blade Design Challenge



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Increasing power output of the blade

Can be achieved by:

1. Increase rotor swept area
2. Improvement of rotor blade aerodynamic efficiency
3. More robust operation
4. Site specific design and optimisation
5. Wind farm optimisation
6. Noise reduction

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Increased rotor swept area (1/2)

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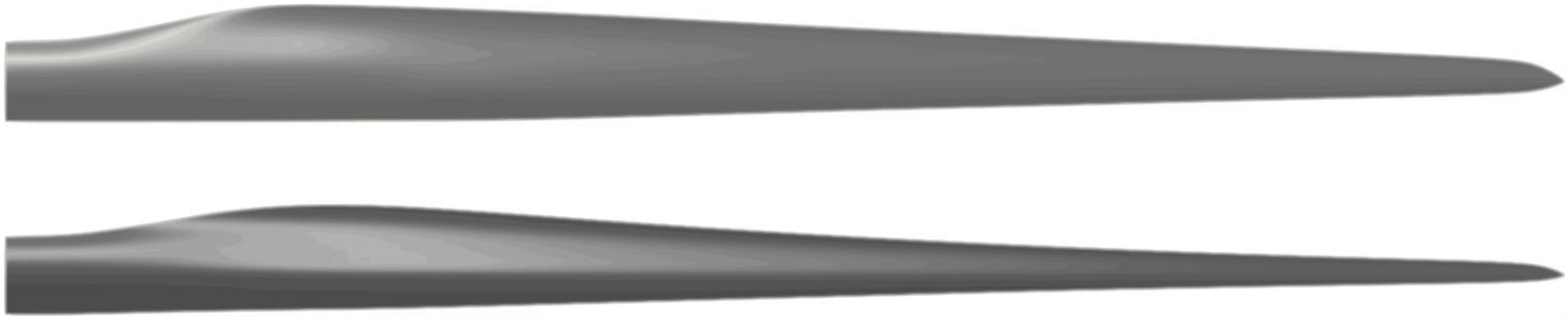
Increased rotor swept area (2/2)

Challenges:

- Optimise blade aerodynamic design with focus on achieving high yield-to-loads ratio
- Maintaining sufficient tip-tower clearance through blade and controller design
- Advanced controller strategies to alleviate blade and turbine loads while maximising yield
- Mitigate rotor blade noise though aerodynamic design, noise reducing add-ons and/or controller strategies



Difference in blade planform between Suzlon 43 m blade upscaled to 54 m (upper, 2006) and Suzlon 54 m blade (lower, 2015).
The newer Suzlon blades utilise the 'slender blade' concept to achieve a high yield-to-loads ratio.

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Improvement of blade aerodynamic efficiency

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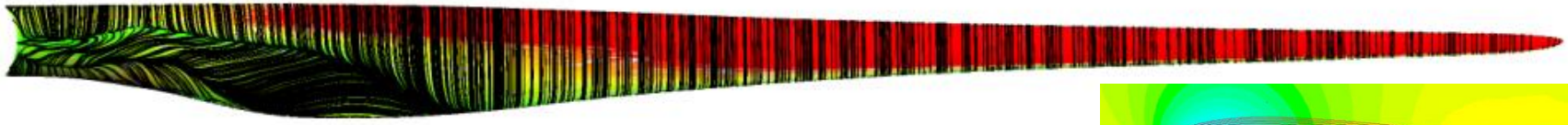
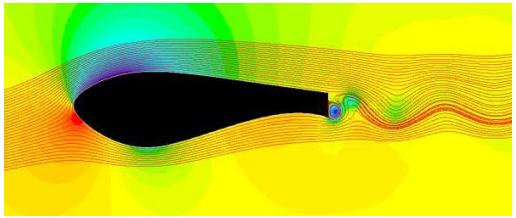
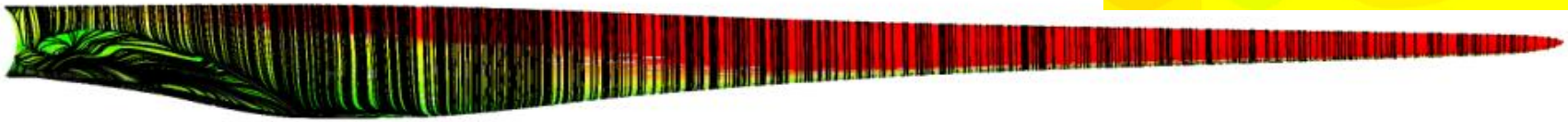
- New aerfoil design
- Blade design optimisation (E.g. Flatback)
- Aerodynamic add-ons. (E.g. winglets, slats,…)
- Optimised turbine operation through advanced controller strategies
- Improve understanding rotor aerodynamics through CFD and flow diagnostics
- Improve blade surface finishing (coating)

Surface stream lines on a baseline blade concept:





Surface stream lines on a flatback blade concept:



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More robust operation

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- Maintaining high aerodynamic performance for a variety of site conditions and dirt contaminations on the blade
- Improving leading edge erosion protection systems to maintain yield and minimise turbine downtime due to repair works

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Source: http://www.rnb-bladeservice.com/

Rotor blade surface roughness related to AEP

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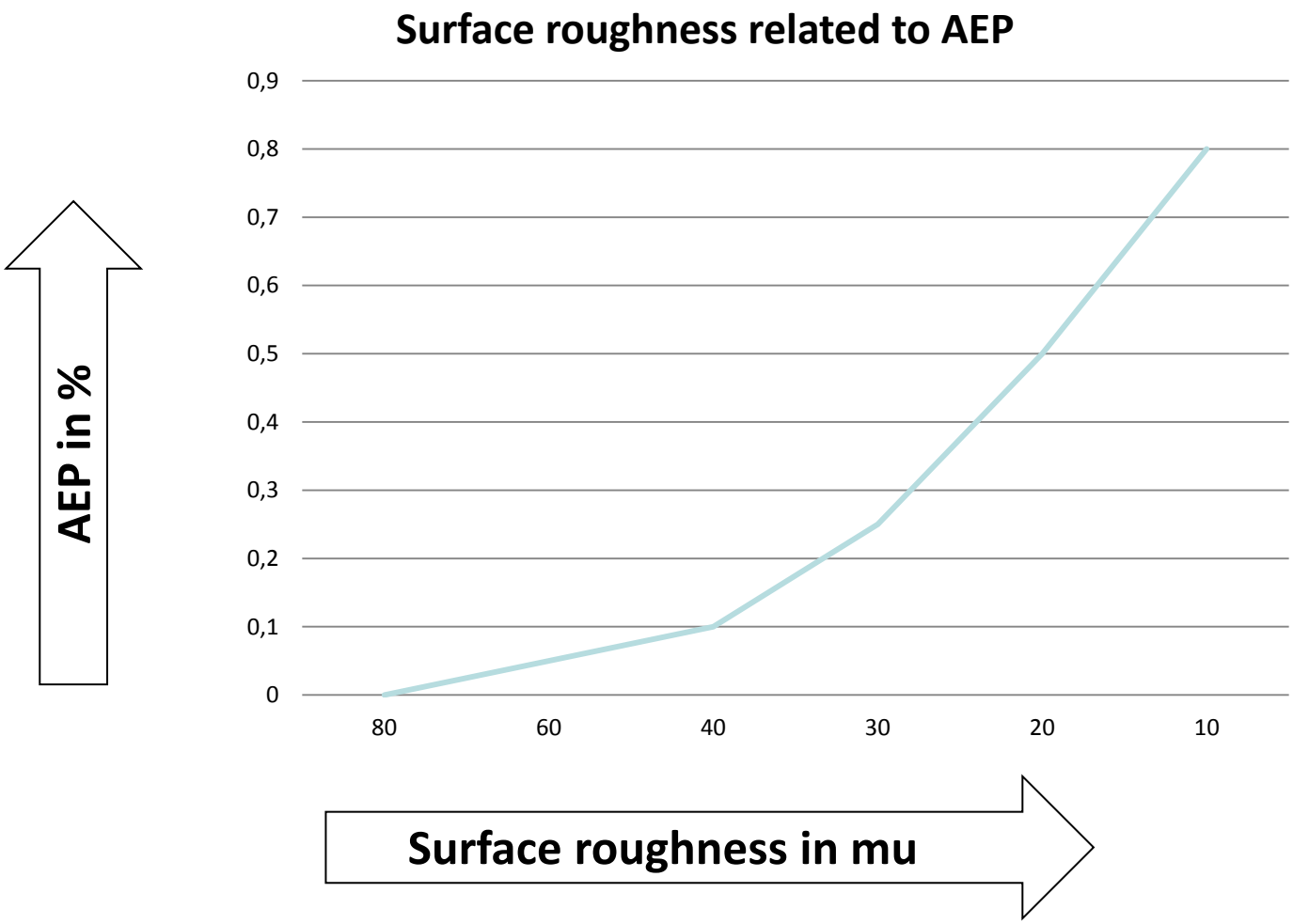

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Leading Edge roughness related to AEP

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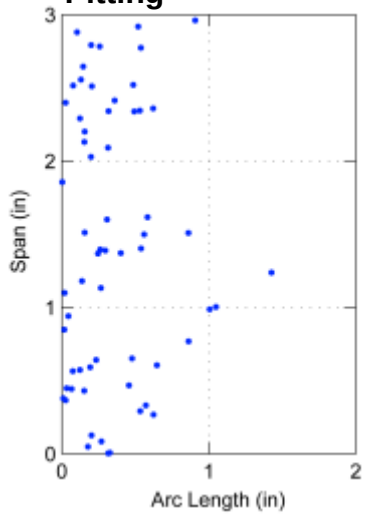
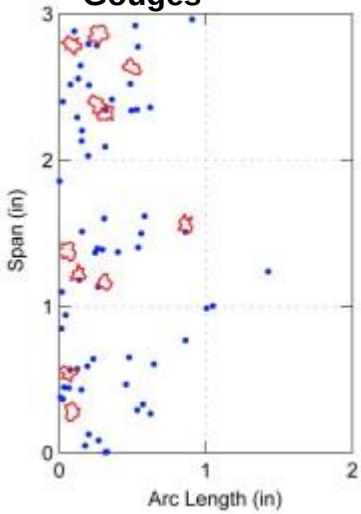
A2 – Moderate Pitting



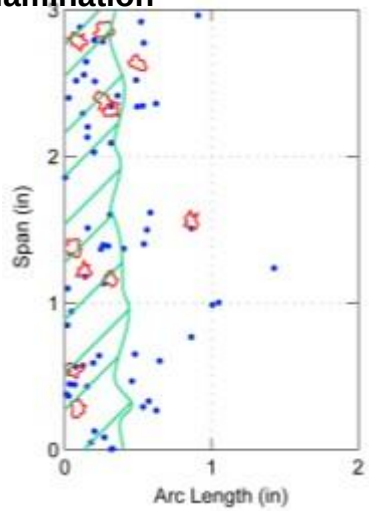
Delta AEP: 4,2 %

B3 – Pits + Gouges



9,8%

C4 – Pits, Gouges & Delamination



20,5%

Assumptions: 1.5 MW turbine, €50/ MWh, 30% capacity factor

Source: 3M Wind Tunnel Studies at University of Illinois

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Site specific design and optimisation

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- Introduce flexibility in blade design and controls to achieve optimal turbine performance for different sites and site conditions
  - Varying tower heights

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Wind farm optimisation

- Blade aerodynamic design for wind farm application
- Development of wind farm control systems to optimise power output

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Noise reduction

Reduction of rotor noise can allow for higher tip speeds. It can also increase the number of sites possible for wind turbine application in case of stringent noise restrictions.

Challenges:

- Find the optimum between blade trailing edge design, rotor noise and improvement of correlation between (field) measurements and manufacturability
- Continuous simulations
- Development of low noise controller strategies
- Development of add-ons for low noise operation

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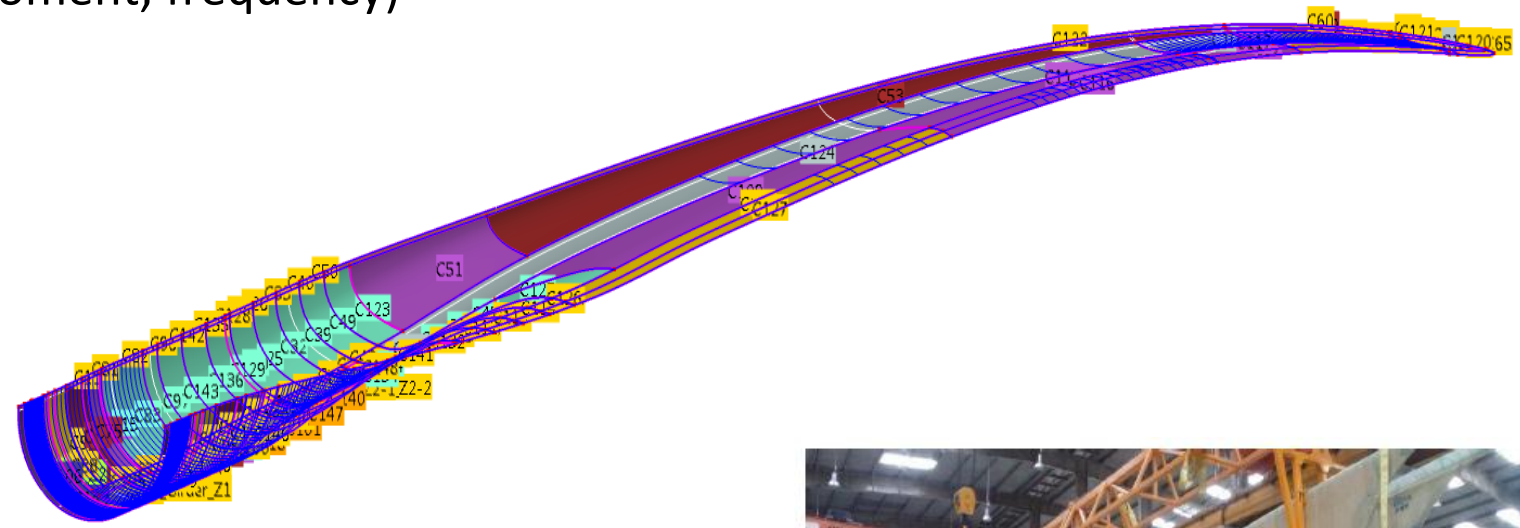
Product Cost

- Cost of Product (wind turbine) is function of blade weight and loads (static moment, frequency)



- Cost of Product (blade) is function of blade BOM cost,
  blade manufacturing cost
  and blade maintenance cost

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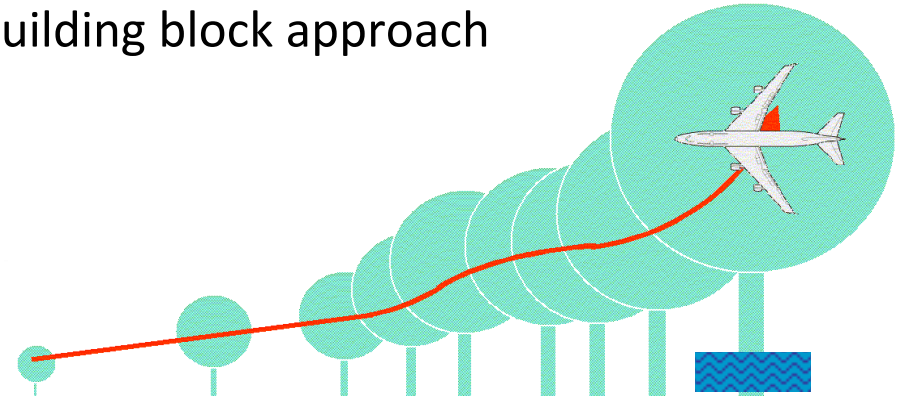
Lowering Blade Weight & Loads

- Optimising blade aerodynamic design more towards structural constraints
  - High performance thick airfoils
- Carbon Fibre Composites
- Reducing design uncertainties by building block approach
- Loads alleviation
  - Individual Pitch Control
  - Smart Blades



$$m_{blade} \sim (R_{blade})^{\cancel{3}\ 2.35}$$

- Improved understanding and correlation between simulated and measured loads, which could reduce the level of conservatism in loads calculations

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Lowering Blade cost

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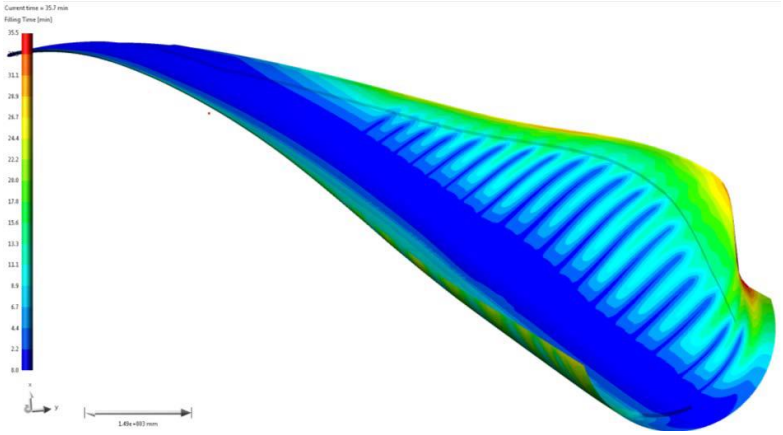
- Lowering the BOM costs
  - Lower blade weight
  - Optimise the use of high cost materials (e.g. glass versus carbon)
    - Reducing design uncertainties by building block approach
    - High performance thick airfoils
  - Loads alleviation
  - Reducing conservatism in loads calculations
- Lowering the manufacturing costs
  - Reduction of Cycle time, eg. 24 hrs to 12 hrs would mean a factor 2 reduction in mould & equipment Capex
    - Process simulation
    - Fast curing
    - Automation
    - Manufacturing simulation
  - Reduction of NC's
    - In-situ process monitoring
    - Process simulation
    - Robust processes
  - Waste reduction & Recycling



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Automation versus Manual Lay-up

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- Total Cycle time < 24 hrs
  - ATL or AFP??

Girder: made separately
appr. 1200 kg at ≈ 50 m
Thickness: 2mm – 10 cm

ATL/AFP: 150 kg/hr-20 kg/hr
> 2 million Euro

Lay-up time: 8 – 60 hrs

Lay-up time: 2 – 3 hrs

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Conclusions

- The key design driver for wind turbine design is LCoE
- To meet all challenges in blade design to obtain the lowest LCoE, an integrated design approach is essential.
  - An integrated Turbine-Blade design approach given the strong influence of Loads and Control on Blade weight & performance.
  - An Integrated Blade design-manufacturing approach given the strong effect of the blade design on manufacturability.
- Special strength of SE Blades is the capability to develop high performance blades for easy & reliable production in low cost countries like India - through integrated blade design and close interaction with manufacturing & procurement

THANK YOU

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