MANAGING RISK DNV

New Guidance for the Design and Manufacture of Wind Turbine Blades

Copenhagen Offshore Wind 2005

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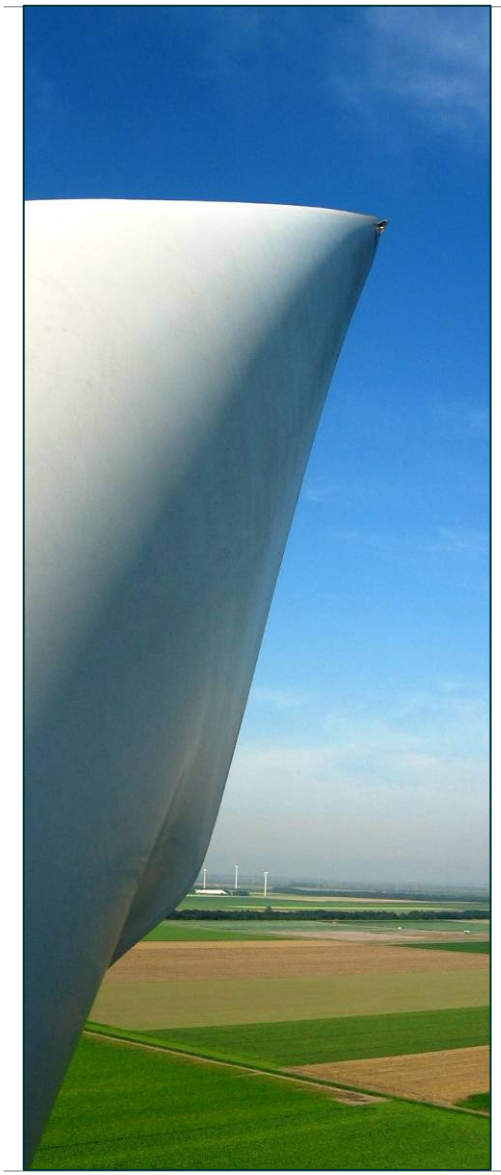
October 2005

Overview



- Introduction
- Trends in the Industry
- The Challenge for Certification
- Key Concepts:
  - Material Qualification
  - Design Analysis
  - Manufacturing
  - Static & Fatigue Type Testing
- Status of the Rules
- Conclusion

Introduction

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- Wind turbines larger and more complex
- Increasing focus on reliability
  - Particularly for offshore applications
- New standard developed to provide guidance for blade design and manufacture
- Focus on structural integrity
- Joins the accepted DNV-OS-J101 standard for offshore wind turbine structures

Trends in the Industry

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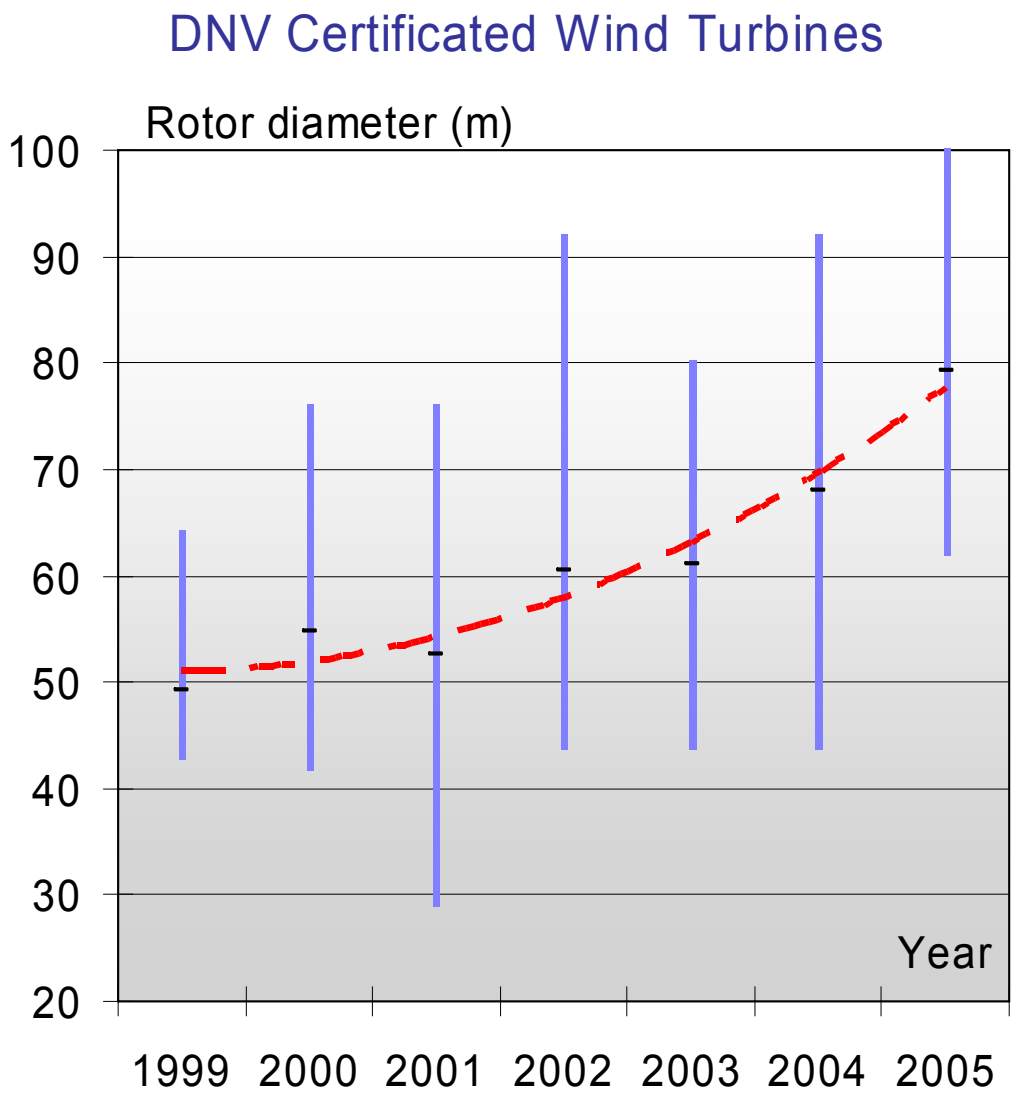
- DNV conducting certification with RISØ for over fifteen years
- Growth in type certificated turbine diameters
- Increasing level of complexity



Trends in the Industry

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- Relatively short development cycles are typical
- Numerous iterations on a ‘family’ of blade types
  - different nacelles
  - Different wind classes

Trends in the Industry

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- Wide range of manufacturing techniques:
  - Vacuum Infusion with secondary adhesive bonding
  - 'Single shot' infusion
  - Wet lay up
  - Filament winding
  - Co-bonded pultrusions
  - Prepreg

Photo courteous: LM Glasfiber, Denmark

Trends in the Industry

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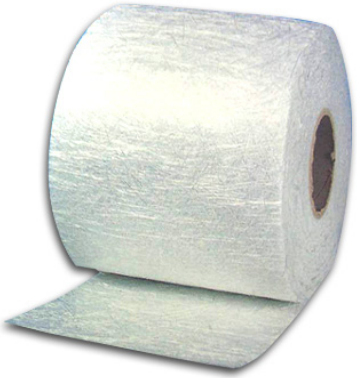
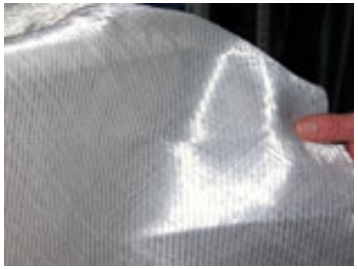
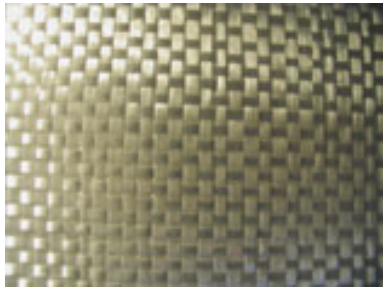
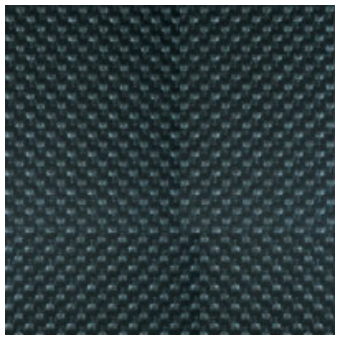
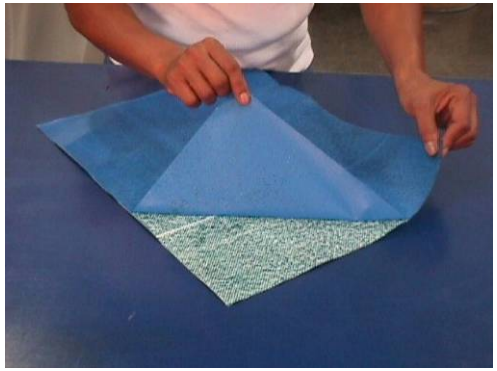
- Wide range of materials used:
  - Polyester, vinylester, and epoxy based resins and adhesives
  - Glass Fibre Reinforced Plastic (GFRP)
  - Carbon Fibre Reinforced Plastic (CFRP)
  - Epoxy prepregs
  - Pultrusions
  - Resin infused plywood
  - Sandwich cores (Balsa, PMI, PVC)











The Challenge for Certification

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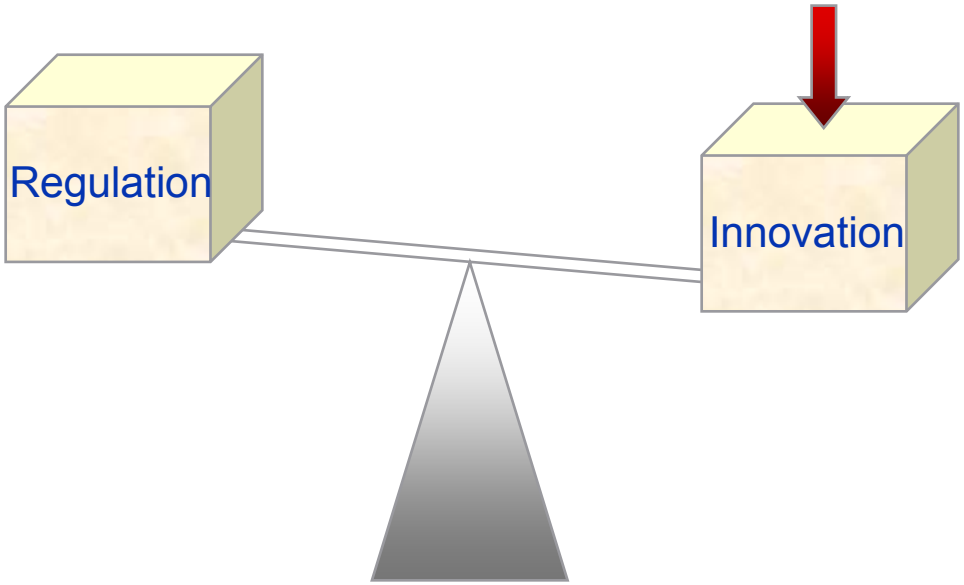
To balance regulation with innovation

- A design basis flexible enough for wide ranges of:
  - Manufacturing techniques and materials
  - Design philosophies
  - Manufacturer's design experience



Key Concepts

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- Consolidates 15 years of industry experience
- A focus on IEC WT-01 type certification
  - IEC 61400-1 and IEC 61400-23
- Detailed guidance for:
  - material qualification
  - design considerations and analysis procedures
  - manufacturing qualification
  - full scale testing
  - documentation requirements

Material Qualification

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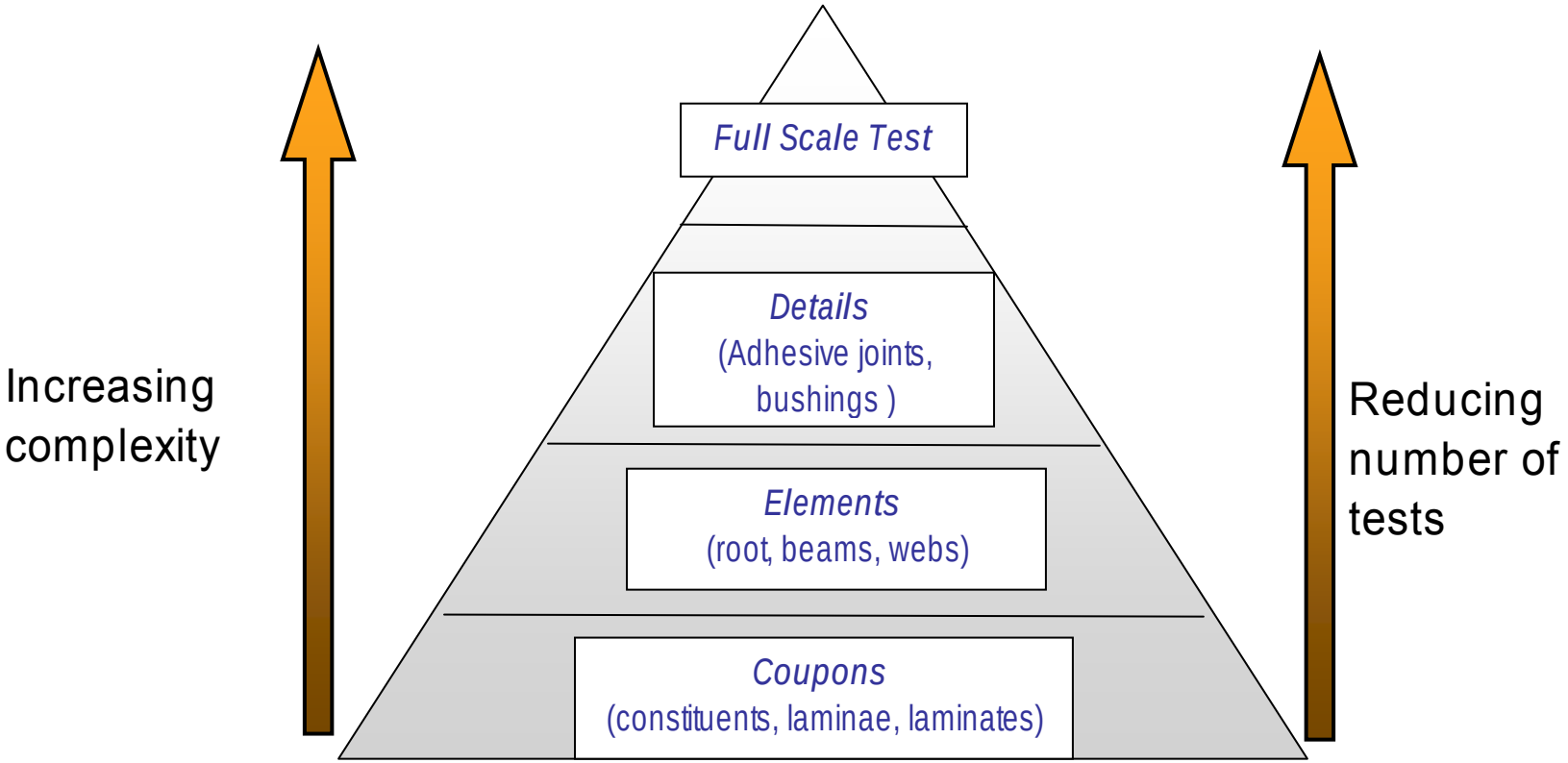
A building block approach

- Flexible framework covering coupon to final test
  - Allows in-house design allowables
  - Generic empirical safety factors (γ_m)



Material Qualification

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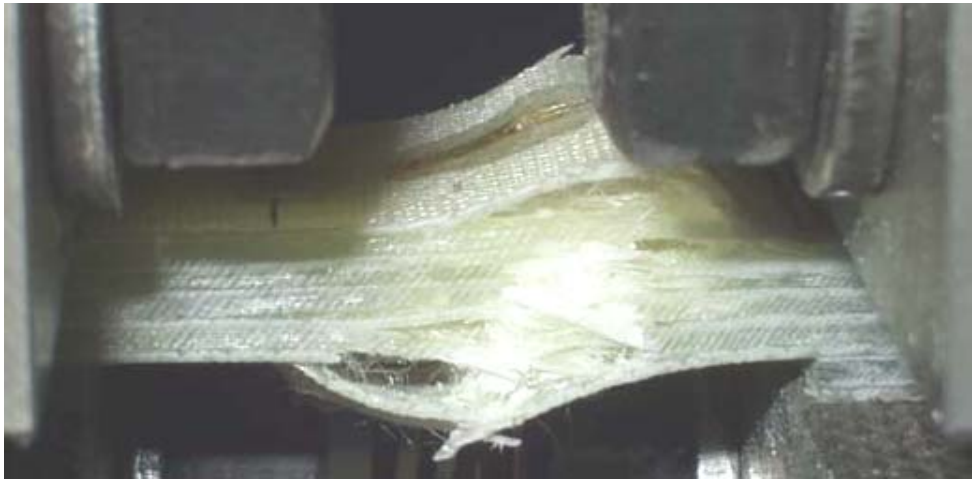
- Testing guidance for complex strength characterisation
  - in-plane and out-of-plane strengths and moduli
- Additional failure modes
  - erosion, environmental protection, temperature effects, and impact damage



Material Qualification - Example

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- Addresses variability in composite materials
- IEC strength characterisation to 95% probability with 95% confidence
- Similar to aerospace requirements

Design Code	**IEC 61400-1** *§7.6.2.2*	**FAR25** *§25.613(b.2)*	**FAR25** *§25.613(b.1)*
Application	wind turbine blades	secondary aircraft structure	primary aircraft structure
Probability *(% of population expected to lie within)*	95%	90%	99%
Confidence level	95%	95%	95%

Material Qualification - Example

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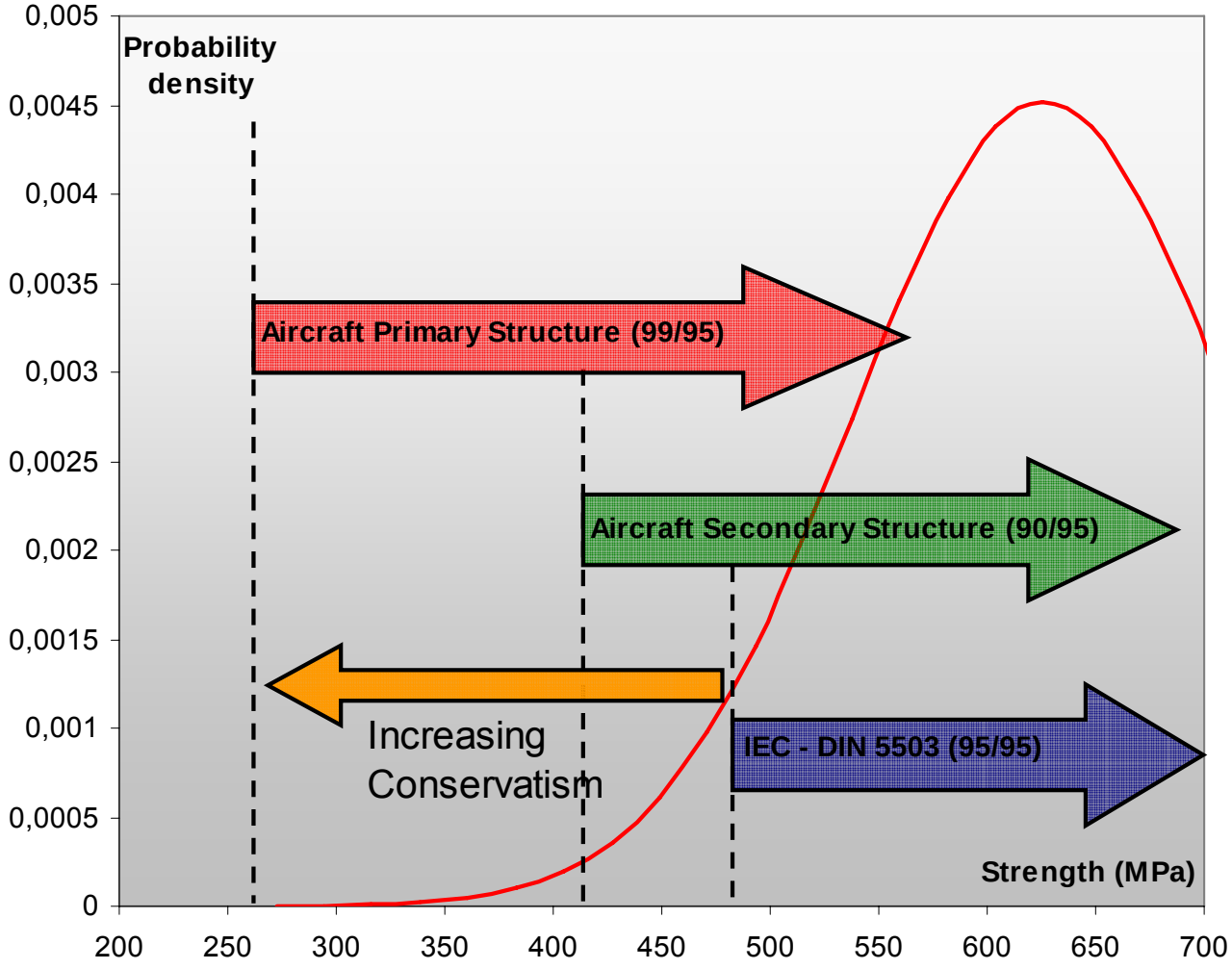
Development of characteristic strengths (f_k)



Material Qualification - Example

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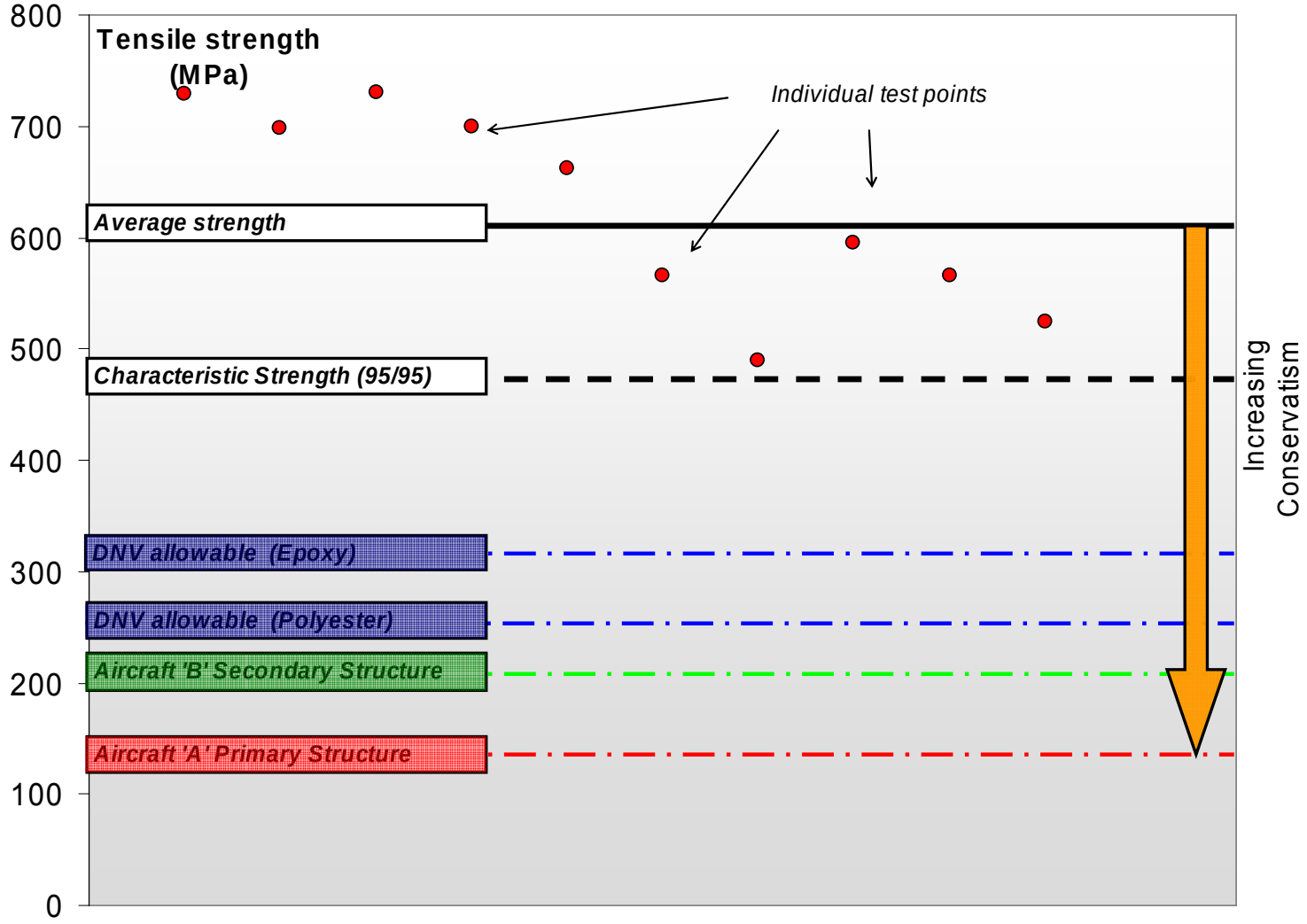
Development of design allowable strengths (f_d)



Material Qualification - Example

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Typical number of material qualification coupon tests	
Wind turbine blade	60-80
Aerospace primary structure	3000-5000

- Different environments and consequences of failure
- Aerospace requires additional testing for:
  - Extreme temperatures (-54C to +82C)
  - Moisture
  - Impact damage
  - Detail effects
- Not directly comparable, however in the ball park
- Based on DNV's experience, meets the IEC safety requirements

Design Analysis

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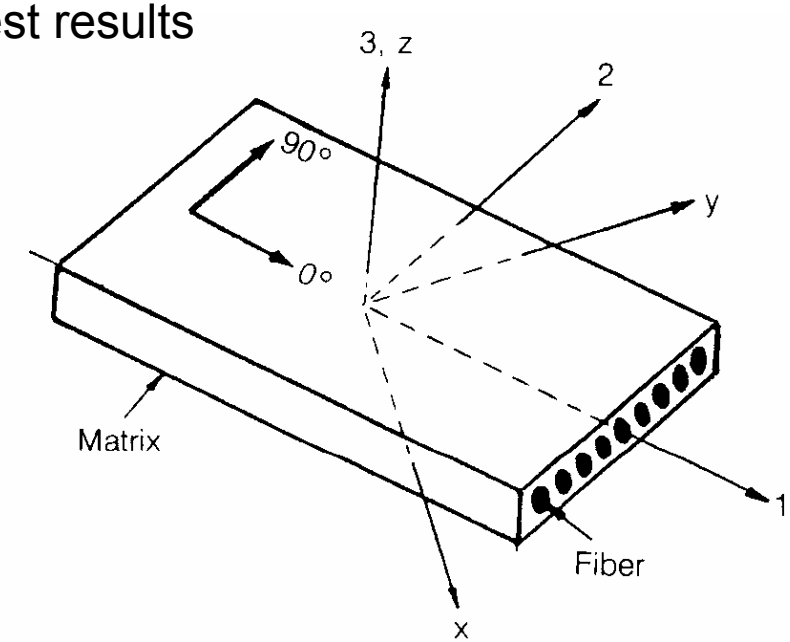
- Analysis techniques becoming more complex
- DNV seeing increased design optimisation
- As a result:
  - Complex stress analysis guidance
  - Detailed composite failure mode considerations
  - More realistic correlation of design with test results
  - Flexibility for design optimisation



Manufacturing

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DNV recognises the criticality of the manufacturing process

- The close relationship with design
- Recommended database for the control of manufacturing procedures
- Requirements for certification documentation

Static and Fatigue Type Testing

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- The right loads
- The right test specimens
- The right documentation

Photo and film courteous: Sparkær Blade Test Center, Denmark

Status of the Rules

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- Technical content is complete
- Currently undergoing industry review
- Expected release April 2006
- Working draft now available:
  - Here at conference
  - http://www.DNV.com

Conclusion

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- Wind turbines are getting larger and increasingly complex
- Design analysis complexity and optimisation increasing
- New DNV blade rules consolidates industry experience, and provides flexibility for continuous innovation
- Detailed guidance for blade designs now and for the future

www.dnv.com

OFFSHORE STANDARD
DNV-OS-J102

DESIGN AND MANUFACTURE OF WIND TURBINE BLADES

WORKING DRAFT 3 OCTOBER 2005

DET NORSKE VERITAS

Acknowledgements

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