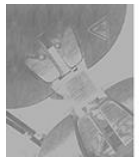


ISMEM 2017
- 2nd International Symposium on Multiscale Experimental Mechanics: Multiscale Fatigue

DTU

Understanding Fatigue of Fiber Reinforced Polymers through Hybrid Simulation and Multi-scale Testing and Modeling

ALEX R. QUINLAN

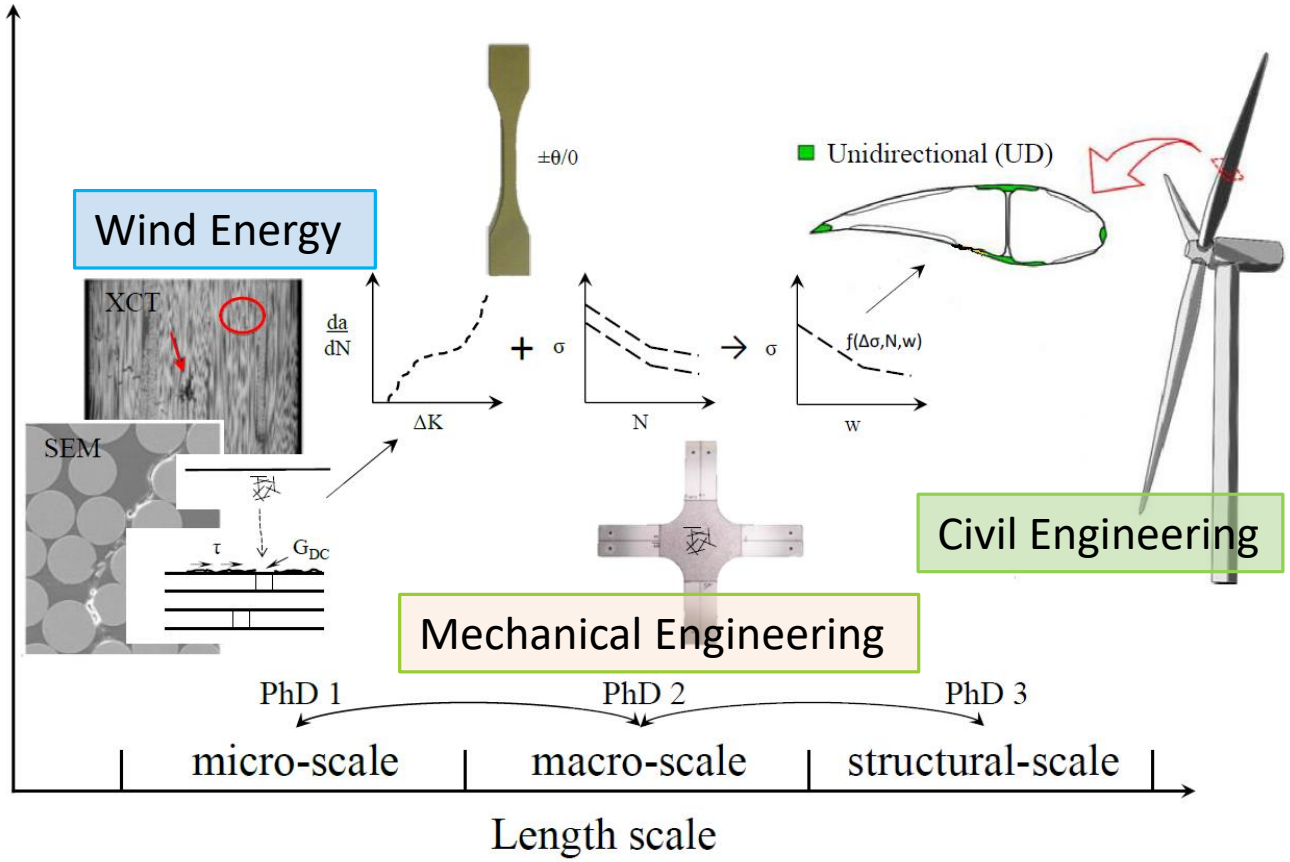
PHD CANDIDATE

DEPARTMENT OF CIVIL ENGINEERING

TECHNICAL UNIVERSITY OF DENMARK

CASMaT Initiation Project

Project Goal:
Inter-departmental collaboration



Fatigue of Fiber Reinforced Polymers

METALLIC FATIGUE LAWS

Crack initiation & growth

Stress concentrations

Isotropic

Homogeneous

FRP COMPOSITE FATIGUE

Failure Mechanisms

- Fiber-matrix interface
- Inter-ply delamination
- Micro-buckling

Fatigue Phenomena

- Stiffness degradation
- Load redistribution

Anisotropy

Project scope: Multi-axial, in-plane

Motivation for Multi-Scale

- Supplement full-scale fatigue testing
  - Long test time
  - High Cost
  - Data is specific to the structure
- Connect micro-mechanics to structural performance
- Improve design tools

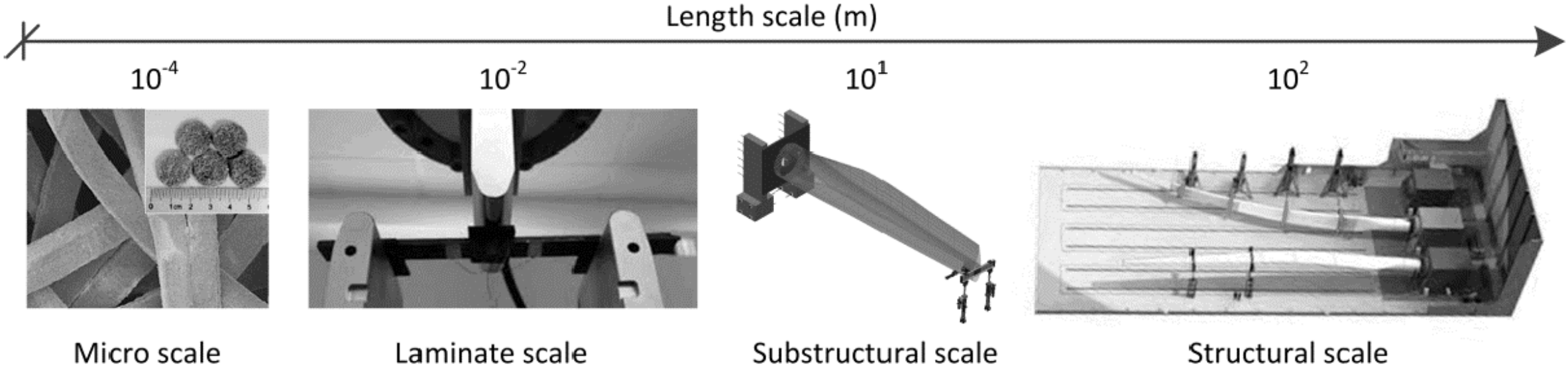


Image credit [1]

PhD 3 – Structural & Sub-Structural Scales

Structural FE models

Experimental Verification

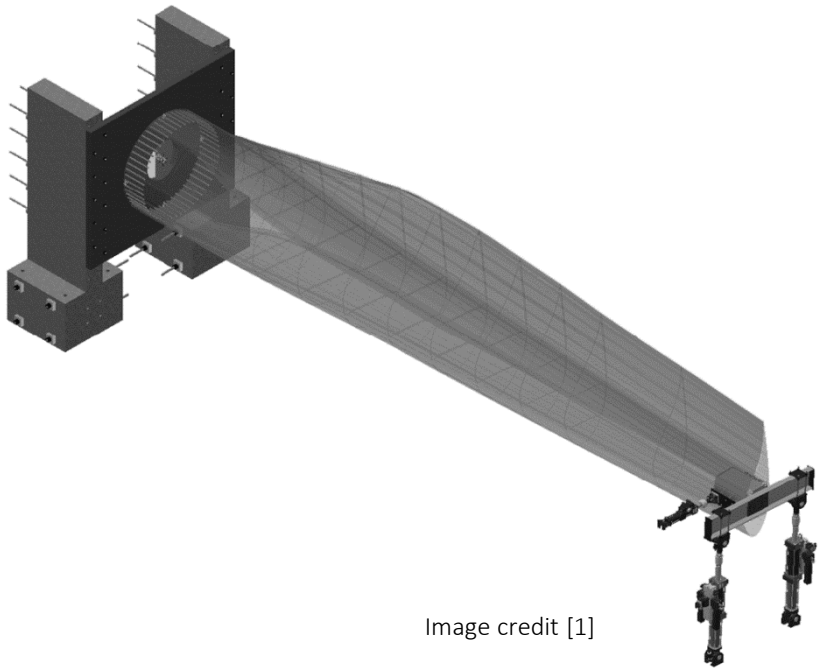


Image credit [1]

DTU Civil Engineering
- Henrik Stang – Supervisor

DTU Mechanical Engineering
- Christian Berggreen – Co-Supervisor
- Jacob Waldbjørn – Co-Supervisor

DTU Wind Energy
- Kim Branner – Co-Supervisor

Project Goal:
FE model capable of predicting fatigue life

Structures for study

T-PYLON - BYSTRUP

Image credit [2]

WIND TURBINE BLADE – BLATIGUE

RATZ, X-DOF projects; funded by EUDP

Image credit [1]

Modeling Fatigue with Finite Element Analysis

Phenomenon to be captured

- Damage accumlation
- Property degradation

Develop with simple loading and geometry

Increase complexity

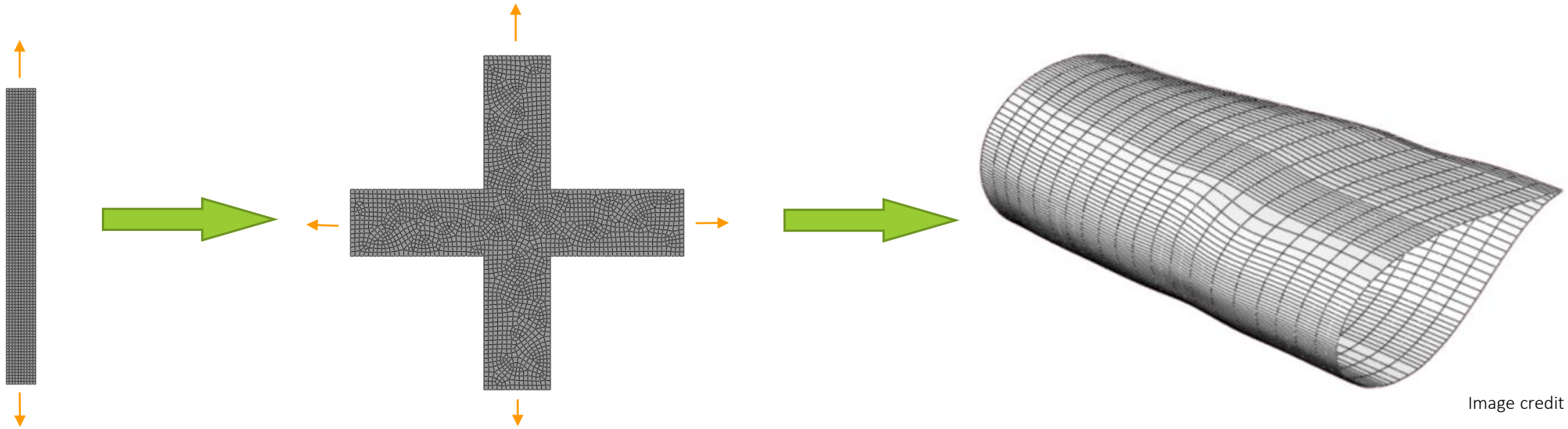
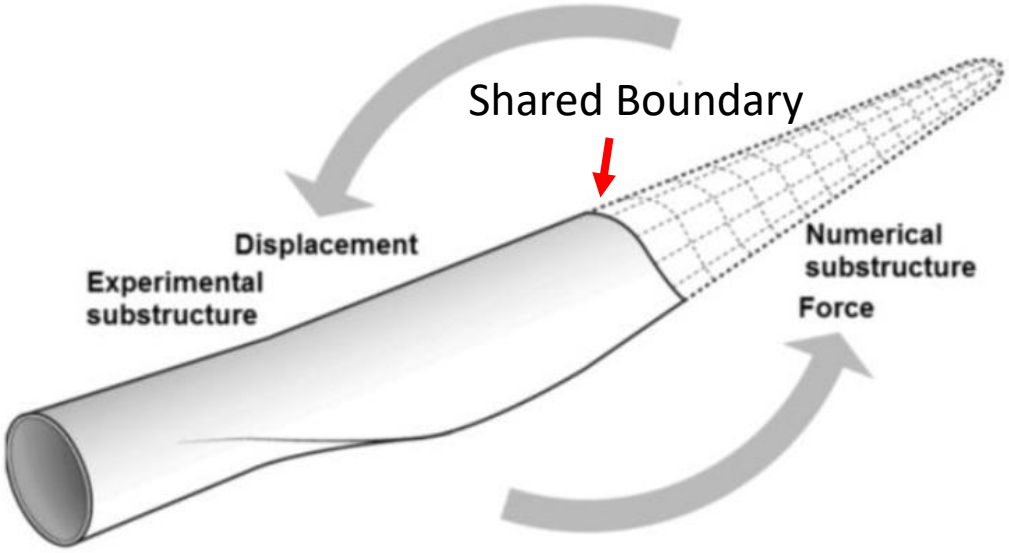


Image credit [3]

Experimental testing using hybrid simulation



Advantages

- Capture of non-linear behavior
- True response in area of interest
- Representative loading of sub-structure

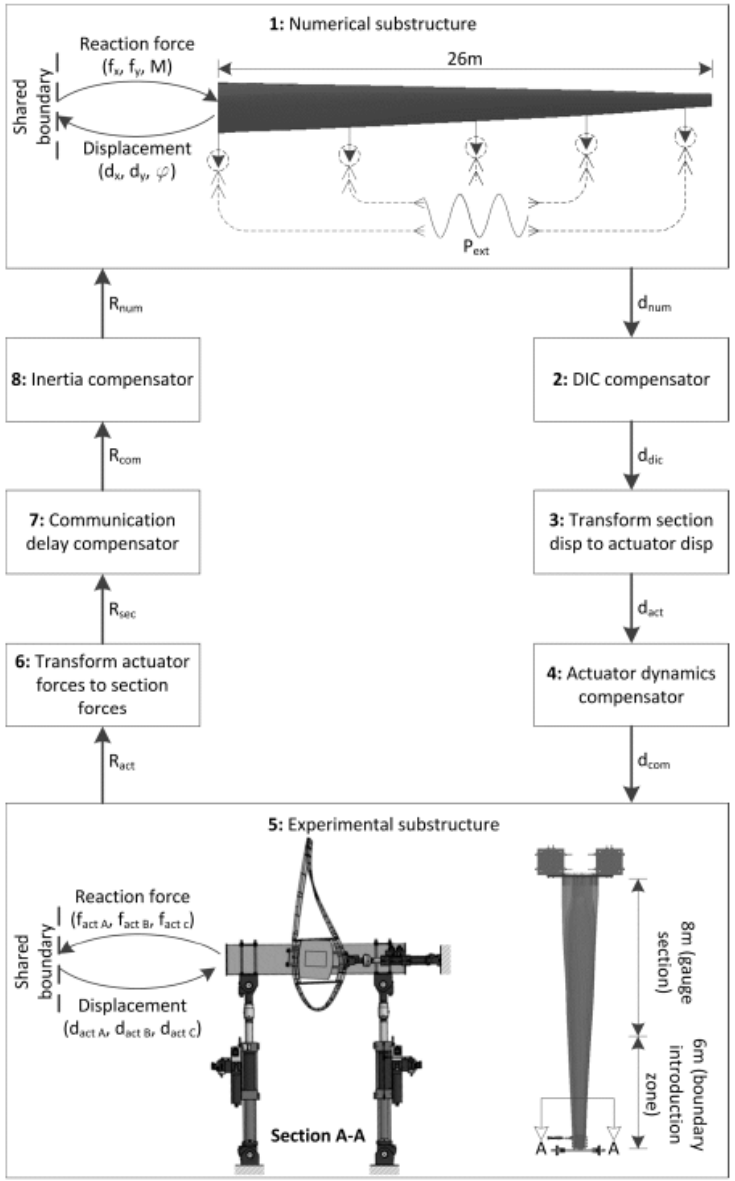


Figure 5.16: schematic block diagram representing the overall architecture for the single-component HS

Image credit [1]

Challenges in Hybrid Simulation

Multi-component -> Single-component

DIC strain monitoring

Quasi-static -> real-time

- Communication
- FE simulation speed
- Load extrapolation

Point load -> Distributed load

Project Goal:
Real-time hybrid simulation

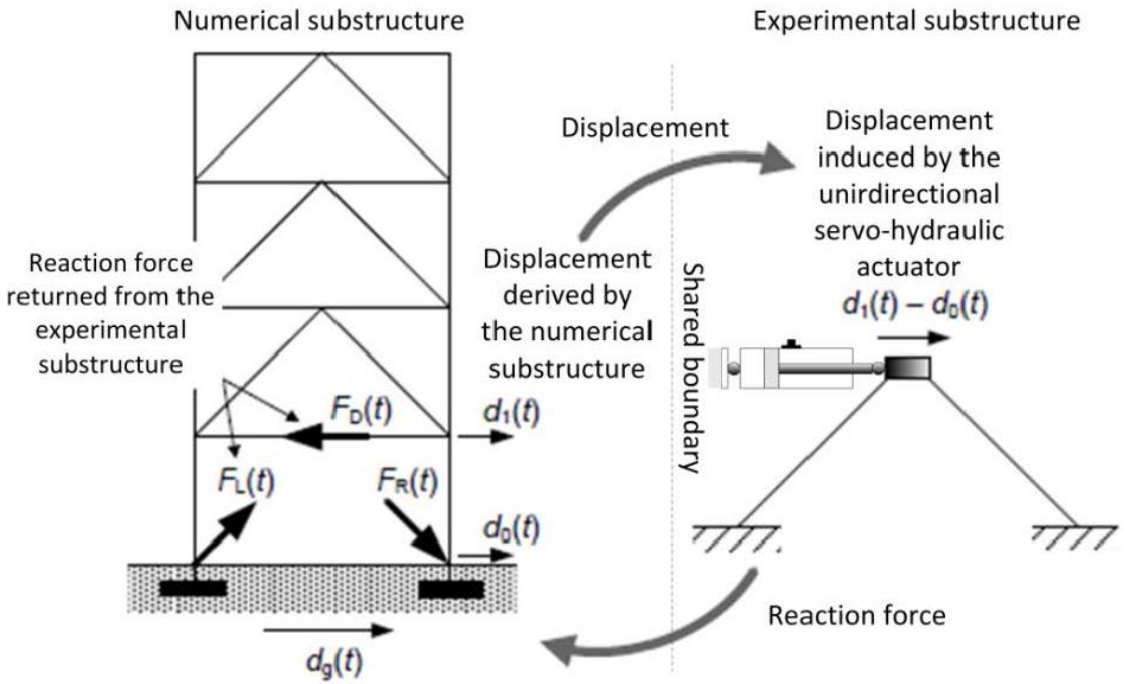
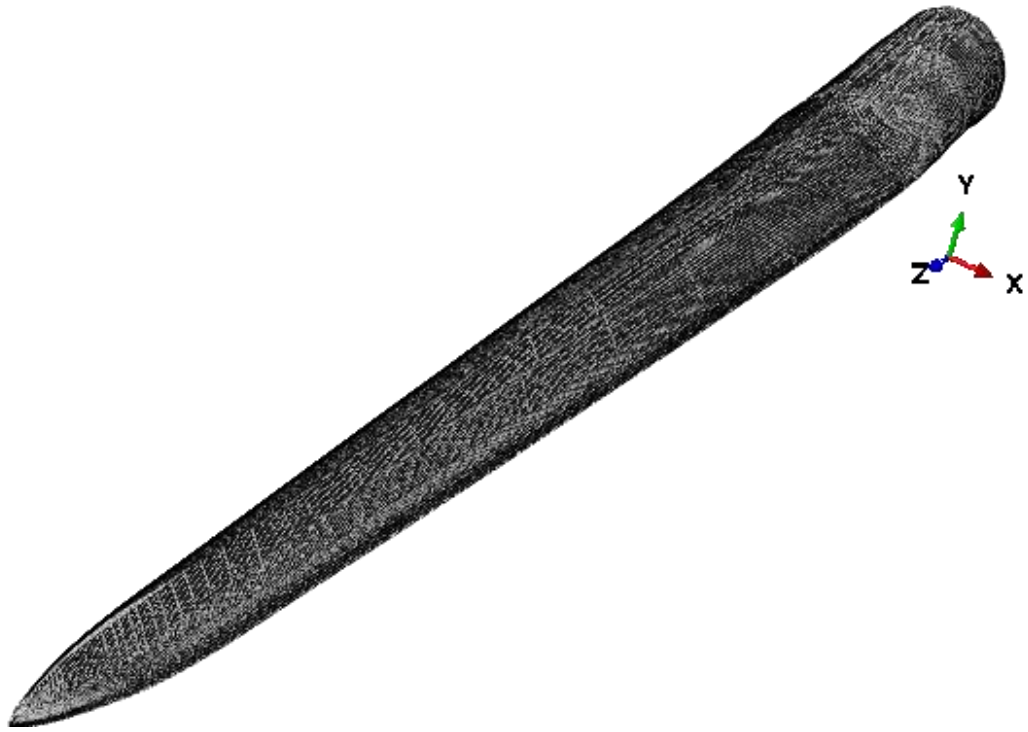


Image credit [1]

Project Objectives

1. Inter-departmental collaboration
2. Fatigue-capable FE structural model
3. Real-time hybrid simulation



Current Work

Planning uni-axial load tests
- Specimen geometry
- Laminate layups
- Loading values for fatigue tests

Developing FE model of uniaxial coupon
- Element selection
- Mesh convergance
- Fatigue modeling approach

Defining our parameters of interest
- Crack density
- Stiffness degradation

Preparation of hybrid simulation rig

References

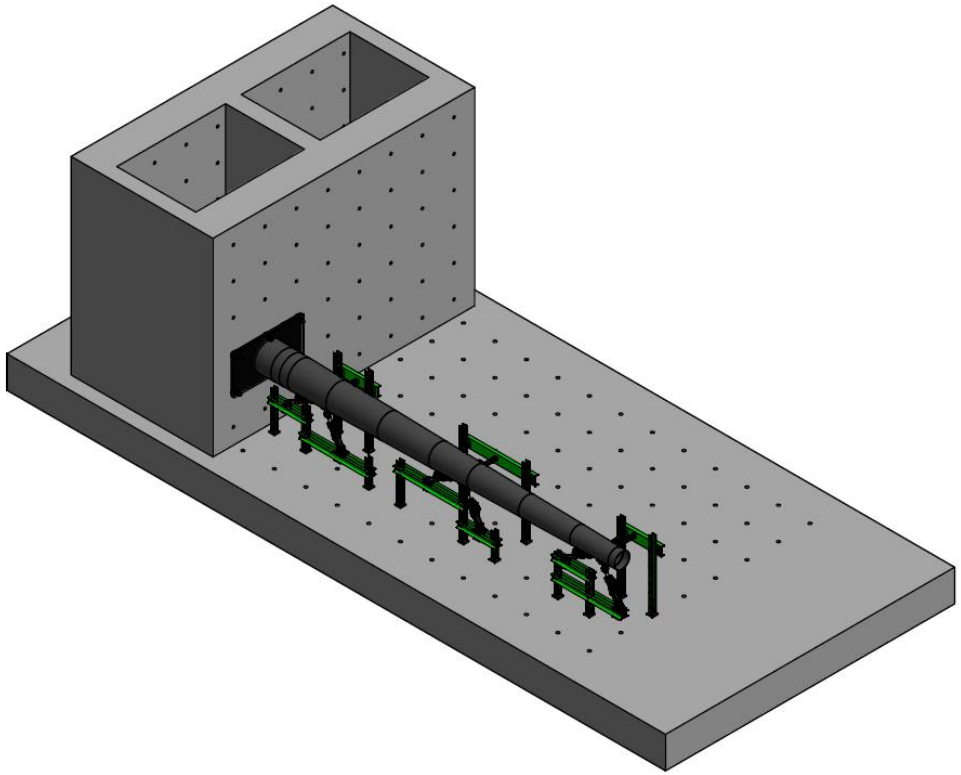
1. Waldbjørn, Jacob (2016) *Hybrid Simulation of Wind Turbine Blades*. (PhD Thesis, DTU Civil Engineering)
2. Image from Bystrup Website. http://www.powerpylons.com/composite-pylon-369813. Accessed Nov 7, 2017
3. Quinlan, Alex (2013). BroncoBlade: An Open Source Wind Turbine Blade Analysis Tool. (Master's Thesis, Western Michigan University, Mechanical & Aeronautical Engineering)

Acknowledgements

CASMaT
Villum Center for Advanced Structural and Material Testing

VILLUM FONDEN

T-Pylon



12m

Loads applied at 3 points, in 3 directions

Geometry is a tapered cylinder

The material laminate is consistant throughout the structure

Mounted to the new strongwall

Wind Turbine Blade

Current load setup

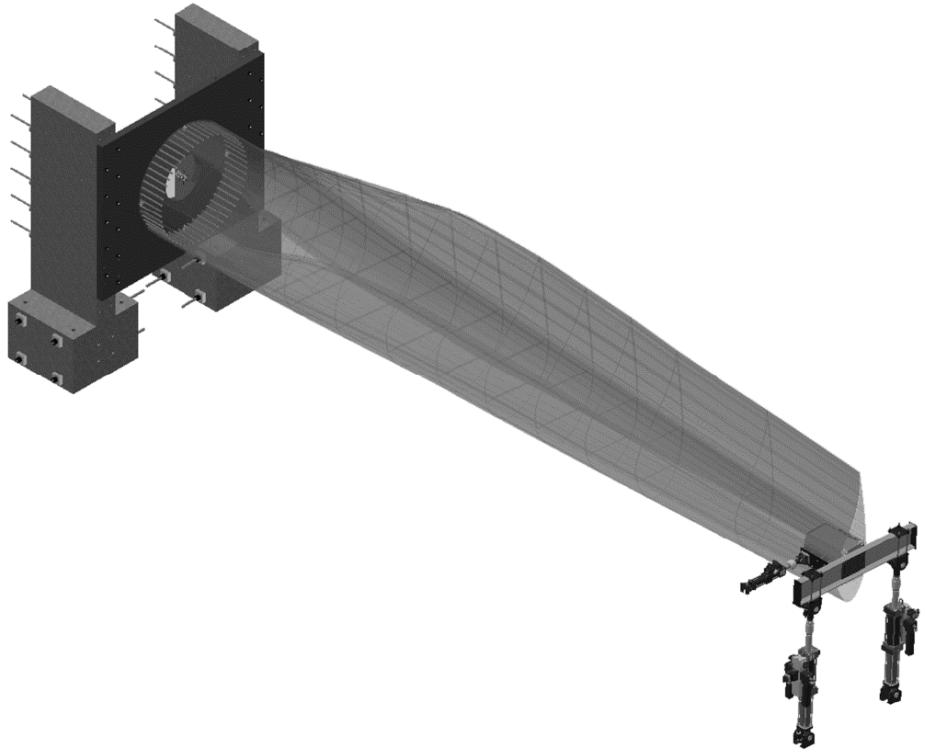
- X and Y displacement
- Rotation about Z-axis

Increased geometric complexity

Material changes throughout

- Variable properties
- Ply drops

Image



Hybrid Simulation Development Rig