A novel single actuator test setup for combined loading of wind turbine rotor blade sub-components

2nd International Symposium on Multiscale Experimental Mechanics
ISMEM 2017
Lyngby Campus, Denmark, Nov 8-9, 2017

QUALITY SYSTEM CERTIFICATION
DNV·GL
ISO 9001

Malo Rosemeier, Moritz Bätge
and Alexandros Antoniou

Fraunhofer
IWES

Content

- Application scenarios for sub-component blade testing
- Sub-component test setup
- Inboard vs. outboard cross-section
- Summary
- Conclusions

Application scenarios for sub-component testing

Scenario A

- Blade type has been certified and is operating in a wind farm
- A critical sub-component was identified during operation and requires a retro-fit
- Sub-component testing can help to validate design variants of such a retro-fit

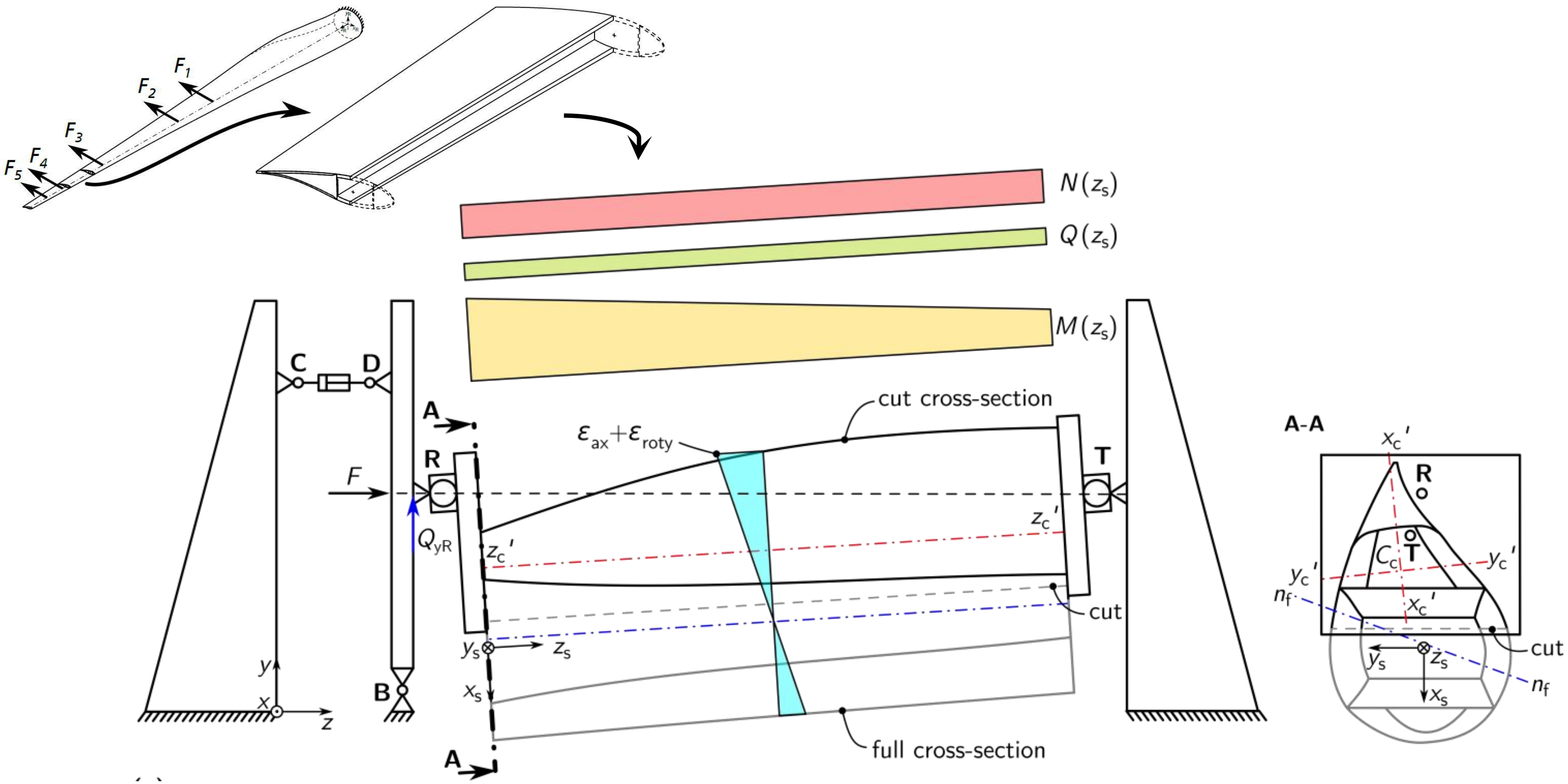
Scenario B

- A sub-component of a new blade design model shows critical deformation effects in fatigue under combined loading
- A resonant fatigue full-scale test may not be able to replicate this combined loading [4].
- Sub-component testing can help to validate design models under such combined load cases

[4] Rosemeier, M., Basters, G., and Antoniou, A.: Benefits of sub-component over full-scale blade testing elaborated on trailing edge bond line design validation, Wind Energy Science Discussions, DOI: 10.5194/wes-2017-35, 2017.

Test setup

From Full-Scale Rotor Blade to Blade Sub-Component



- Rigid body motion constrained by gravity
- What are the scaling design drivers of the setup?

Fraunhofer IWES

Test setup

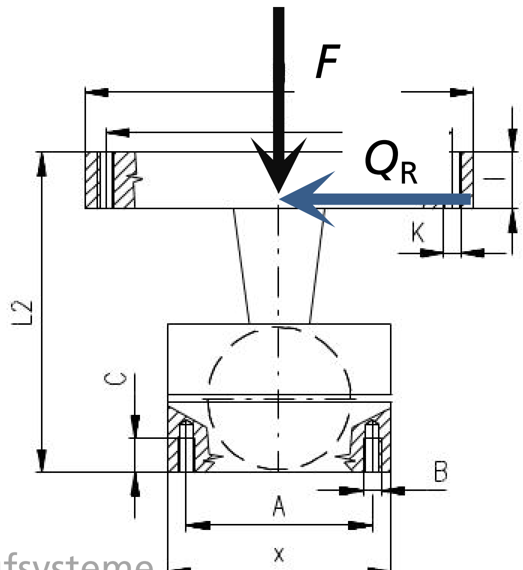
Ball joint as design critical component

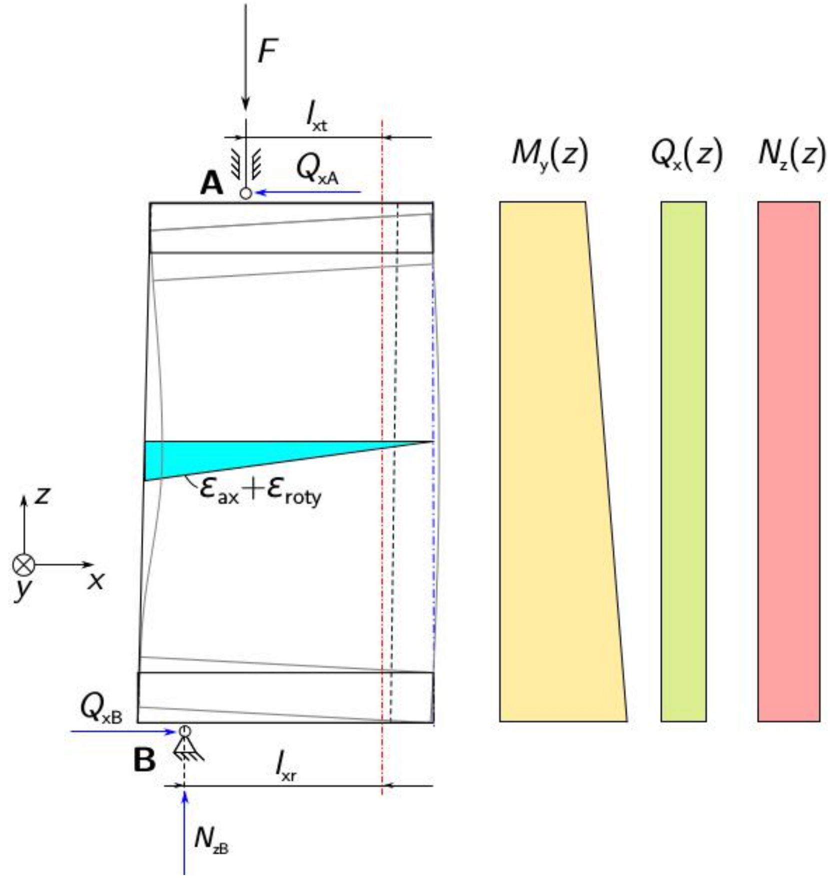
- Shear force is defined by

$$Q_R = \frac{l_r - l_t}{L} \cdot F \ ,$$

  where L denotes the specimen length.
- Q_R introduces critical bending moment.

INOVA Prüfsysteme



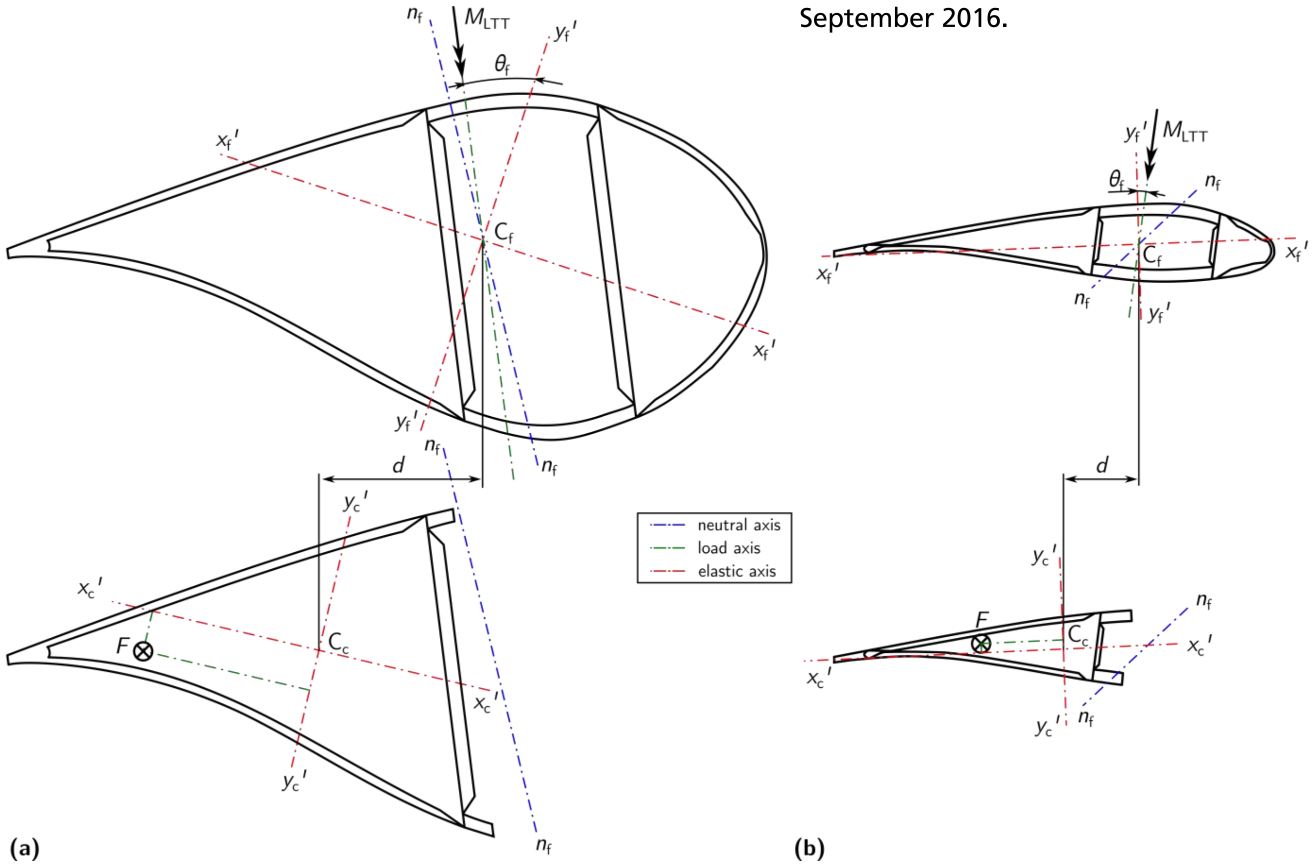


Fraunhofer IWES

Inboard vs. outboard SCT

[1] Rosemeier, M., Massart, P., and Antoniou, A.: Tailoring the design of a trailing edge sub- component test, https://doi.org/10.5281/zenodo.153837, presented at 3rd annual IRPWind conference in Amsterdam, the Netherlands, 19-20th September 2016.

Structural and geometric properties

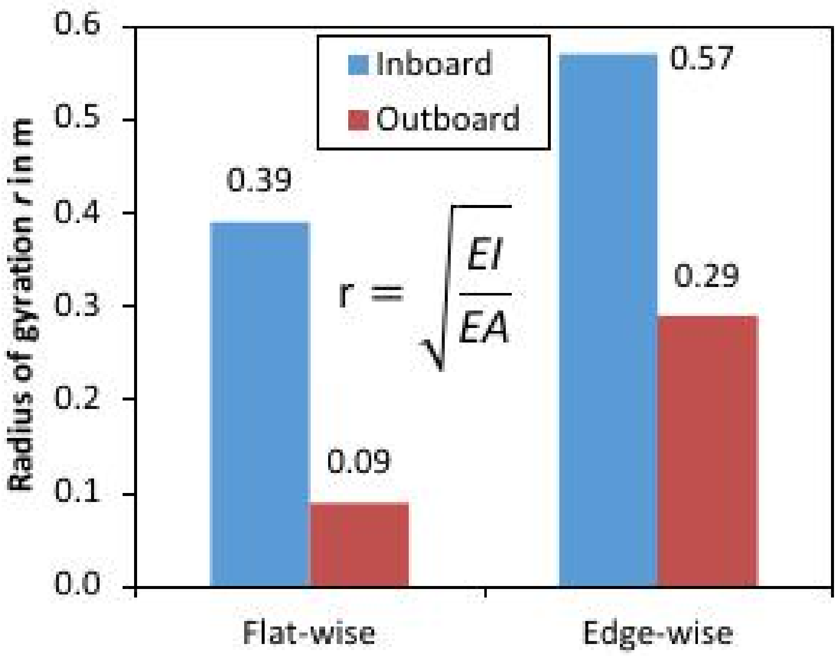


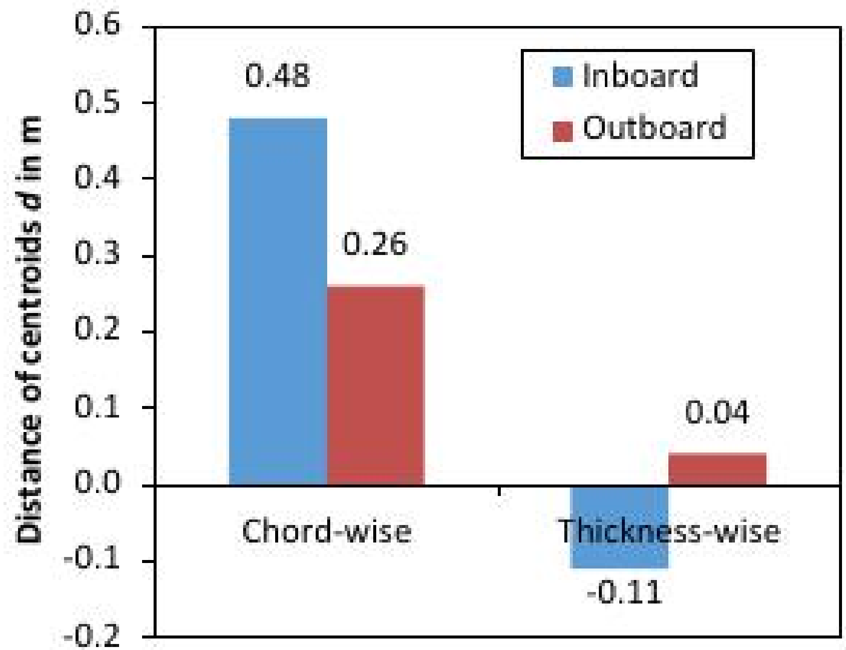
- Larger flat-wise stiffness contribution inboards due to larger θ

Fraunhofer IWES

Inboard vs. outboard SCT

Stiffness ratios and distance of centroids



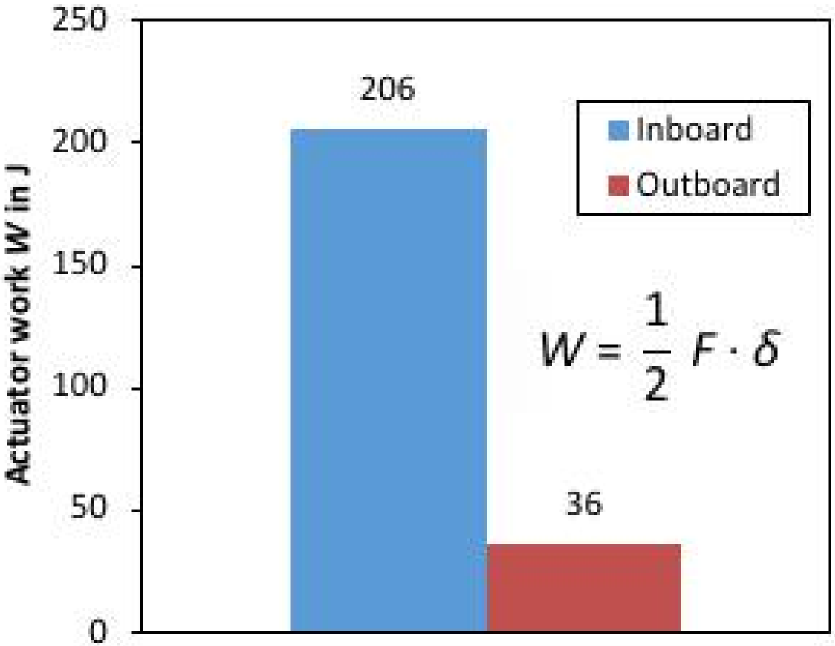


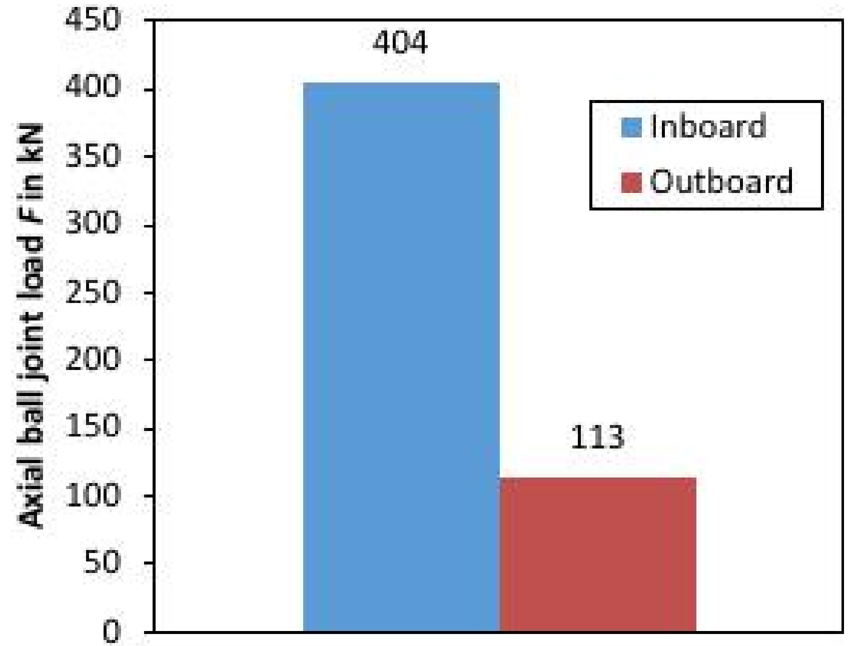
- The magnitude of the axial force *F* is influenced by radius of gyration *r* and distance *d* between centroids between full and cut cross-section.

Fraunhofer IWES

Inboard vs. outboard SCT

Actuator work and axial ball joint load



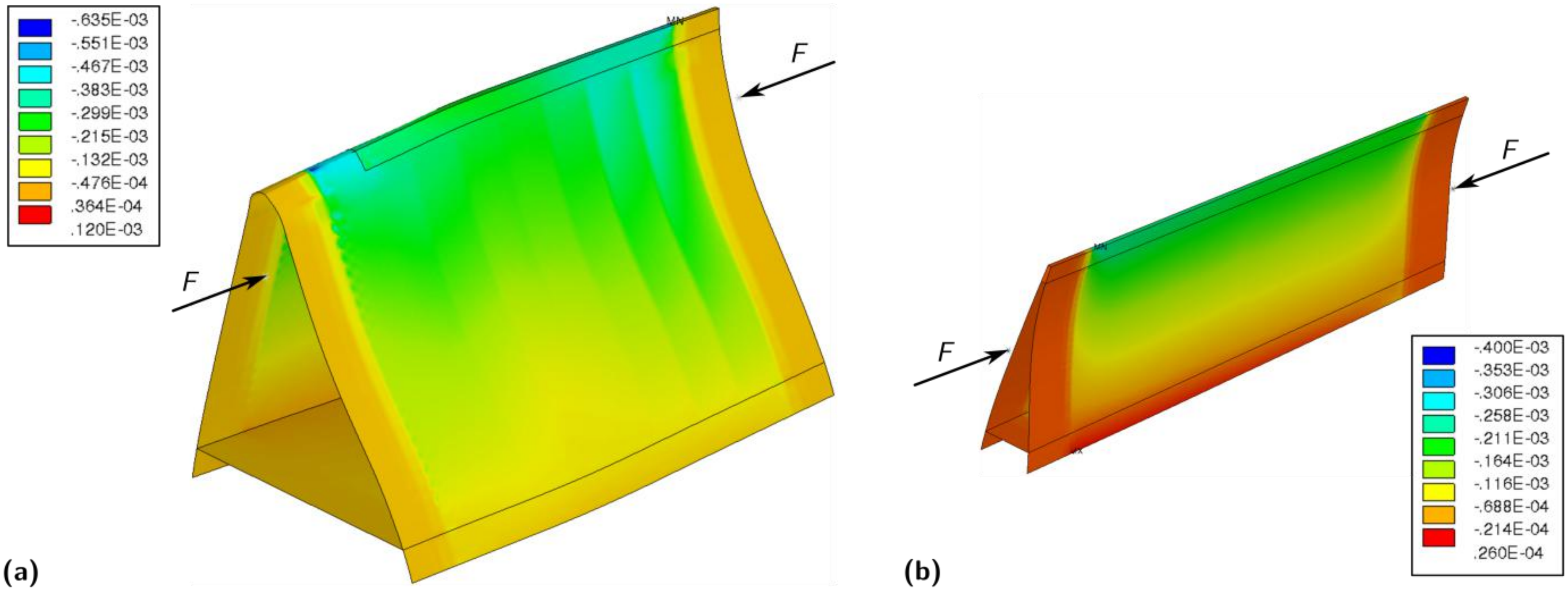


- Actuator work *W* is larger by a factor of 5.8.
- Contribution of F to *W* is more prominent than displacement;
  F is larger by a factor of 3.6, 62% compared to δ.

Fraunhofer IWES

Inboard vs. outboard SCT

Longitudinal strain response

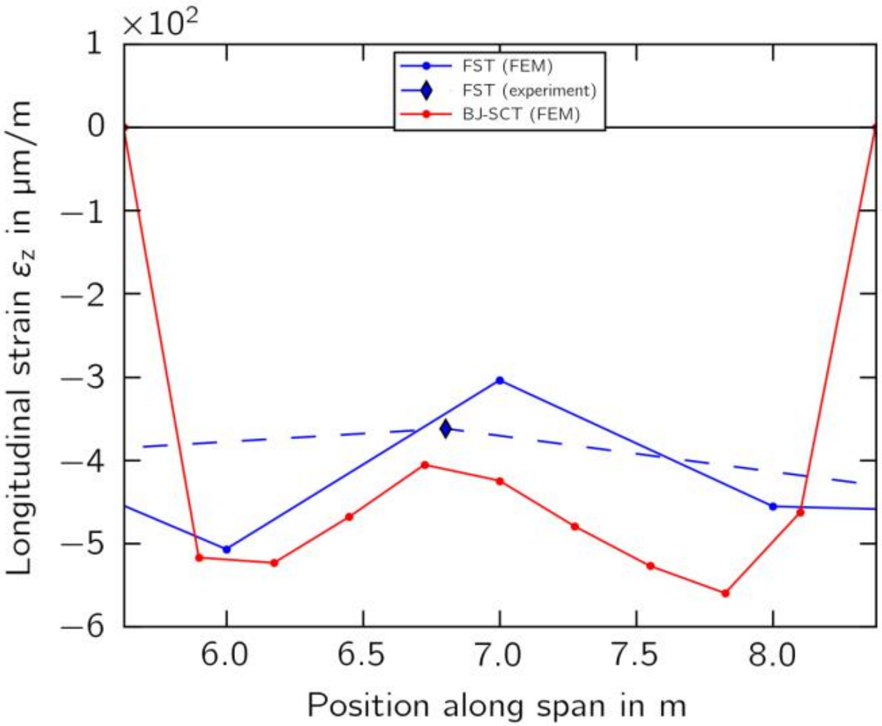


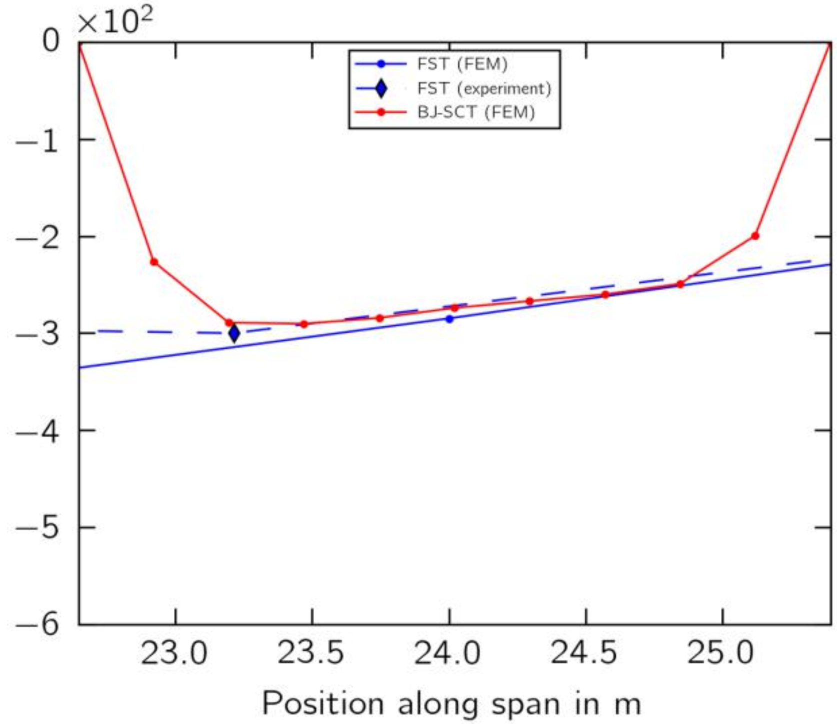
(a) (b)

- Target strain is irregular along specimen for inboard due to more prominent geometric and structural changes
- Outboard component is rather a prismatic extrusion

Inboard vs. outboard SCT

Longitudinal strain along trailing edge

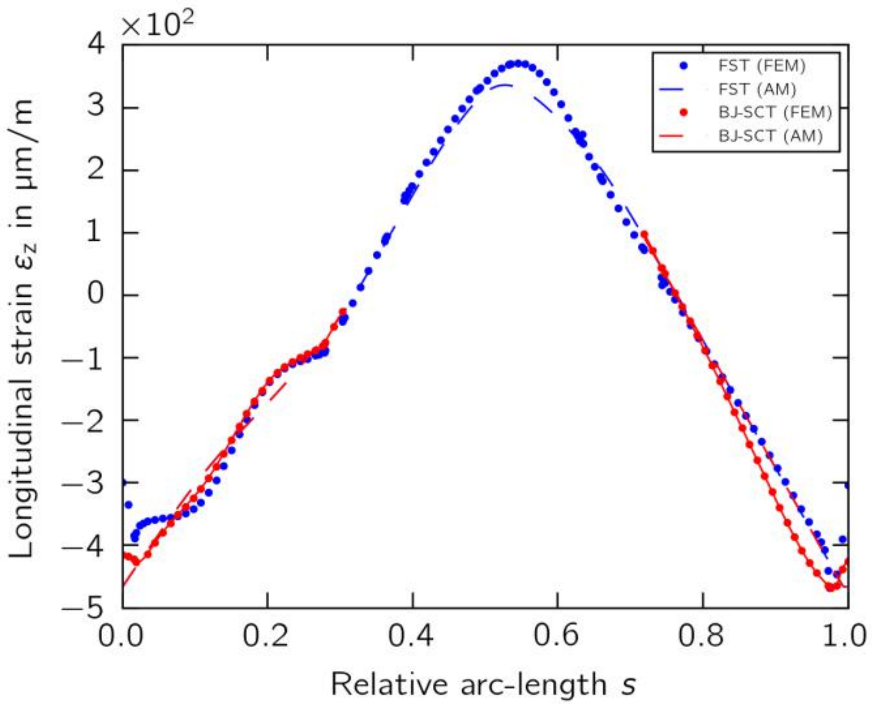


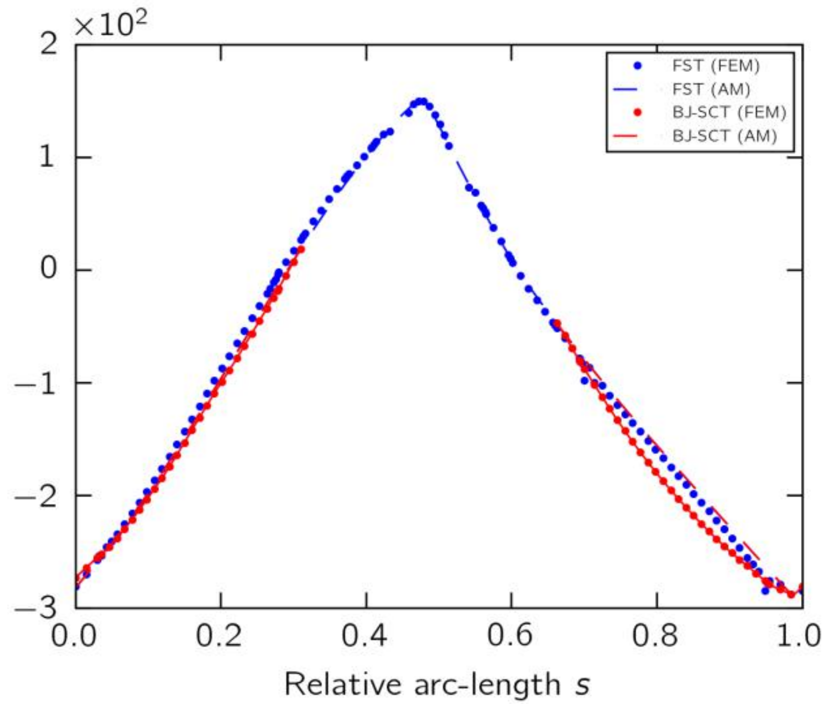


- Target strain is irregular along specimen for inboard due to more prominent geometric and structural changes
- Outboard component is rather a prismatic extrusion

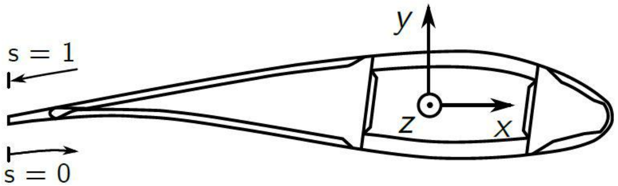
Inboard vs. outboard SCT

Longitudinal strain along blade surface of target cross-section





- Analytical model fits better for outboard component.



Fraunhofer
IWES

Summary

- Scalibility of novel sub-component test setup addressed
- Ball joint identified as design driving component
- Force F is disproportionally larger contributing to inboard's actuator work than displacement; however, displacement dominated work would be more favorable
- F depends on:
  - inclination angle θ between load axis and elastic axis
  - ratio between bending and axial stiffness expressed by radius of gyration
  - distance between centroids

Fraunhofer
IWES

Conclusions

- Shear force Q_R can be eliminated by specimen tilt
- Rigid body motion can be constrained by horizontal orientation
- Axial load F can be minimized by
  - reducing the distance between the full and cut cross-section centroids
  - while keeping the radii of gyration low
- Can be realized by
  - reasonable span-wise cut
  - or addition of material or springs in parallel to specimen

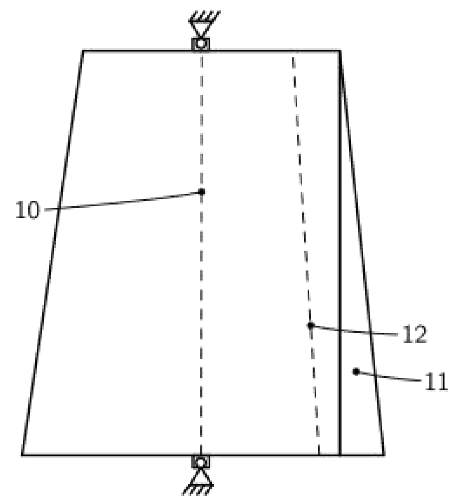


FIG. 5

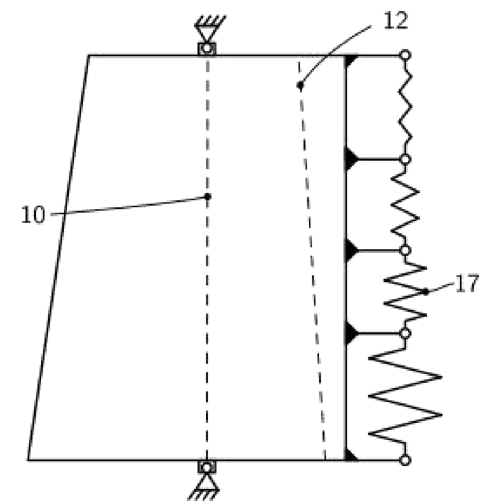


FIG. 6

Thank You For Your Attention

Any questions?

malo.rosemeier@iwes.fraunhofer.de

Acknowledgements
Fraunhofer IWES is funded by the:

Federal Republic of Germany

Federal Ministry for Economic Affairs and Energy

Federal Ministry of Education and Research

European Regional Development Fund (ERDF):

Federal State of Bremen

- Senator of Civil Engineering, Environment and Transportation
- Senator of Economy, Labor and Ports
- Senator of Science, Health and Consumer Protection
- Bremerhavener Gesellschaft für Investitions-Förderung und Stadtentwicklung GmbH

Federal State of Lower Saxony

Federal Ministry for Economic Affairs and Energy

Federal Ministry of Education and Research

European Union
Investing in Bremen's Future
European Regional Development Fund

FUNDED BY EFRE

Bremen Bremerhaven

Europa fördert Niedersachsen

Lower Saxony

Fraunhofer IWES