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Tailoring the design of a trailing edge sub-component test

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Objective

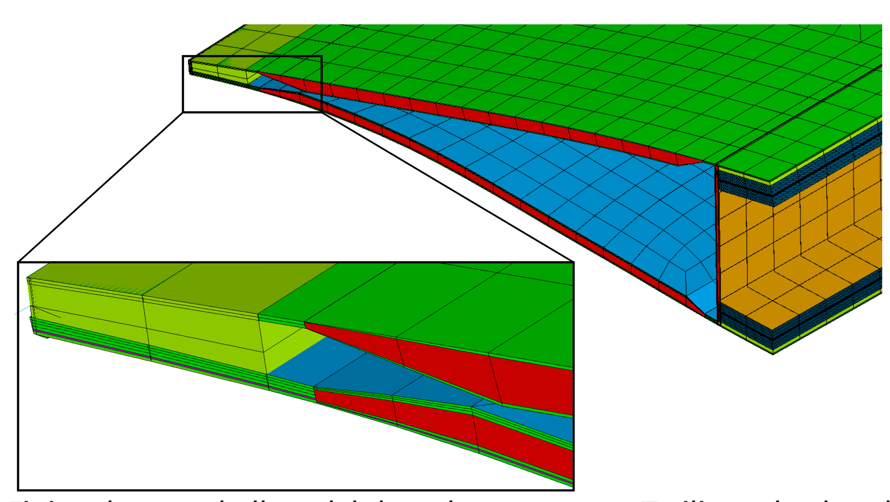
The sub-component test should replicate the lead-lag full-scale rotor blade certification test such that the structural static and fatigue responses of the trailing edge are matched.

Introduction

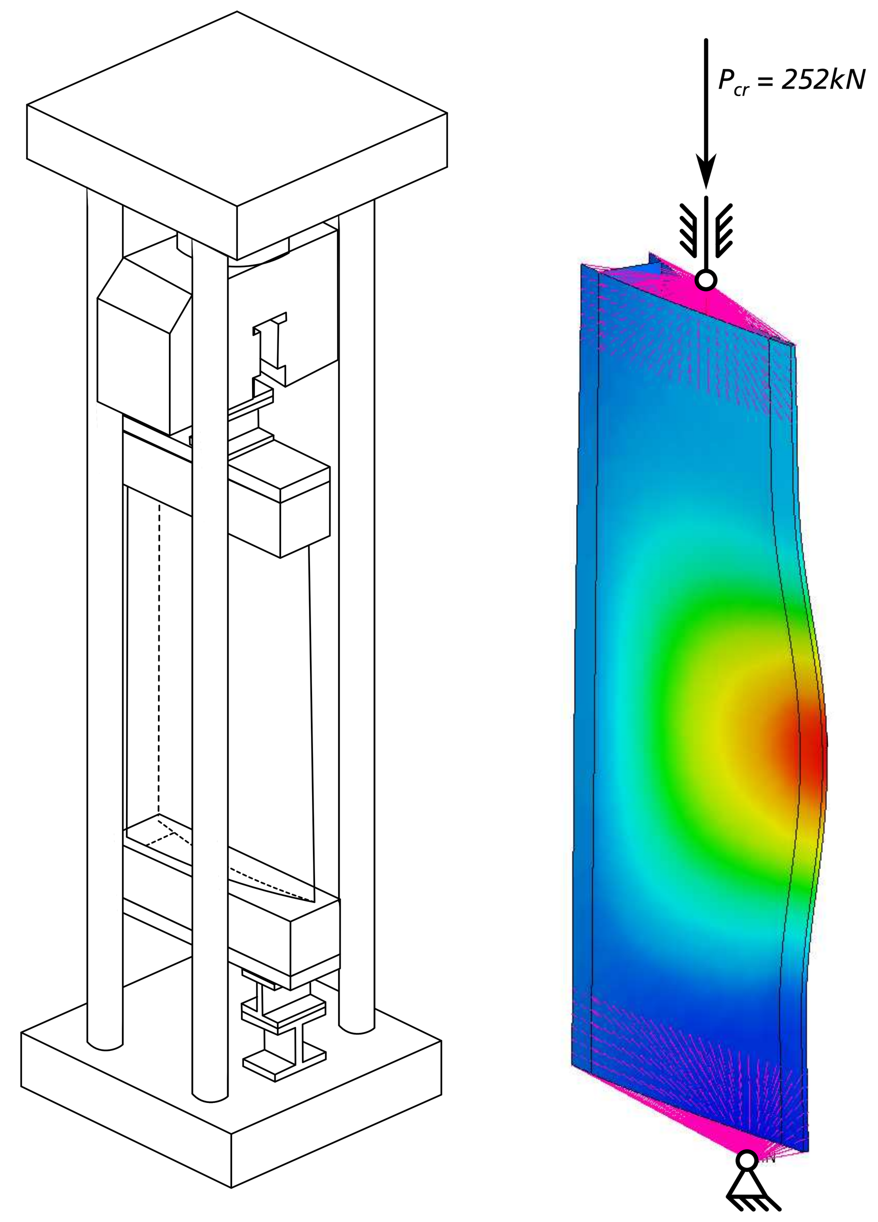
The development and operating costs of a test setup can be minimized by using a ready-to-use and calibrated testing environment. Therefore, an innovative sub-component testing method is proposed, tailored to a universal, uniaxial, hydraulic testing machine. To keep the energy consumption low, a blade segment is reduced to its area of interest, i. e. the trailing edge, which in turn decreases the specimen stiffnesses and thus the required test loads to achieve a certain strain level.
The challenge lies in the design of the test to replicate the structural response of a 34 m blade certification test within the available mounting space of the machine.

Models

Both analytical and numerical models were used to design the test setup. The BEam Cross-section Analysis Software BECAS was used to determine the cross-sectional properties such as bending stiffnesses EI_x and EI_y and axial stiffness AE, as well as the elastic center and principal bending axes. The blade was modeled using FEPROC, a Python based wrapper for ANSYS APDL. Geometrically non-linear finite element simulations of the full-scale blade certification test and the sub-component test were then performed. Numerical results were verified with the corresponding experimental data.



Finite element shell model the sub-component. Trailing edge bond line modeled using solid elements. Shells are shown extruded.



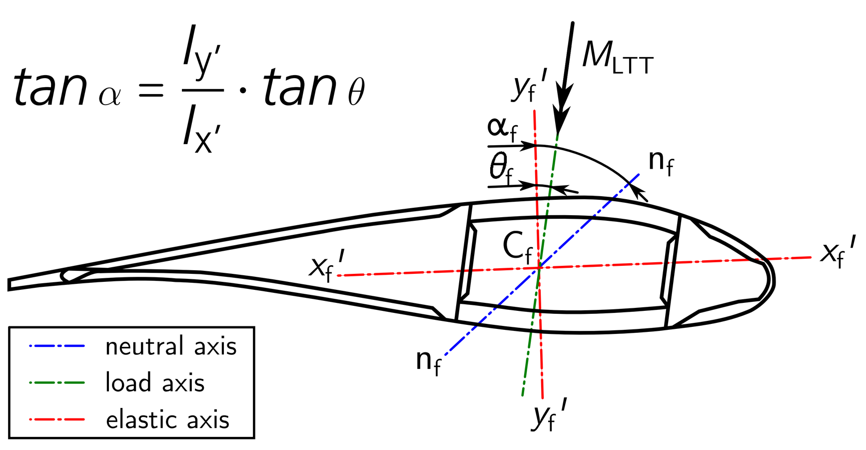
Trailing edge mounted into a universal, uniaxial hydraulic testing machine (left). Geometrically non-linear static deformation at buckling load (right).

Design steps

The cross-section of interest was cut to reduce the stiffness and dimensions of the specimen allowing for lower loads and displacements during static and fatigue testing.

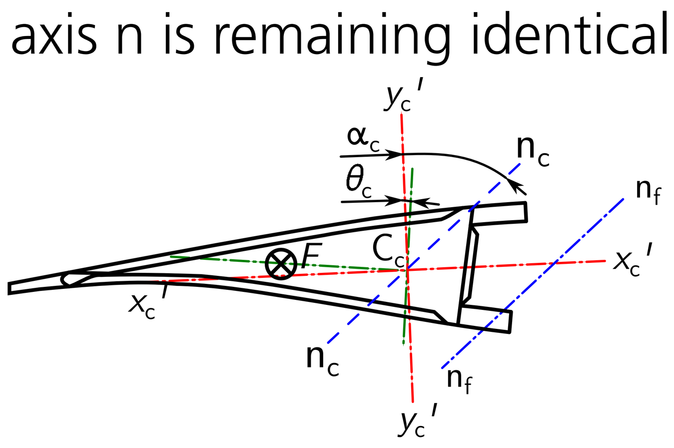
- In the full-scale test configuration the elastic center C_f, the inclination angle between the elastic and the neutral axis α_f as well as the inclination angle between the elastic and the load axis θ_f of the full cross-section are determined using the relation:

$$\tan \alpha = \frac{I_{y'}}{I_{x'}} \cdot \tan \theta$$

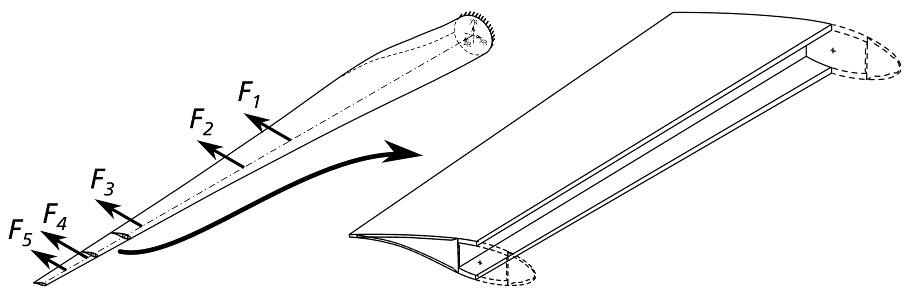


Properties of the full cross-section.

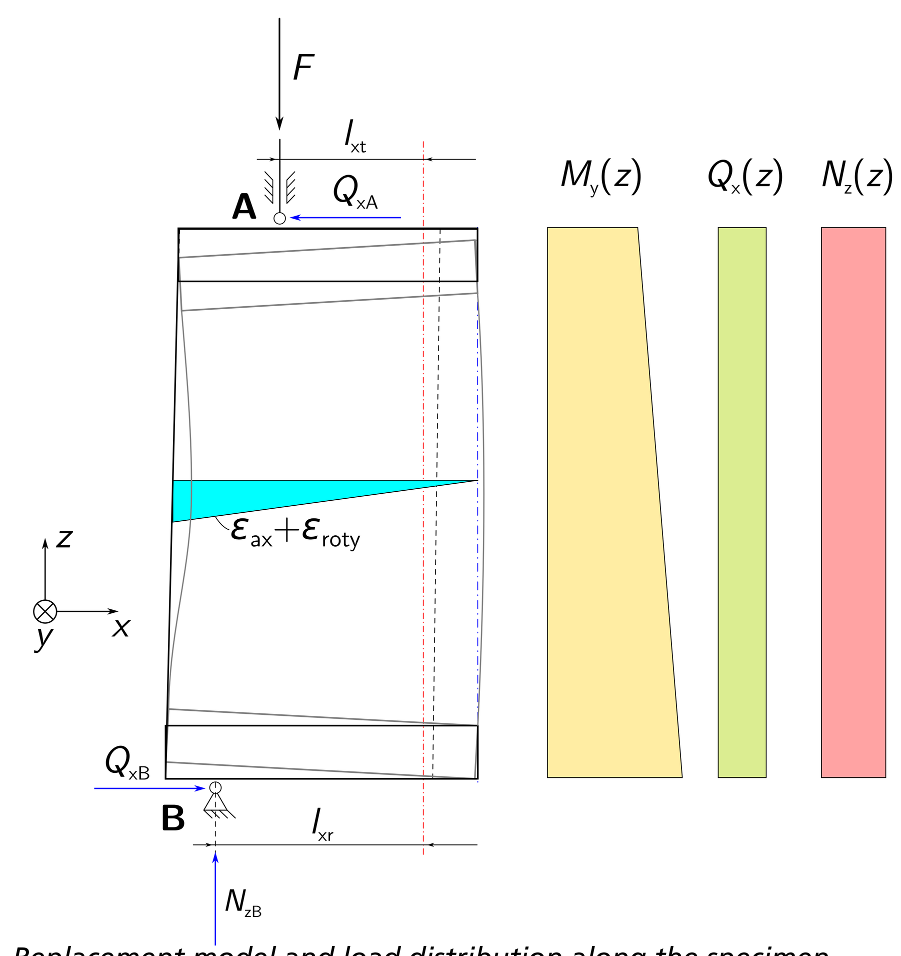
- The full cross-section is cut and the new elastic C_c and angle α_c are determined.
- The required inclination angle of the load axis θ_c and the load introduction point F are determined such that in both cut and full cross-sections the neutral axis n is remaining identical:



Properties of the cut cross-section.



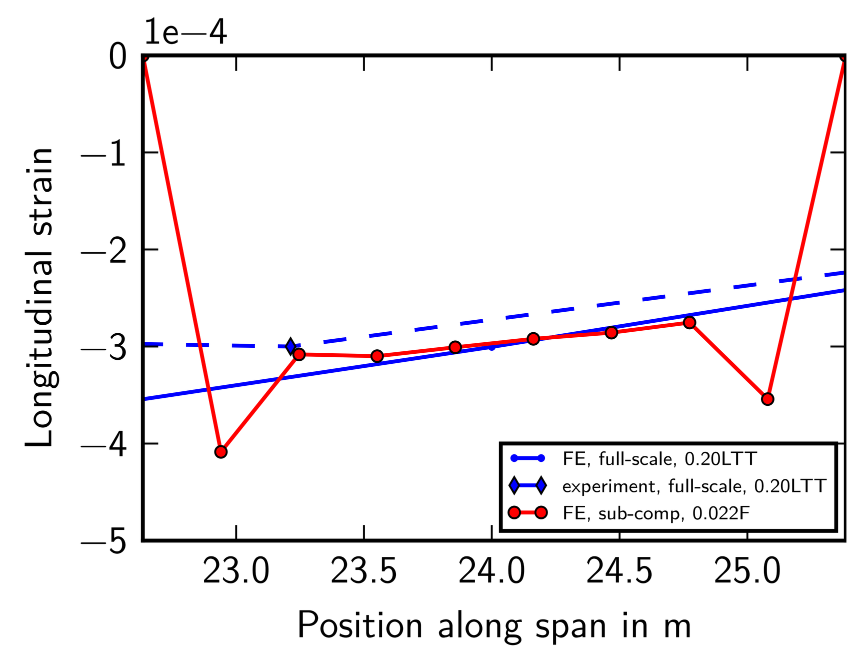
Full-scale blade under lead-lag test load case and cut out trailing edge sub-component.



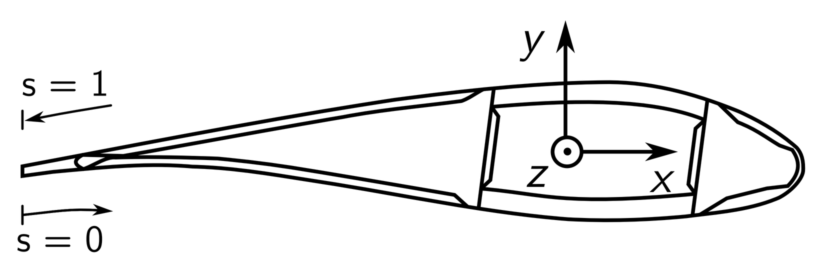
Replacement model and load distribution along the specimen.

Results

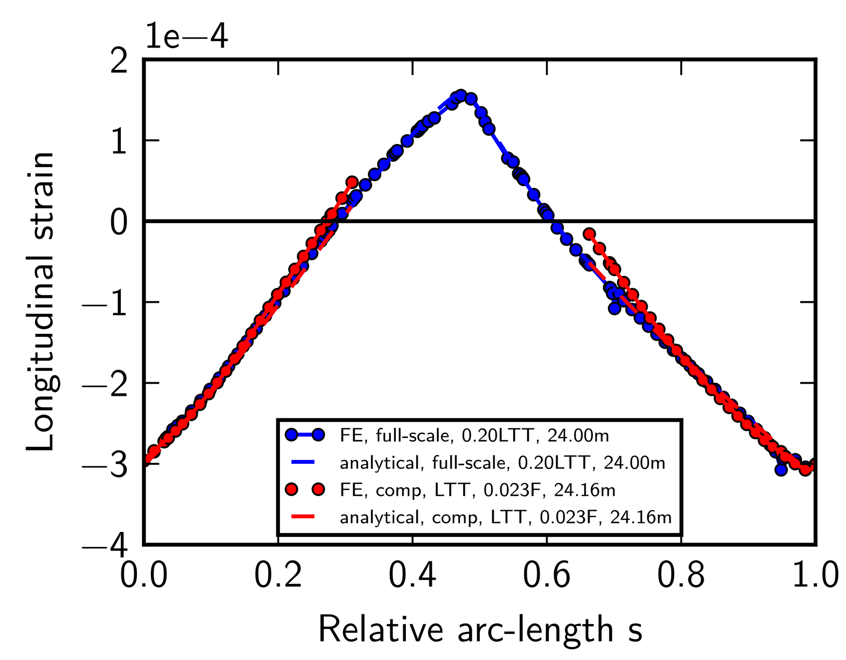
The strain comparison between full-scale blade and sub-component setup shows a good agreement. The numerical model's strain response over the cross-section, however, shows slight deviations on the pressure and suction side of the trailing edge panels.This discrepancy might be caused by inaccuracies in the numerical model.



Strain at the trailing edge along the length of the specimen.



Definition of relative arc-length s around the surface.



Strain along the surface at the middle cross-section of he specimen.