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Design and Analysis of Equipment for Load Introduction during Full Scale Blade Testing

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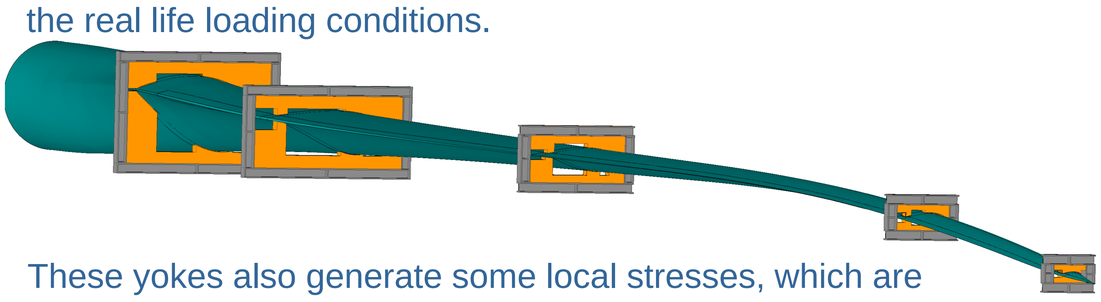
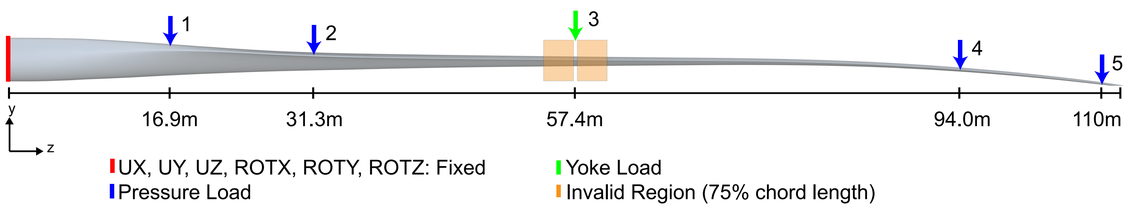
1. Wind Turbine Blade Testing

A full scale test is an important part in the design process of a wind turbine blade. The current setup for these tests uses wooden yokes that follow the profile of the blade to pull the blade down, to simulate the real life loading conditions.



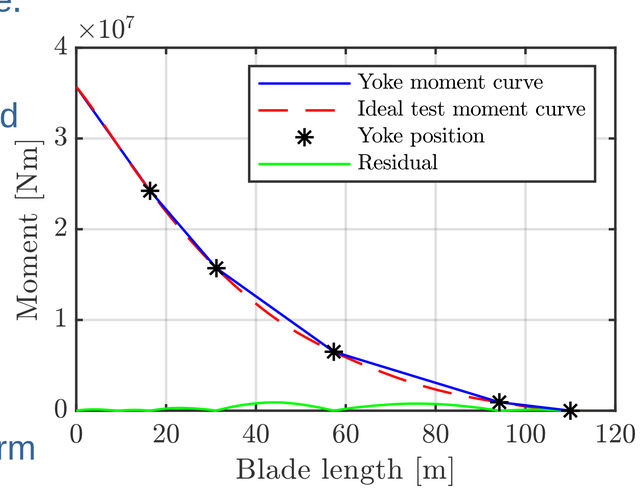
These yokes also generate some local stresses, which are assumed to invalidate an area with a width of about 75% of the chord length at that section for mounting any sensors. The goal of this project is to evaluate the local effects produced by the yoke load and devise a way of minimizing them.

2. Loading



During a full scale test, the applied loads are determined based on ideal moment curves. In a full scale multi-point test, the loads are applied in discrete points along the blade. As the yokes introduce an undesirable effect, it is desired to apply as few yokes as possible, while approximating the moment curve as well as possible and not causing any failure in the blade.

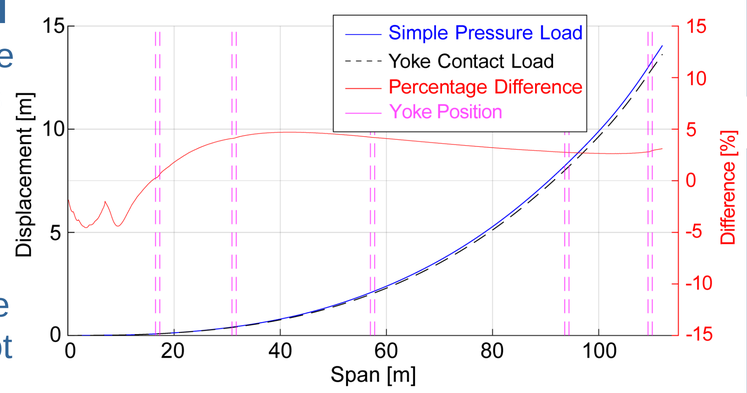
The optimal yoke positions along the blade are determined based on a optimization problem, where all loading directions are considered.
The optimization problem is evaluated by minimising the sum of residuals between the yoke moment curve and the ideal moment curve, in a p-norm function.
The loading positions that were found in this optimization problem are used throughout this study.



3. Results

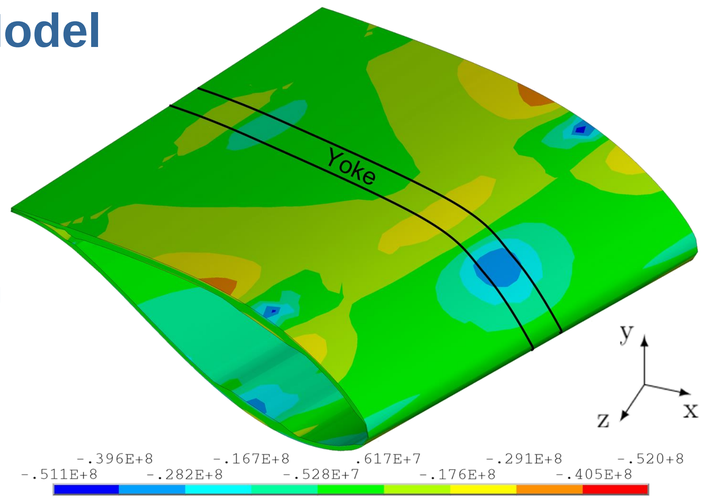
Full Shell Model

A model of the full blade made of shell elements is used to simulate the global behaviour of the blade to study the stiffening effect of applying the yokes. The blade is fixed at the root and the yokes are placed at all five load introduction points. The results show only minor stiffening of blade, with a change in displacement of around 2-5%.



Refined Blade Model

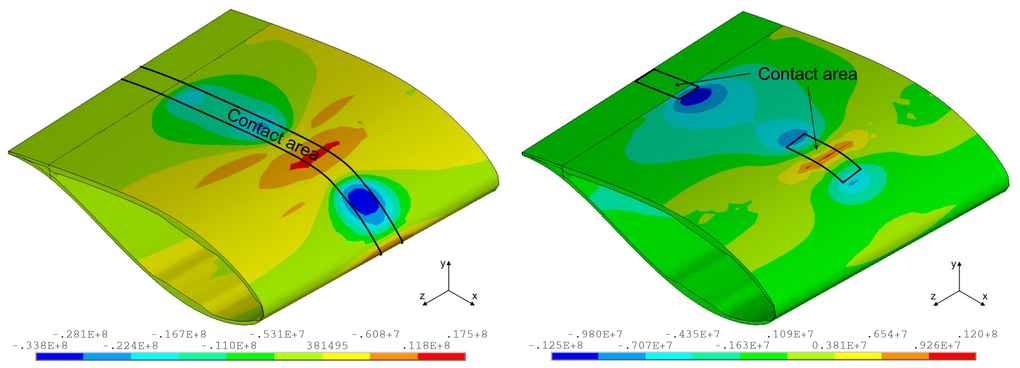
In order to study the local effects in terms of stresses, a refined solid model of the blade has been made. The effects of the yoke can be seen at the centre of the model where stress concentrations are seen in the panels and in the spar cap.



The stresses are shown in the material y-direction. The x-direction is defined in the global z-direction and the material z-direction is defined perpendicular to the outside, whereafter the y-direction can be defined using the right hand rule. It is seen that the stress concentrations are rather local around the load introduction. The influential distance can be evaluated to be around 650 mm, which is 20% of the chord length.

Design study

In order to investigate the influence of the yoke designs on the local effects, two different designs are investigated, a yoke with full contact and a yoke with the contact area concentrated around the spar cap. Avoiding contact on the panels was observed to reduce the stress concentrations at the transitions between the spar cap and the panels. However, the extension of the local effects in the spanwise directions was not reduced by concentrating the contact near the spar cap.



4. Conclusions

In this study it was found that five yokes should be used when a full scale test of this blade is done. It was further found that applying the loads through the yokes only had a minor global stiffening effect on the blade. Regarding the local effects, it was found that the invalid region comprising 75% of the chord length in the spanwise direction can be reduced. However, an exact value cannot be defined due to modelling limitations, and further studies must be done.

Based on the design study, a yoke design should generally comply with the following guidelines:

- Focus the contact area on the stiffest part, i.e. over the spar cap.
- Rubber should be used at the interface between the yoke and the blade in order to distribute the load more evenly.

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