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Substructure Testing and Structural Optimisation of Wind Turbine Blade Web Bond Detail

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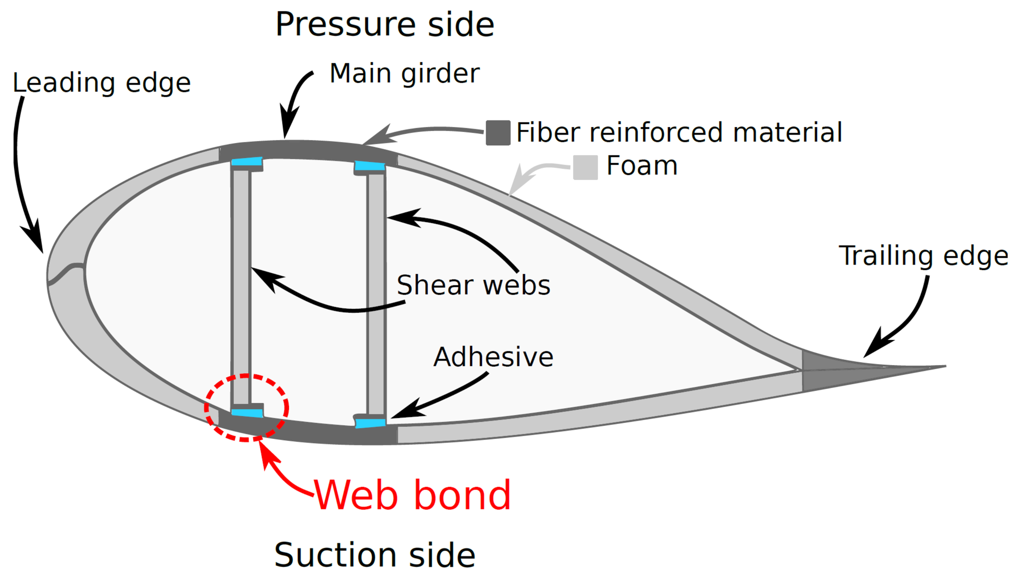
1. Introduction

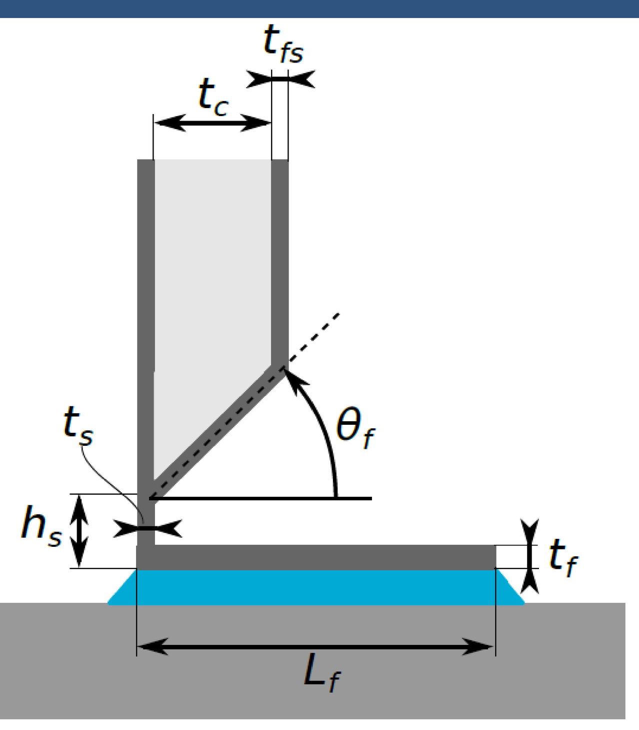
Wind turbine blades become progressively longer as it allows to achieve a greater power output [1]. Consequently, the shear webs located between the outer shells are subjected to increasingly larger forces. A critical area could be the web bond detail connecting the shear webs to the outer shells.

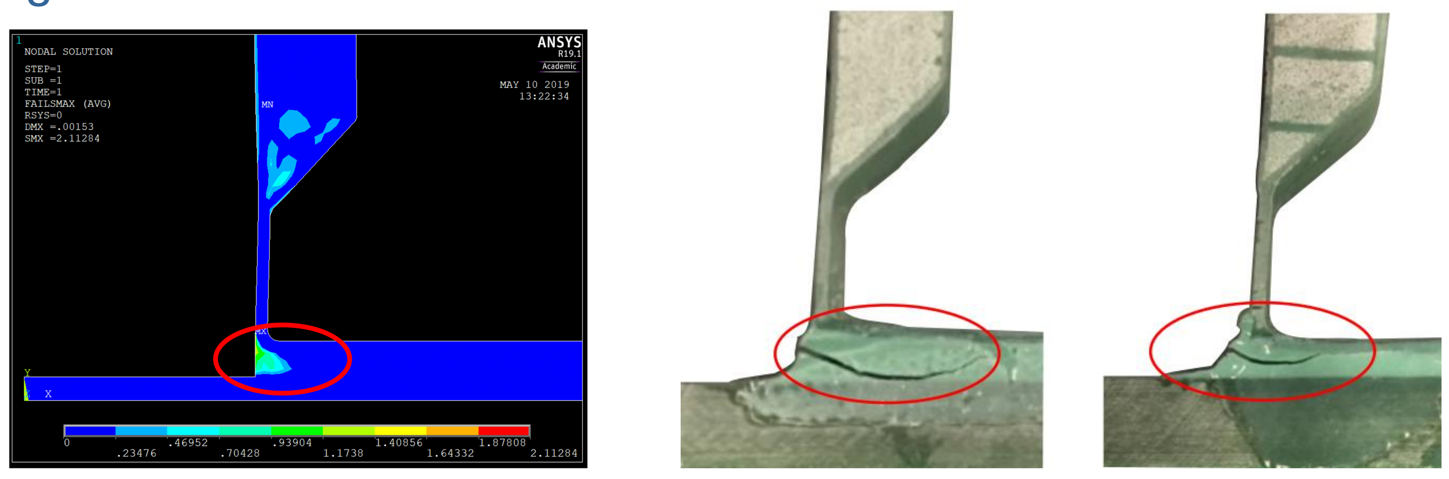


Following the latest design guidelines for the wind blade industry [2], the load capacity of an initial design of the web bond detail is investigated through testing and modeling. It is then optimized and validated through further testing.

2. Testing and Structural Analysis

Shear webs are usually made of a sandwich composite material, with glass/epoxy face sheets and a foam core, while the outer shells consist of pure fibre reinforced material. They are then bounded together with an adhesive layer. The initial design is a low stiffness connection meant to reduce the magnitude of bending moments. Specimens are produced using the same manufacturing process employed for full-scale blades. The specimens are tested for four test modes : Tension, Compression, Positive bending (away from the foot) and Negative bending. Additionally, one specimen is strain-gauge tested for model validation.





The results of the testing were compared to a tailored structural analysis of a submodel replicating the different experimental load cases. Failure indices based on the max stress criterion were extracted from the FEM analysis, thus providing the failure envelope of the initial design of the web bond detail.

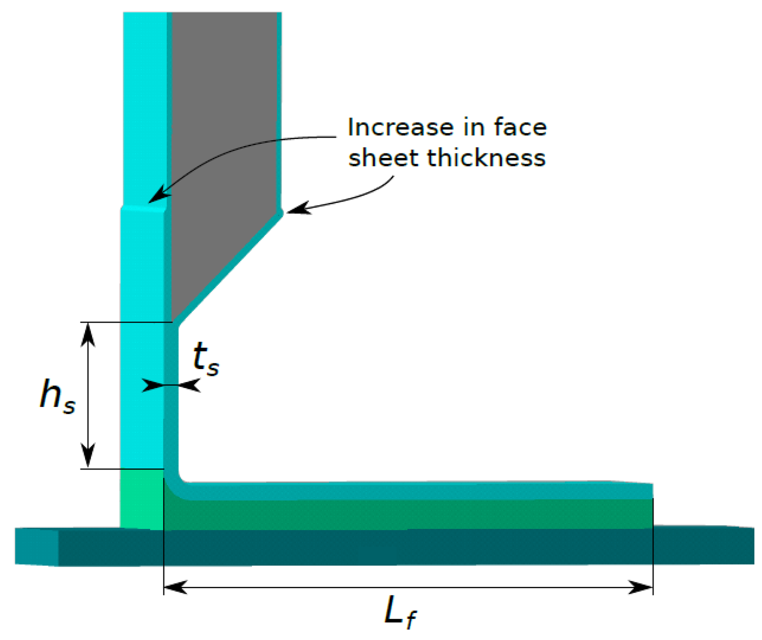
References

[1] A. Kafas et al. *"Future Energy Industry Trends."* NorthSEE project, 2017

[2] DNV-GL. *"DNVGL-ST-0376 Standard, Rotor blades for wind turbines.",* December 2015

3. Optimisation and Analyses

The submodel is optimised for three parameters using the *fmincon* Matlab algorithm. As it is desired to only change the web bond and not the whole shear web, the core and face sheet thickness remained unchanged. In order to increase the stem thickness, plies are added and then dropped internally one at a time to reduce the magnitude of the stress concentrations. The optimization, constrained in mass, resulted in a shorter and thicker stem while reducing the foot length.

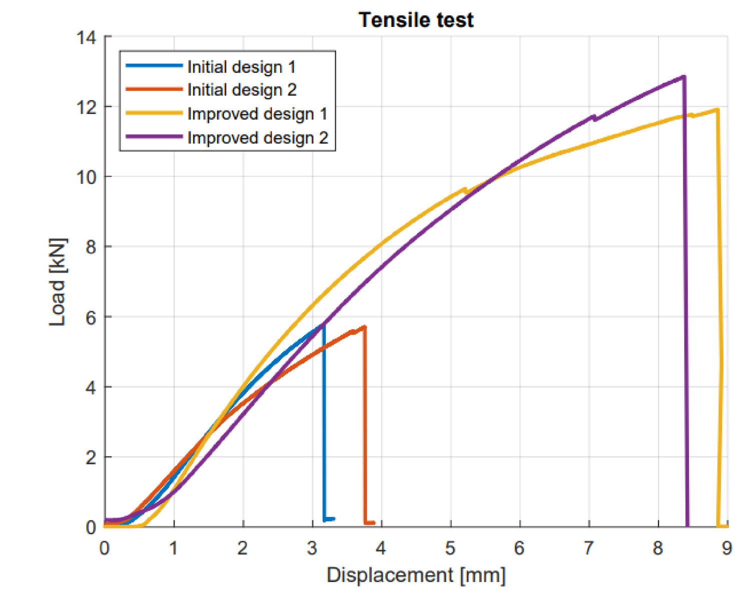


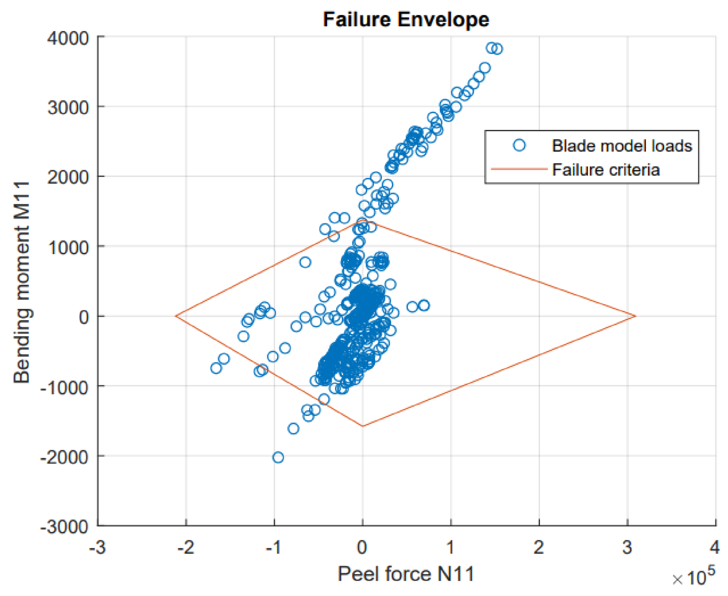
Further testing was carried out with the same setup. As it is a low stiffness design, the shear web may experience buckling and therefore a stability analysis is performed on the submodel. In parallel, fatigue calculations are done using SN curves.

4. Conclusions

Testing and analysis of the optimized design showed great improvements over the initial design :

- +107% in max tension load, +104% in compression
- +334% in max positive bending load, +221% in negative.





However, as can be seen below some of the load in the full blade model are outside of the failure envelope of the web bond. This is likely due to singularities in the model and need to be further assessed. These results stand only for the chosen soft-hinge design. As there are many other possible solutions, the purpose of this project was mainly to provide data on one relevant and easy to manufacture design of the web bond detail. This project depicts one of the challenge engineers must face when increasing structures in scale, as previously formulated mechanical assumptions become doubtful for certain sizes and new studies must be performed in order to assess the reliability of the structure and improve its safety.

Acknowledgement

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