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Structural Optimisation of Web to Sparcap Connection

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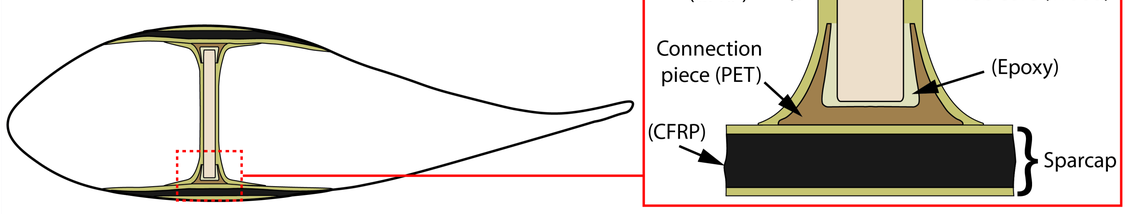
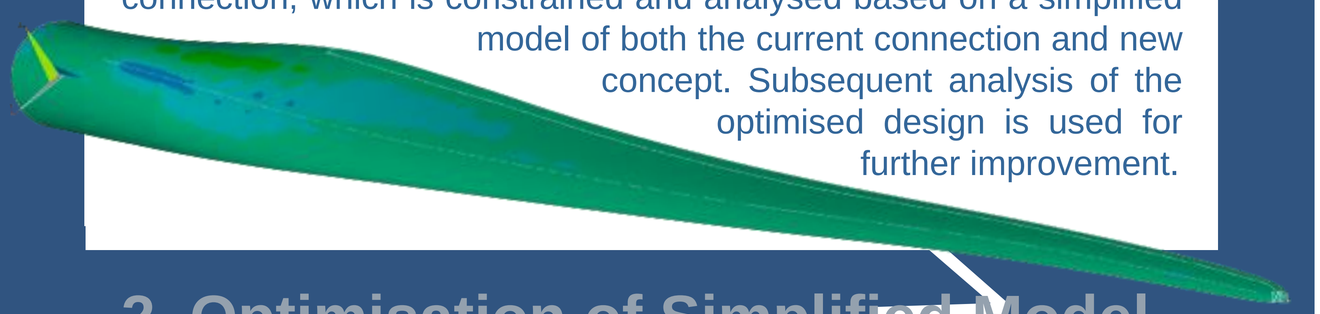
1. Web to Sparcap Connection

Increasing demands for renewable energy requires increases to the power output of wind turbines. This requires longer wind turbine blades with stronger structural components. This project aims to optimise the strength of the web to sparcap connection, to maintain the functionality of the two primary structural components for wind induced bending.

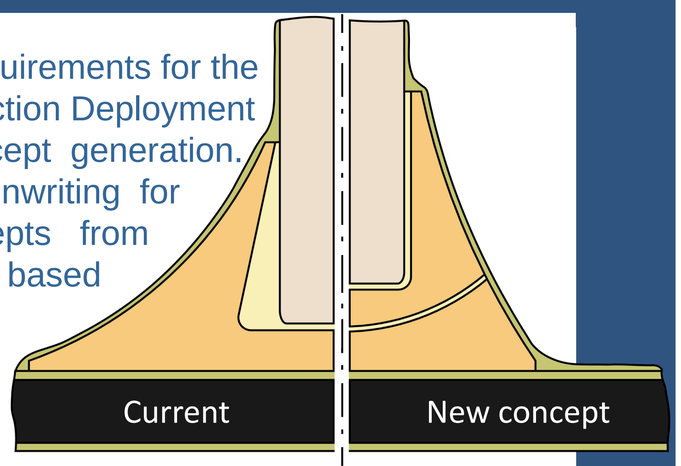


Structural optimisation is applied to a new concept for the connection, which is constrained and analysed based on a simplified model of both the current connection and new concept. Subsequent analysis of the optimised design is used for further improvement.



2. Optimisation of Simplified Model

Analysis of the wishes and requirements for the connection using the Quality Function Deployment method, was used for the concept generation. Morphological analysis with brainwriting for idea generation, led to concepts from which a final concept was chosen based on an evaluation matrix.

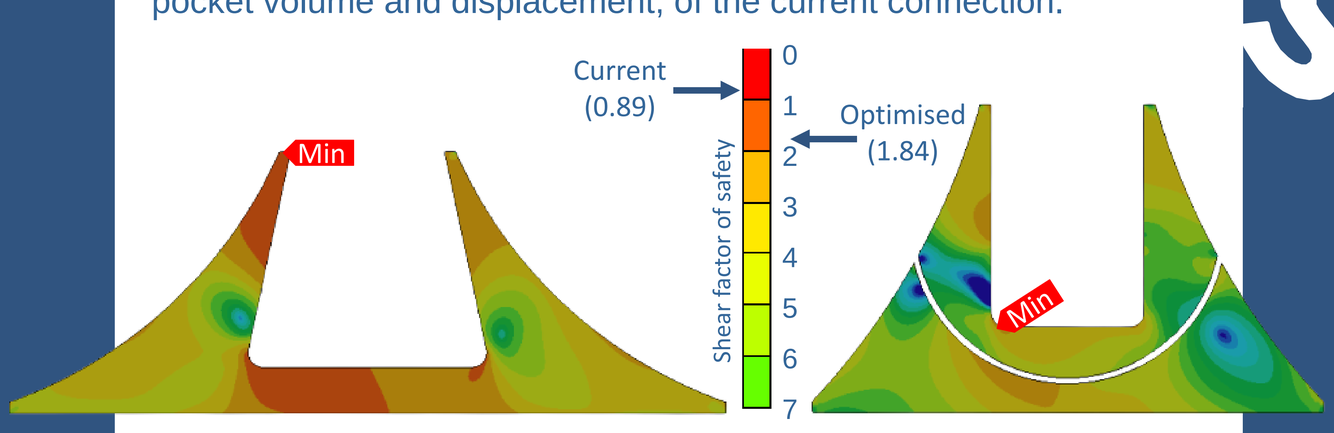


A simplified 2D model of the current connection and new concept is analysed using finite element modelling, with linear solid and solid shell elements for the connection piece and laminates respectively. The evaluated stress-fields contain stress singularities, due to changes in stiffness between different materials. The stress singularities are accounted for, by approximating stresses in the singularities with the Hot Spot method.

The maximum-stress and Puck failure criteria are used on the approximated stress-field to evaluate the factor of safety, which is used as the measurement for strength.

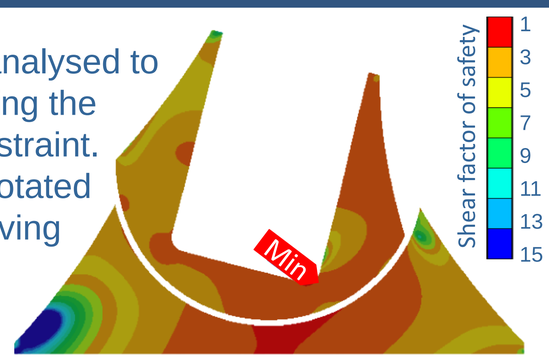
$$SF = \min(SF_c, SF_t, SF_s, SF_{puck})$$

The lowest safety factor from the various failure criteria constitutes the objective in the sequential quadratic programming algorithm, Non-linear Programming by Quadratic Lagrangian. The optimisation is constrained based on the mechanical properties, mass, resin pocket volume and displacement, of the current connection.



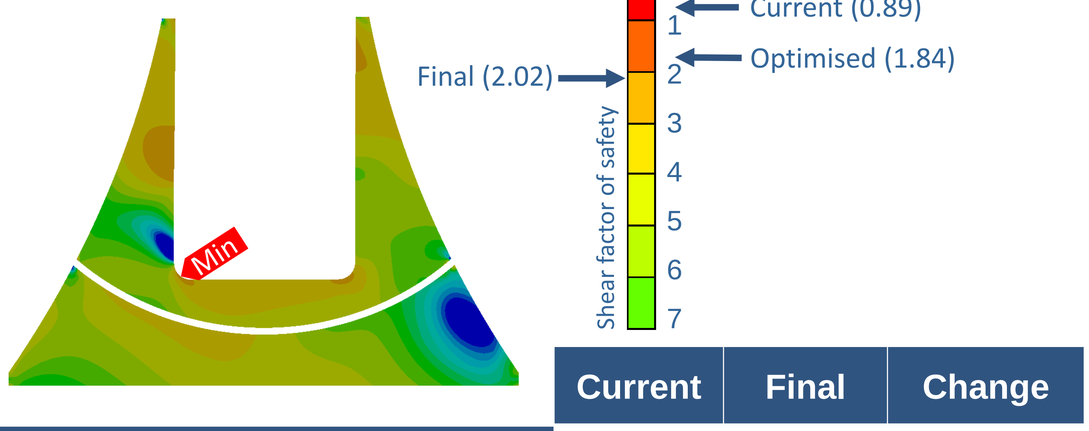
3. Further Improvement

An optimised solution was further analysed to identify failure mode, effect of rotating the web and influence of the mass constraint. The analyses of failure mode and rotated web indicated a possibility of improving the optimisation by increasing complexity at the inner fillet. The rotation of the web was shown to decrease the factor of safety, for both the current and optimised designs, with failure at the inner fillet.



Changes to the mass constraint indicated no connection between the mass constraint and safety factor. This means that other constraints are likely limiting further improvement. The optimisations with mass constraint changes used a different initial point, from which a new solution with improved mechanical properties, was found. This improved design was used as the final design.

The dimensions of the final design were rounded in the direction of the objective function gradient, to reach a design with reasonable dimensions for manufacturing.



	Current	Final	Change
Lowest factor of safety	0.89	2.02	**+128%**
Mass of PET and resin pockets [g]	1.38	1.17	**-14.9%**
Resin pocket volume [mm^3]	739	575	**-22.3%**
Displacement [mm]	1.11	1.00	**-9.9%**

4. Conclusions

The applied methodology for optimising the web to sparcap connection, yielded a final design with an improved factor of safety and additional improvements to mass, resin pocket volume and stiffness. The analyses of the optimised design, indicated the existence of better designs and potential for improvement of the optimisation. This would be through changes to the parameterisation of the concept, and searching for additional optimised solutions.

The methodology is considered useful for the optimisation of the web to sparcap connection, since it is inferred that a stronger design has been developed. However, further validation of the final design using experiments or more advanced models, is needed as an extension to the methodology to acquire a valid strength prediction.

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