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MODELLING OF WIND TURBINE BLADE TRAILING EDGE CORE DESIGNED AND OPTIMIZED FOR RAPID PROTOTYPING

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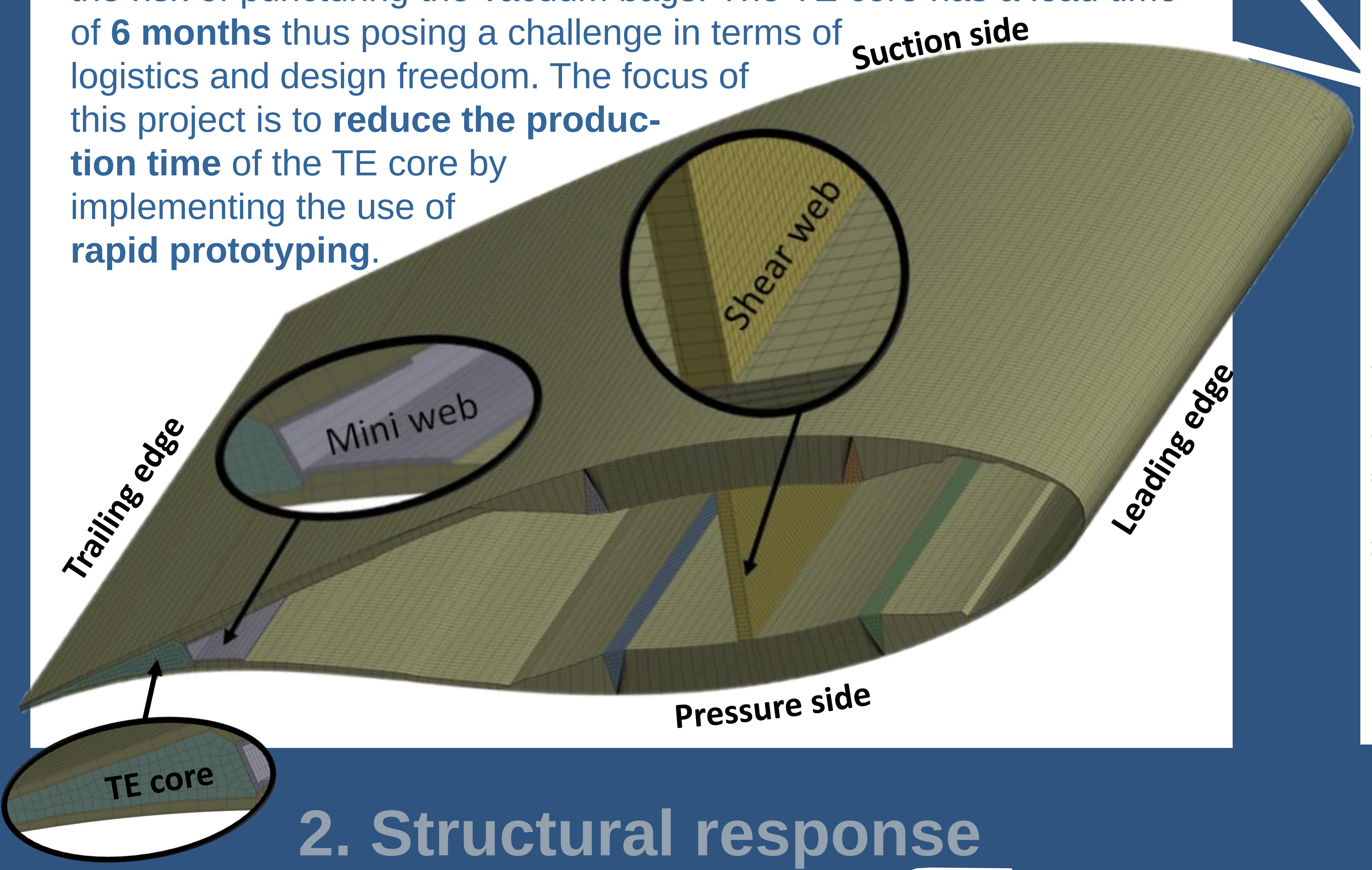
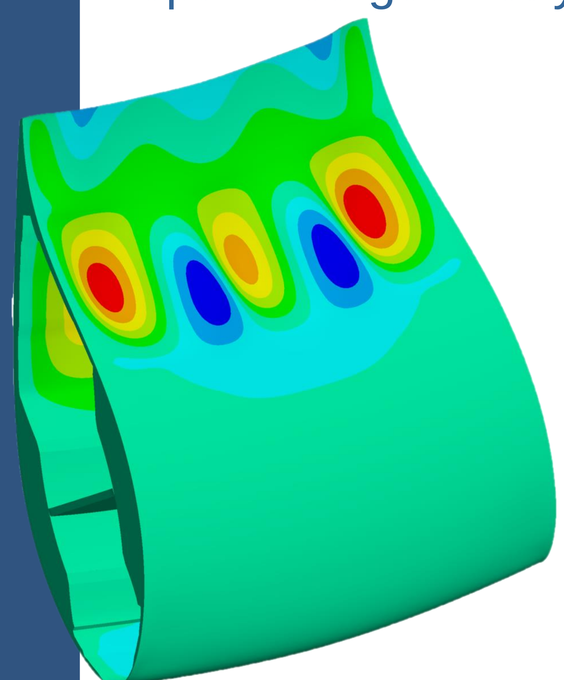
1. Introduction

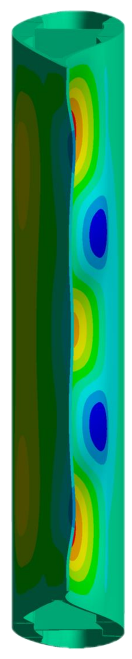
Siemens Gamesa Renewable Energy (SGRE) have developed a patented method of manufacturing blades called **IntegralBlade®**, which eliminates the need for the glued joints at the leading edge (LE) and **trailing edge (TE)** by casting the blade in one piece.
With this production method, a core is introduced in the TE to avoid the risk of puncturing the vacuum bags. The TE core has a lead time of **6 months** thus posing a challenge in terms of logistics and design freedom. The focus of this project is to **reduce the production time** of the TE core by implementing the use of **rapid prototyping**.



2. Structural response

3D printing (FDM) is chosen as the manufacturing method. This leads to a material change from PUR to PC, which increases the mass by a factor of 8. As such **optimization** is necessary and the structural response of the existing TE core is investigated, as the optimized geometry must have similar mechanical properties.

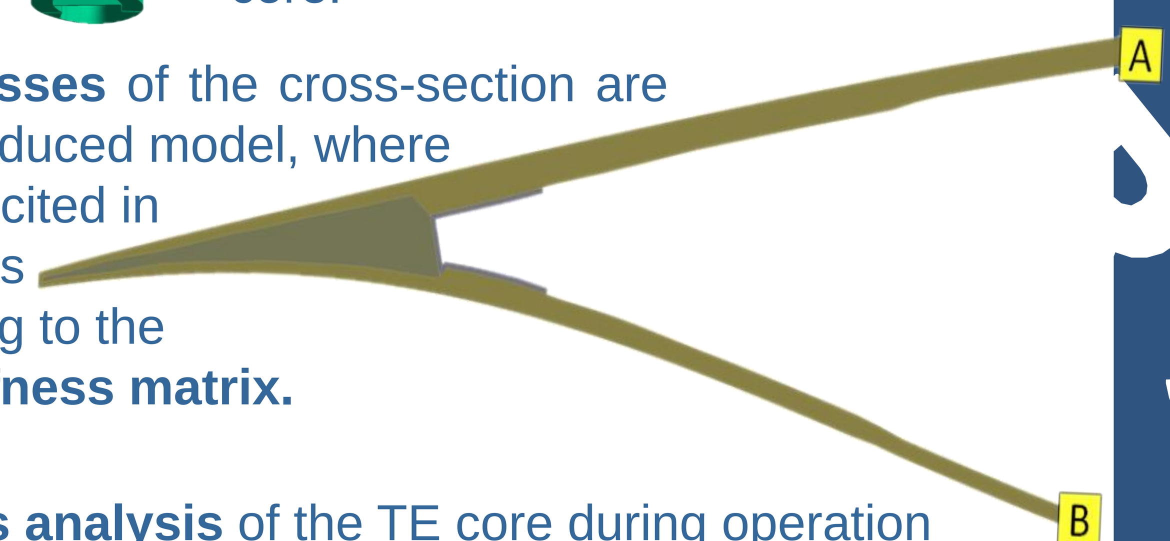




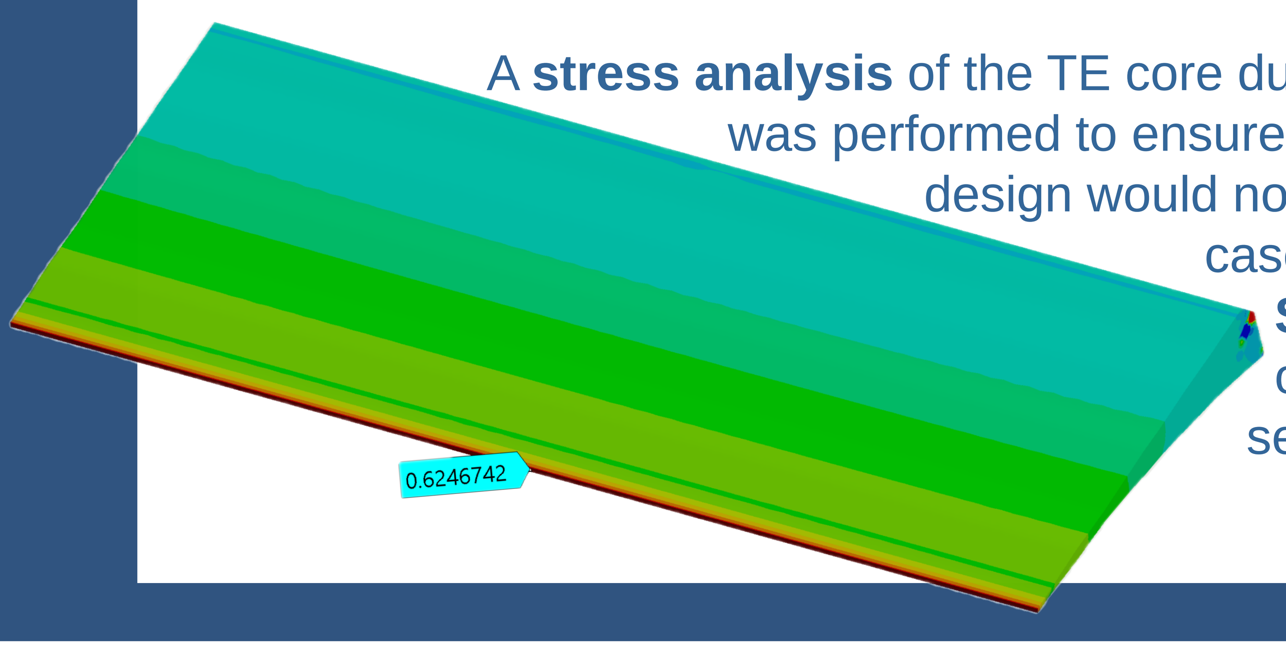
Buckling analysis is performed on a 3 [m] **sub-model** of the blade cross-section at 80 [m]. Due to the location of the TE core, it contributes significantly to buckling resistance.

A preliminary analysis found **a factor of 3** in difference between a model with TE core and without TE core.

The **in-plane stiffnesses** of the cross-section are characterized on a reduced model, where points A and B are excited in turn, and the reactions are measured, leading to the construction of a **stiffness matrix.**



A **stress analysis** of the TE core during operation was performed to ensure the optimized design would not fail. The load cases are supplied by **SGRE** and applied on a reduced 1 [m] segment of the core.



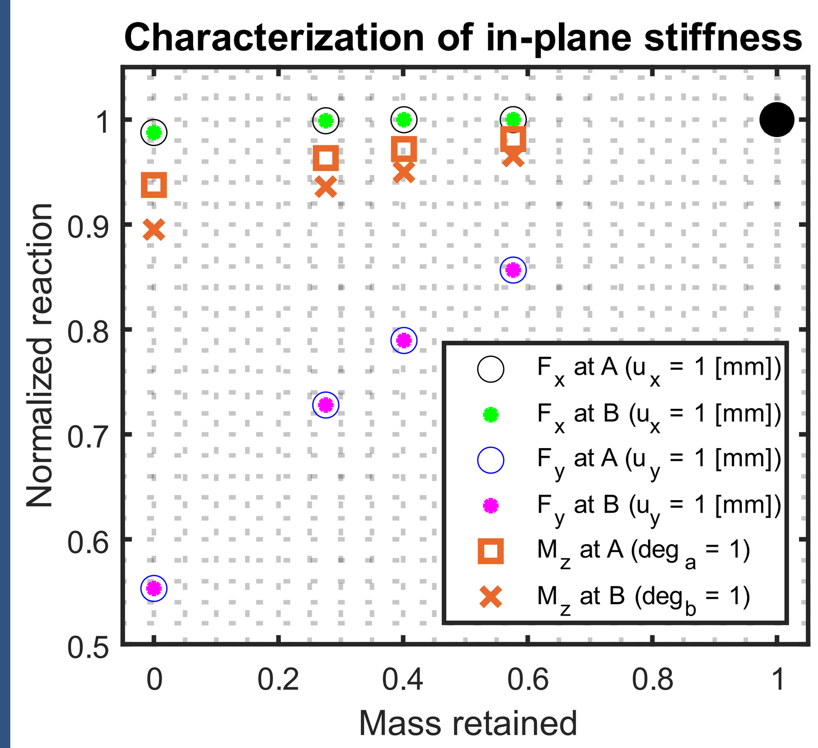
3. Optimization

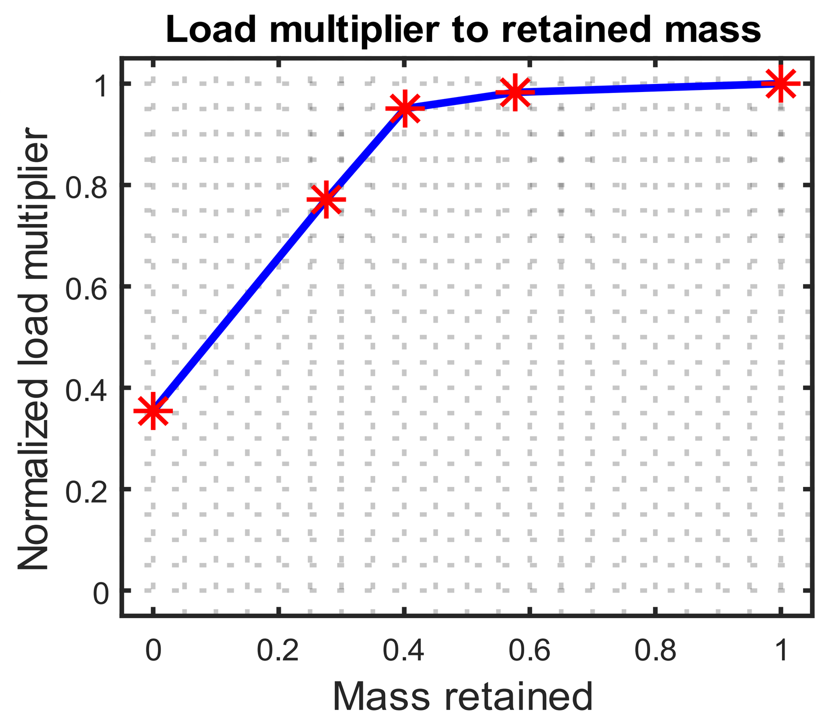
Topological optimization is utilized to reduce the mass while minimizing compliance.

$$\underset{\tilde{x}_e}{Minimize}: \; U = \frac{1}{2}\sum_{e=1}^{n} \tilde{x}_e^p \{u\}[k]_e\{u\}^T$$
$$\text{s.t.} \qquad g(\tilde{x}_e): \frac{\sum_e v_e \tilde{x}_e}{V^*} - 1 \leq 0$$

The load case used for the optimization is a combination of **two load cases** given by SGRE and imposed on a 1 [m] sub-model of the TE core.

The optimization is run with the goal of reaching three different **volume fractions**.





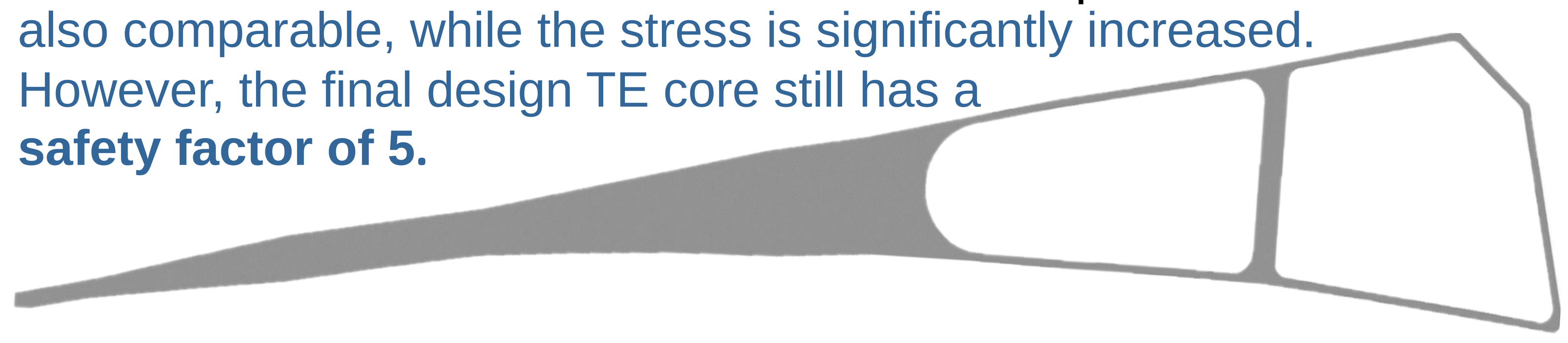
The resulting designs were **extruded** to 3 m and analyzed similarly to the original TE core.

4. Results and comparison

The results from the analyses of the generated optimized designs led to an **intuitive design**. Offset was taken in the model with **40% retained volume where** a '**core web**' was introduced to improve stiffness in the y-direction.

$$[\boldsymbol{K}]_{\%} = \left[\begin{array}{ccc|ccc} \mathbf{2.0} & 0.7 & 0.5 & \mathbf{2.0} & 0.7 & 0.9 \\ 0.7 & -0.9 & -0.2 & 0.7 & -0.9 & -1.0 \\ 0.5 & -0.2 & 0.1 & 0.5 & -0.2 & -1.1 \\ \hline \mathbf{2.0} & 0.7 & 0.5 & \mathbf{2.0} & 0.7 & 0.9 \\ 0.7 & -0.9 & -0.2 & 0.7 & -0.9 & -1.0 \\ 0.9 & -1.0 & -1.1 & 0.9 & -1.0 & -0.2 \end{array}\right]$$

The final TE core design performs similarly in buckling with a deviation of **1.5%.**
The in-plane stiffnesses are also comparable, while the stress is significantly increased. However, the final design TE core still has a **safety factor of 5.**



The **mass** of the core is increased by a factor of **2.2** which is deemed acceptable as the mass of the TE core is small compared to the mass of the blade.

5. Conclusion

The final design TE core can be produced in approximately one day while having similar mechanical properties. Thus, it is concluded it is possible to design a TE core suited for rapid prototyping, at the cost of increasing the mass by a factor of 2.2

Acknowledgement

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