Metal to Composite: Redesign of Centrifugal Pump Impeller

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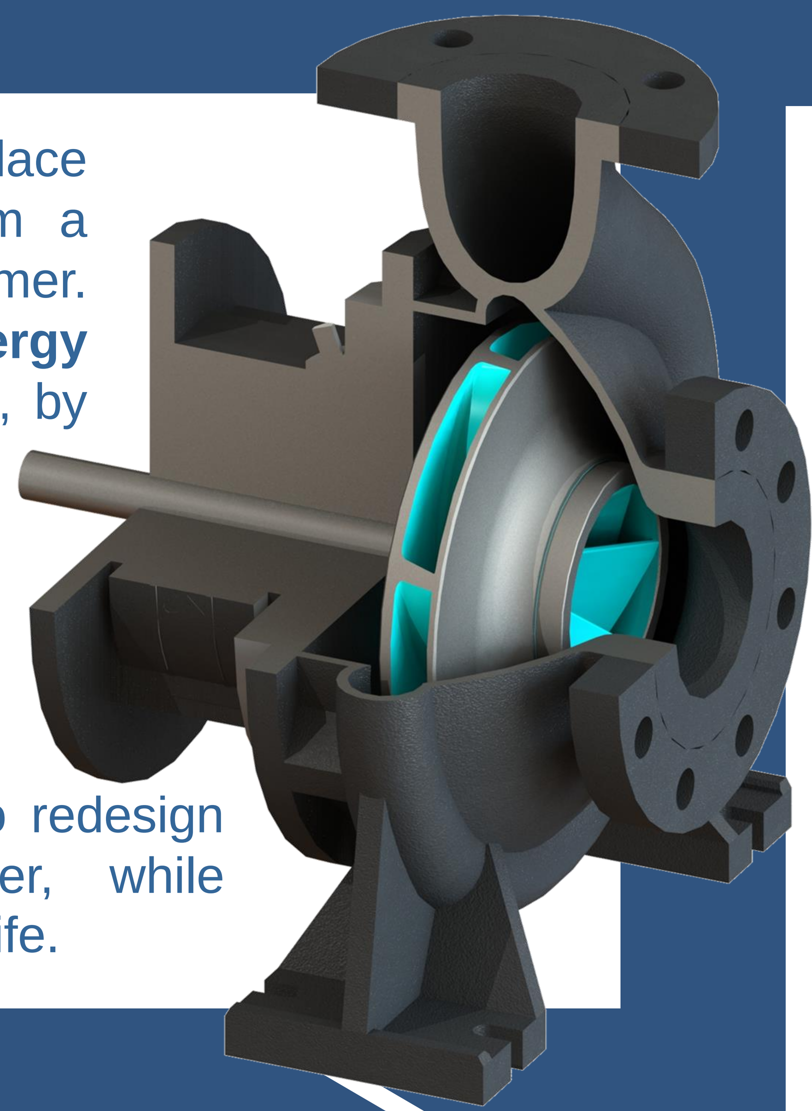
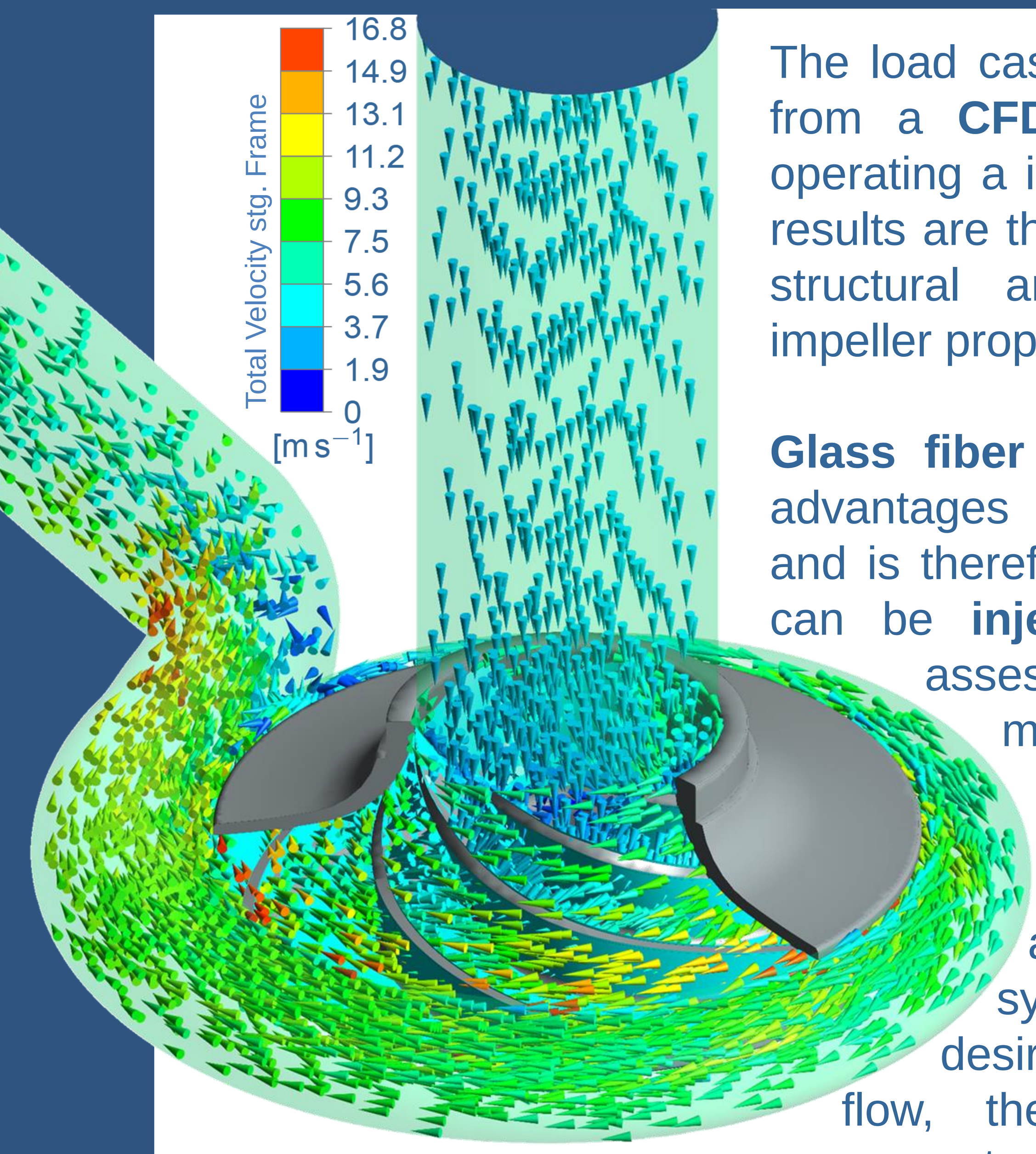
1. Centrifugal Pump

The focus of this project has been to replace and redesign a cast iron **impeller** from a Grundfos pump, using fiber reinforced polymer. The objective is to reduce the **energy consumption** of the pump during startup, by reducing the impeller's mass **moment of inertia**.

A study of material alternatives and manufacturing techniques has been done. Furthermore, a **structural shape optimization** algorithm has been used to redesign the external surfaces of the impeller, while maintaining all its functionality and fatigue life.



2. Metal to Composite



The load case for the study is obtained from a **CFD** simulation of the pump operating a its maximum flow rate. The results are then exported to a **FEA**, so a structural analysis of the cast iron impeller properties can be done.

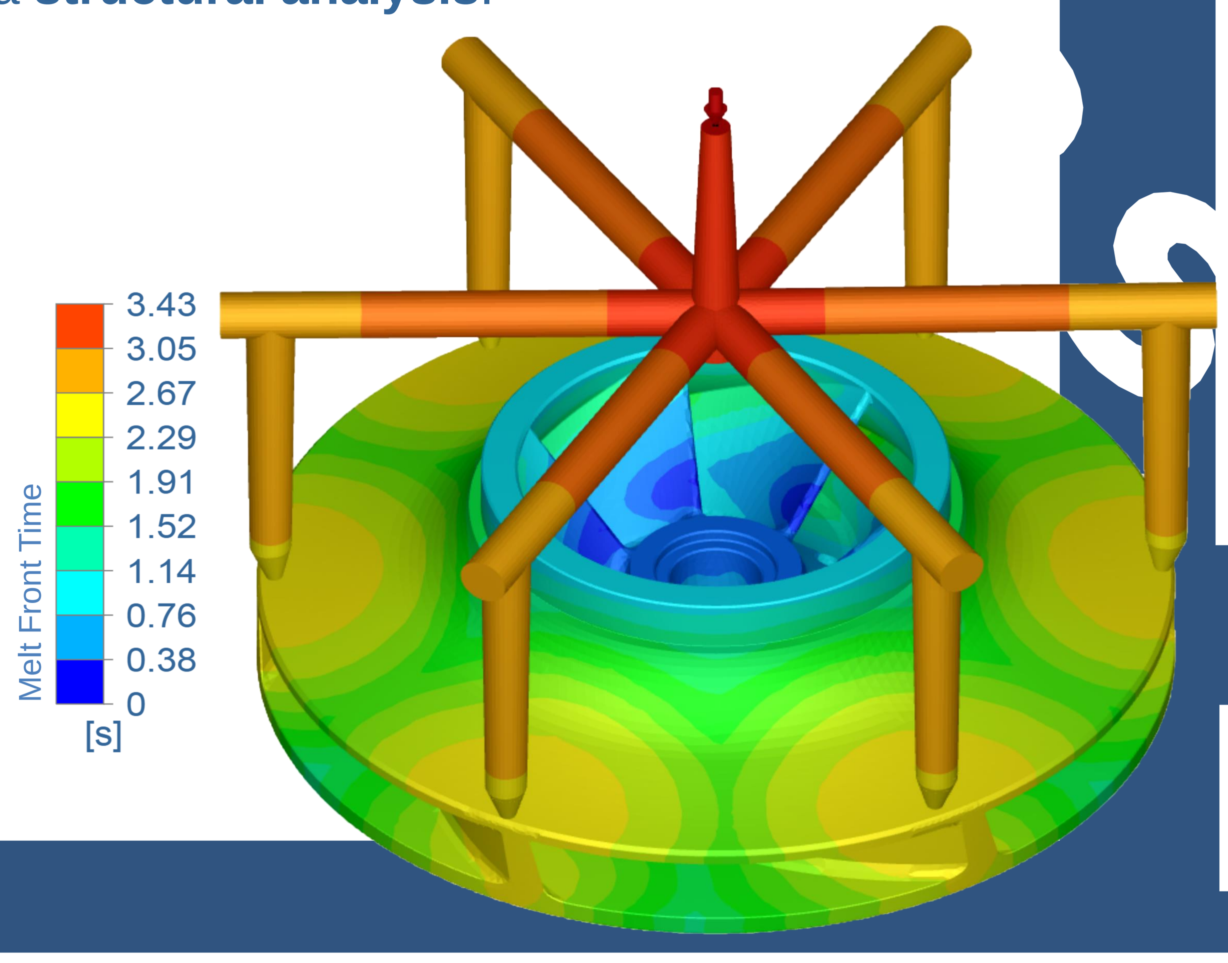
Glass fiber reinforced **polyamide** has advantages properties for the redesign and is therefore chosen. Furthermore, it can be **injection moulded** which is assessed the best option for manufacturing the impeller.

A **process simulation** is performed. The placement and the design of the runner system is made to achieve the desired flow direction. From the flow, the **fiber orientation** and amount of fiber breakage can be estimated.

These results are used to calculate the correspondent material properties for each element of the model. The load case is then applied to this model in a **structural analysis**.

The analysis estimates the deformations, stresses and strains of the injection moulded impeller.

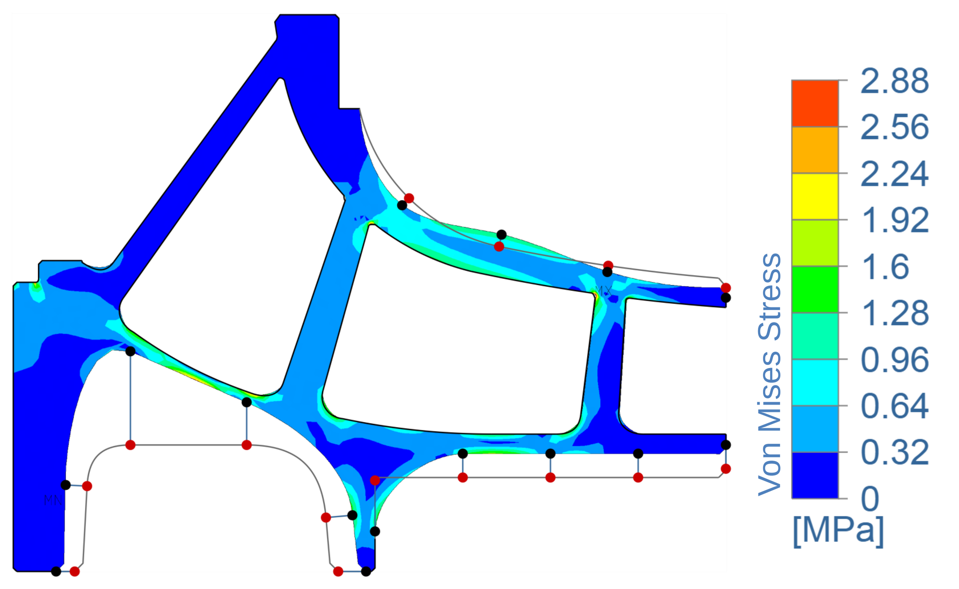
The results are used to calculate the **static** and **fatigue failure index**, from which the life of the impeller can be determined.



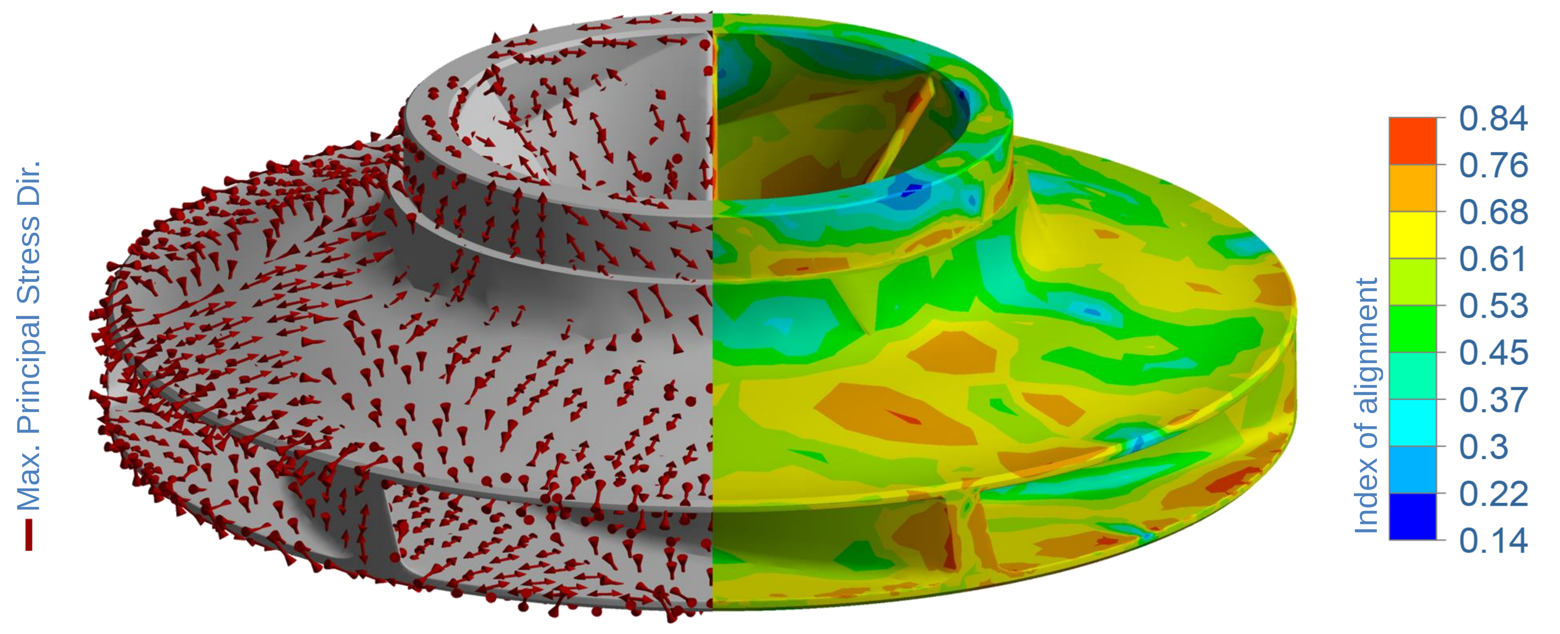
3. Structural Shape Optimization

The **shape optimization** is based on a simplified 2D model of the impeller.

Using a deflection and stress constrained **SQP algorithm**, the cross section of the impeller was optimized with respect to mass moment of inertia.



The optimized geometry is modelled as the 3D impeller, so the process simulation and **structural analysis** can be done. From these analyses the direction of the max. principal stress can be compared with the fiber orientation. The more aligned they are, the more strength and stiffness of the fibers is utilized.



4. Conclusions

The impeller was redesigned by changing the material to polyamide reinforced with glass fibers. An optimization algorithm was used to change the impeller's shape in order to reduce the mass moment of inertia. Through the optimization this was reduced to 86.5% of the original impeller, while keeping the required fatigue life relatively unchanged.

The new material has advantageous properties regarding **cavitation** and **corrosive resistance**, which would prolong the impeller's **estimated life** compared to cast iron. The **energy saved** during acceleration of the impeller is scaled linearly with the mass moment of inertia, thus being reduced 86%.

	Mass [kg]	**Mass Moment of Inertia** [kg m^2]	**Failure index at 10^{10} cycles**
Original	4.51	22.4 10^{-3}	0.40~0.81
Optimized	0.62	3.03 10^{-3}	0.66~2.38
Change	-86.3 %	-86.5 %	

Acknowledgement

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