Optimizing aircraft engine components for additive manufacturing

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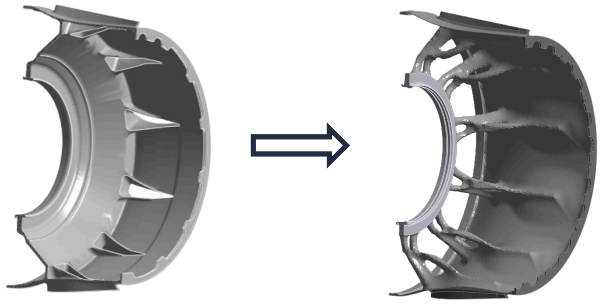

Aircraft engines must be light, strong and able to withstand extreme heat. This thesis investigates how a central engine component can be redesigned for metal additive manufacturing using topology optimization. The work shows both the potential of the method and the challenges that arise when the component is exposed to high temperatures.

The studied component is the hub of the Turbine Rear Structure, or TRS, in a turbofan aircraft engine. The TRS is located behind the last turbine stage, where it is exposed to hot exhaust gases. It supports the rear bearing of the turbine shaft, guides the exhaust flow and transfers loads from the rear engine mounts to the aircraft. The hub is positioned at the centre of the TRS and is therefore a critical part of the structure.

Today, the hub has a relatively simple shape compared with what is often seen in topology optimized components. One reason is that conventional manufacturing methods, such as casting, limit the geometry of the component. Metal additive manufacturing makes more advanced shapes possible. This opens up the possibility to place material only where it is needed, which could reduce weight while maintaining or improving the required structural performance.

To achieve this, topology optimization was used. This is a FEA-based design method that mathematically determines where material should remain in a component and where it may be removed for its intended purpose. For many mechanically loaded components, this is relatively straightforward. For the TRS hub, however, the problem is more complex. Since the hub is exposed to high temperatures, it expands during operation. If this expansion is restricted, large stresses can form. A good design therefore cannot simply be as stiff and light as possible. It must also handle thermal expansion by having some thermal compliance.

Directly applying thermal loads in the optimization did not produce usable results. Instead, a workflow was developed where results from previous thermal simulations were converted into mechanical loads and displacements for the optimization. This made it possible to include the thermal load cases by analyzing them in a mechanical way.

The thesis shows that topology optimization of thermally loaded components is challenging, but also promising. The developed workflow provides a starting point for future TRS hub development and for further work on additively manufactured aircraft engine components.