

Final work : Structural modeling of propeller for multi-disciplinary design optimization

Auteur : Sharma, Manthan

Promoteur(s) : Hillewaert, Koen

Faculté : Faculté des Sciences appliquées

Diplôme : Master en ingénieur civil en aérospatiale, à finalité spécialisée en "turbomachinery aeromechanics (THRUST)"

Année académique : 2021-2022

URI/URL : <https://www.tudelft.nl/lr/appu>; <http://hdl.handle.net/2268.2/15869>

Avertissement à l'attention des usagers :

Tous les documents placés en accès ouvert sur le site le site MatheO sont protégés par le droit d'auteur. Conformément aux principes énoncés par la "Budapest Open Access Initiative"(BOAI, 2002), l'utilisateur du site peut lire, télécharger, copier, transmettre, imprimer, chercher ou faire un lien vers le texte intégral de ces documents, les disséquer pour les indexer, s'en servir de données pour un logiciel, ou s'en servir à toute autre fin légale (ou prévue par la réglementation relative au droit d'auteur). Toute utilisation du document à des fins commerciales est strictement interdite.

Par ailleurs, l'utilisateur s'engage à respecter les droits moraux de l'auteur, principalement le droit à l'intégrité de l'oeuvre et le droit de paternité et ce dans toute utilisation que l'utilisateur entreprend. Ainsi, à titre d'exemple, lorsqu'il reproduira un document par extrait ou dans son intégralité, l'utilisateur citera de manière complète les sources telles que mentionnées ci-dessus. Toute utilisation non explicitement autorisée ci-avant (telle que par exemple, la modification du document ou son résumé) nécessite l'autorisation préalable et expresse des auteurs ou de leurs ayants droit.

Title of the work: Structural modeling of propeller for multi-disciplinary design optimization.

Author: Manthan Sharma

Section: Aerospace Engineering Turbomachinery Aeromechanics (THRUST)

Academic year: 2021-2022

Supervisors: Prof. Koen Hillewaert and Dr. Tomas Sinnige

Summary: Aircraft propellers have been an essential propulsion source since the origins of aviation. In order to allow aviation to continue to remain a viable means of mass transportation, the aircraft of tomorrow should become more energy-efficient, have less greenhouse gas emissions and have a lower noise signature. Due to their high propulsive efficiency and the introduction of electric propulsion in aviation, there is a renewed interest in propeller design. However, conventional propellers are often considered noisy compared to turbofan engines. On top of that, further propulsion integration into the air-frame, for instance, Boundary Layer Ingestion, results in additional sources of propeller noise due to increased non-uniform inflow. In order to meet the challenges mentioned and develop novel energy-efficient propellers with a low acoustic footprint, a multi-disciplinary framework is being developed to optimize the propeller design. Present work focuses on the structural analysis of the propeller blade in a steady rectilinear flight operation to predict the blade stresses and ensure that the optimized blade can withstand the aerodynamic and centrifugal loads.

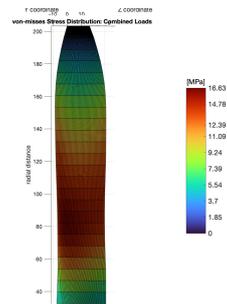
The structural model is based on the Euler-Bernoulli beam theory for bending loads and the Saint-Venant theory for torsional loads in the blade. The proposed low-level structural model is more robust, fast, and efficient in terms of computational time and power than structural FEM simulations and can thus be easily integrated into a multi-disciplinary design optimization framework, including aerodynamics and aeroacoustics. The model is sensitive to changes in the blade's planform (chord, twist, and sweep) and airfoil geometry. In addition, to build confidence in the results the low-fidelity model was validated against high-fidelity structural (Fluid-Structure interaction) simulations of the propellers in both propulsive and regenerative regimes.

The sensitivity analysis was performed using various geometrical and operational parameters such as advance ratio, propeller pitch, and blade sweep. Expected outcomes from the sensitivity study were achieved, concluding that the centrifugal loads dominates over aerodynamic loads, and further consolidating the structural model and demonstrating that the low-level model performs satisfactorily in estimating the stress distribution. The proposed structural model serves as the foundation for aeroelastic analysis, which includes unstable aerodynamic loadings, which were not considered in the current work.

UZ sweepmesh
 Equivalent Stress
 Type: Equivalent (von-Mises) Stress
 Unit: MPa
 Time: 1
 17-8-2022 20:42



(a) High Fidelity Model - Pressure Side

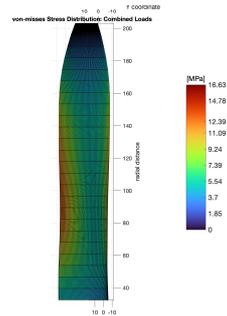


(b) Low Fidelity Model - Pressure Side

UZ sweepmesh
 Equivalent Stress
 Type: Equivalent (von-Mises) Stress
 Unit: MPa
 Time: 1
 17-8-2022 20:45



(c) High Fidelity Model - Suction Side



(d) Low Fidelity Model - Suction Side

Figure 1: Comparison of high-fidelity and low-fidelity model: Propulsive regime operation