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Strategies, software tools and methods for numerical and semi-analytical propeller design and shape optimization

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Abstract:

For many use cases propeller-based aircrafts have proven to be robust, reliable and cost-efficient. This applies especially for applications in military transportation as well as unmanned surveillance or logistic drones. The general design of propellers for such aircrafts as well as their topology and shape optimization are crucial tasks concerning the overall performance and usability of the aircraft. In the applications stated above this can break down to complex multi-objective optimization tasks to ensure and improve the overall performance, efficiency and usability of the aircrafts and drones. Over the engineering design process of the aircraft including its propeller, aspects of multi-physics optimization can be relevant, e.g., to improve propeller thrust and minimal sound radiation likewise. Well-established numerical methods like Finite Element Analysis (FEA) and Computational Fluid Dynamics as well as Fluid-Solid-Interaction (FSI) can be used to evaluate and optimize the propeller structural design and performance during digital product development. The shape is to be optimized with respect to power, thrust, performance, and structural stability, but also downstream design goals like acoustic sound radiation, material choices or feasibilities in production methods. Besides the very general approach using numeric simulation (FEM/CFD), another approach for propeller theory to calculate the static condition based on empirical data models and the lifting-line theory or vortex theory can also be used. This method is almost purely analytical and utilizes the Biot-Savart law and Kutta-Joukowski theorem. Thus, allows a fast and efficient execution of propeller optimization tasks with little computational resources, because no computationally expensive equations like Navier-Stokes need to be solved. The author will present existing methods, tools and software implementations for numerical as well as vortex-theory-based approaches and their possible interaction and interconnection. The presented tools and methods aim for a smooth and efficient integration in engineering processes and digital product development. In particular, the interaction with modern CAD, CAM and CAE tools is being discussed and demonstrated. Therefore, the described fast semi-analytical methods will be used in early design stages to limit the optimization domain for further downstream analysis methods, based on more general approaches like FEA, CFD or FSI. Own software implementations will be presented as well as integration and interaction of them with well-established numerical frameworks like ANSYS. Especially with respect to small feature design issues, e.g., tip or trailing edge optimization, which cannot be well captured by the mentioned semi-analytical approaches, or with respect to improvement of acoustic sound radiation, numerical frameworks like ANSYS offer a powerful toolset for engineers.

Biography:

Felix Frischmann has completed his Master's program in Computational Mechanics (M.Sc.) at Technische Universität München (TUM) in 2011 at the age of 27 years. From 2011 to 2016 he worked as a research assistant at TUM in the field of computational mechanics with focus on FEM mesh generation, CAD pre-processing & clean-up and design-through-analysis. Since 2018 he is working as a lecturer and researcher at Rosenheim Technical University of Applied Sciences in the field of digitalization in engineering and acoustics. Since 2012 he is working as a freelancer and and entrepreneur in the field of software development for various engineering and simulation applications ranging from civil, mechanical to aerospace solutions.

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