Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: PROPHY / SYSINT / HEPAEM
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Type: Oral
Status of corresponding author: student (PhD Candidate)
For student corresponding author: -

Title
Organic Rankine Cycle Waste Heat Recovery for Turboshaft Engines of Turboelectric Aircraft

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Abstract
The thermal efficiency of modern large power capacity aircraft engines is around 50%. This means that half of the chemical energy provided by the combustion of fossil fuel is lost to the environment in the form of a hot exhaust gas stream. Further efficiency improvement of conventional gas turbines is proving increasingly difficult. Combined-cycle engines may allow to overcome this limitation. One such concept widely adopted for medium-power-capacity, stationary gas turbines is the addition of an organic-Rankine-cycle (ORC) bottoming unit recovering waste heat from the exhaust of the engine by means of a heat exchanger. As the propulsion systems of future aircraft generations are likely to employ an increased degree of electrification, the potential application of such a combined-cycle engine could be a hybrid-electric powertrain. An aircraft with a turboelectric propulsion system may benefit from a highly efficient power plant based on a turboshaft engine coupled to an ORC waste heat recovery (WHR) system. Conceptual-level studies of turboelectric architectures indicate that benefits such as improved propulsive efficiency and aircraft aerodynamics may be derived from the decoupling of power production and provision of thrust. However, research on optimal engine configurations for turboelectric aircraft is still scarce. The aim of this work is to investigate the potential benefit on fuel consumption of employing an ORC WHR system to a turboshaft engine of a turboelectric powertrain. The reference aircraft for this study is similar to the one proposed by [1], which utilizes two turboshaft engines to generate electrical power for a wing mounted distributed propulsion system consisting of ducted fans. A multidisciplinary simulation framework is developed in Python to analyze the thermodynamic performance as well as the volume and weight of a combined-cycle turboshaft engine and to evaluate its impact on mission fuel consumption. This framework integrates modules for gas turbine and ORC performance simulations, ORC turbine and heat exchanger preliminary design as well as aircraft preliminary sizing and mission analysis. All models are integrated based on the openMDAO library [2]. This simulation infrastructure is coupled with an optimizer to identify optimum design parameters of the combined-cycle engine with the objective of minimizing mission fuel mass. The optimization problem takes into account volume constraints dictated by the chosen reference aircraft. The results indicate that adopting an ORC WHR system coupled to a turboshaft engine of a turboelectric aircraft may improve thermal efficiency by 5% which results in a mission fuel mass reduction of 5%. The optimized ORC WHR system has a mass specific power of 2kW/kg and volume constraints imposed on the condenser are identified as limiting factor for performance.

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