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Thermal Integration and Performance of Hydrogen powered SOFC-GT turboprop aircraft engine

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The push toward net-zero aviation has increased the requirement for propulsion technologies that reduce carbon emissions without compromising performance. Hydrogen is a clean energy carrier for zero-carbon flight, but its combustion in gas turbines presents challenges such as NOx emissions. In contrast, Solid Oxide Fuel Cell-Gas Turbine (SOFC-GT) hybrid systems offer a high-efficiency and low emission alternative [1]. SOFCs provide fuel flexibility, less noise and vibration, high electrical efficiency, and low emissions. Integrating SOFCs with gas turbines in a hybrid cycle allows the fuel cell to generate electricity while its waste heat contributes to driving a turbine, enhancing the overall efficiency [2, 3].
The SOFC-GT hybrid combines the clean, efficient power of SOFCs with the high specific power of gas turbines, improving heat recovery, reduced fuel consumption, well-suited for aviation. The hybrid enables effective thermal integration, using SOFC waste heat to drive the gas turbine, reducing exergy losses and improving fuel utilization. Turbine exhaust can preheat air for the SOFC with operating temperatures between 873 K - 1223 K. Since both subsystems run at high temperatures, efficient heat transfer, especially for cathode air preheating, depends on exhaust temperature and flow rate. This study investigates steady-state thermal integration and performance of a hydrogen-powered SOFC-GT hybrid turboprop engine for an ATR 72 aircraft during take-off. A 0D model developed in a thermodynamic cycle analysis tool called PyCycle [4] simulated the exhaust temperature profile for varying turbine inlet temperatures (TIT) and overall pressure ratios (OPR), including thermal management and performance variation with varying power splits. Results show that at low TIT and high OPR, limited temperature differences reduce heat recovery potential, and at high power splits, cathode air cooling becomes insufficient to manage SOFC heat. Conversely, lower power splits enhance cooling but increase fuel consumption. The study emphasizes the need for optimized thermal management and architecture modification to balance cooling, weight, and efficiency. Future work will examine off-design performance, system weight, and thermal stress impacts for hybrid integration in regional aircraft.

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