TURBINE-LESS JET ENGINE POWERED BY SOLID OXIDE FUEL CELL (SOFC) FOR AIRCRAFT PROPULSION

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ABSTRACT

Recent reports from various institutions suggest that harmful emissions from aircraft are far greater, and more dangerous than those from other transport vehicles, since aircraft emit pollutants at high altitudes, and emissions are prone to remain in the atmosphere for long time before they are dispersed. This research presents a novel configuration of a hybrid fuel cell-Gas turbine to produce jet thrust for aircraft propulsion. The work is based on research performed at the faculty of engineering science and technology at UiT, and patented in Norway under Patent No. 346132, Patentee: UiT, Issue date: 14 March 2022. [1]. This configuration is shown in figure (1).

Various combinations of FC-GT for stationary and mobile applications are proposed in the open literature, but none of them proposes full integration of the two components to produce jet thrust for aircraft propulsion[2] [3]. Eelman et al., proposed the system shown in figure (2), claiming that they achieved system efficiencies of up to 75% [4].

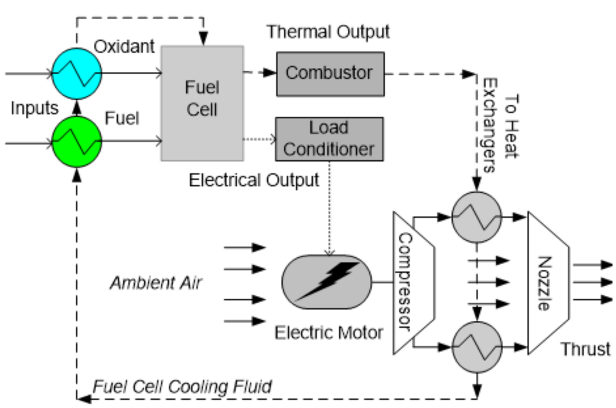

Figure 2. The combined cycle- power plant Jet Engine, top schematic for the current analysis, while bottom schematic is for the final configuration [1].

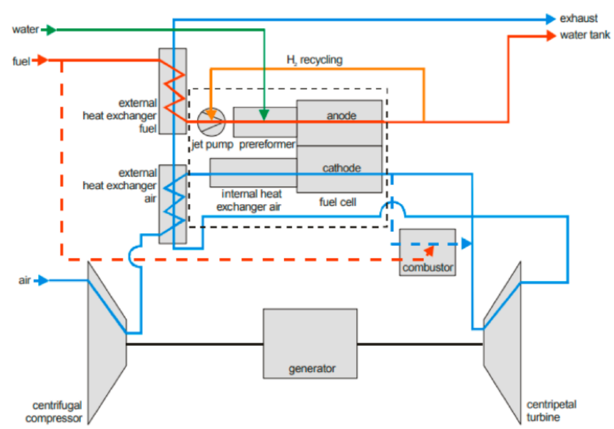

Figure 2. SOFC-GT APU system design as presented by Eelman et al. [4]

In the present work, the two components in the system are fully integrated and all energy output of the fuel cell is utilised to produce jet propulsion. The electrical and heat outputs of the fuel cell are utilised in the jet engine to compress and heat the air cycle through the engine. The compressor in the engine is driven by the electrical output of the fuel cell, which makes the turbine in the jet engine redundant, hence simplifying the design of the jet engine. This is a very important development as it reduces the cost, weight and complexity of the jet engine and improves its power and environmental performances. In this document, the results of a parametric study of the influence of the principal design parameters of a novel full-scale plant on its performance is presented, reduction in carbon emission, increase in energy utilisation efficiency and reduction in thermal loading on the environment, while operating in standard atmosphere.

Thermodynamic analysis of the cycle

A comprehensive thermodynamic analysis of the cycle was performed to calculate the thrust produced by the jet engine. The analysis is based on a Brayton cycle in which the second compressor and after burner are not included. SOFC operating at 1000 oC is assumed, inlet air STP conditions are assumed for inlet air, and Cp, the "Specific Heat at constant pressure" is assumed constant over the range of temperatures considered, pressure drop in the fuel cell heat exchanger is negligible. Assuming a subsonic nozzle, where Mach numbers are specified, and adiabatic conditions apply at the nozzle.

The analysis shows that the overall efficiency of this cycle is (0.7309) which is higher than reported efficiency of latest generation gas turbine engines in simple and combined cycles.

It is noted from the expression for the overall efficiency that significant improvement in efficiency can be achieved by reducing the compressor inlet temperature. Testing of such engines is normally undertaken at sea level, where the compressor inlet temperature is near the standard ambient temperature, while in actual operation at high altitudes, the compressor inlet temperature is very much reduced below zero Celsius, which improves the efficiency further.

Discussion and Conclusions

1. The results of a parametric study of the combined power plant comprising a fuel cell and a gas turbine are presented in this work. The heat rejected by the fuel cell is used to heat the compressed air in a closed cycle gas turbine system.
2. The design point for the proposed jet-engine was specified at 0.8 M, which results in a subsonic jet thrust being produced at the nozzle. The results show that even when using a conservative figure of 50% for the fuel cell efficiency, the overall efficiency can be increased to approximately 73%, this increase in energy efficiency offers a solution to the two serious problems facing the power generation industry, these problems are: (a) energy conservation and (b) reduction in pollution and thermal loading on the environment.
3. Parametric study is a very useful tool for investigating the effect of system parameters on its performance. The authors hope that the results of a parametric study presented in this paper would be helpful to designers and applications engineers working in the field of power generation.

References

[1] M. Y. Mustafa, "Fuel cell powered turbine-less jet engine". Norway Patent 346132, 14 March 2022.

[2] Damo, U.M.; Ferrari, M.L.; Turan, A.; Massardo, A.F. , "Solid oxide fuel cell hybrid system: A detailed review of an environmentally clean and efficient source of energy," *Energy* , p. 235–246, 2019.

[3] Fernandes, M.D.; Andrade, S.D.P.; Bistritzki, V.N.; Fonseca, R.M.; Zacarias, L.G.; Gonçalves, H.N.C.; de Castro, A.F.; Domingues, R.Z.; Matencio, T., "SOFC-APU systems for aircraft: A review.," *Int. J. Hydrogen Energy,* vol. 43, p. 16311–16333, 2018.

[4] Eelman, S.; Daggett, D.; Zimmermann, M.; Seidel, G., "High Temperature Fuel Cells as Substitution of the Conventional APU in Commercial Aircraft.," *Ger. Aerosp. Congr.,* p. 1601–1608, 2003.