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Title

Heat exchanger integration into an aero-engine bypass duct

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Abstract

The requirement to reduce the environmental effect of aviation has led manufacturers to the design and development of Ultra-High Bypass Ratio (UHBR) aero-engines with geared fans [1]. The heat losses within the gearbox [2][3] introduces a challenge in the form of thermal management of the engine gearbox system [4]. This can potentially be achieved through the integration of air-to-oil heat exchanger (HEX) [5] embedded into the bypass duct of the engine. However, the introduction of a HEX can incur losses in the bypass duct and lead to a deterioration in engine fuel consumption. It is therefore essential to design and integrate HEX systems which minimize these potential detrimental impacts. This paper identifies the prominent HEX design parameters for the HEX installation and quantifies the sensitivity of engine and HEX performance to the integration of the HEX with the bypass duct.

An in-house exhaust design tool (GEMINI) [6] was used to conduct a large sensitivity study for the HEX integration with the bypass duct. The tool is capable of parametrically producing engine and HEX geometries. GEMINI was used to generate a range of aero-engine configurations with embedded HEX systems. The effects of systematic perturbations in the bypass geometry and embedded HEX system were assessed. Perturbations of HEX size, HEX system immersion into the bypass and bypass aeroline geometry were evaluated to quantify the trade-off between HEX heat transfer and engine thrust. This was evaluated through computational fluid dynamic studies (CFD) at three main operating conditions: cruise, maximum take-off (MTO) and ground idle (GI). A low fidelity method [7] was used to model the ventilated HEX heat transfer and pressure losses as part of a mixed-fidelity system for the CFD assessment of the embedded HEX.

The analyses showed that there is a trade-off design space between the HEX heat transfer levels and the impact on the thrust (Figure 1). This depended on the main geometric aspects of the HEX integration with the bypass duct as well as the operating condition (cruise, MTO, GI). For example, a radially short and axially long HEX was able to meet the heat transfer requirement at MTO and GI while loss in thrust was minimized at cruise. Overall, impact on the exhaust performance is a balance between the increase in exhaust total temperature, from the HEX, and the loss in total pressure. The main contributor to thrust loss was the pressure drop across the air-side of the HEX. It was found that the effect of rise in bypass total temperature on exhaust performance was significantly lower than the effect of total pressure loss. The bounds of the design space were limited by the heat transfer requirement at MTO and GI, and the flow separation at the intake of the HEX at cruise and MTO (Figure 2). Overall, this work highlights the development of a multi-fidelity system to enable design and trade-off studies between the HEX heat requirements and the aerodynamic performance of the exhaust system.

References

[1] H. Cao, Z.G. Zhou, X.L. Ye, Aerodynamic characteristic comparison of ultra-highly and normally loaded fans, The Aeronautical Journal, Vol. 125, No. 1293, 2021

[2] L. Larsson, T. Gronstedt, K. G. Kyprianidis, Conceptual design and mission analysis for a geared turbofan and an open rotor configuration, Turbo Expo: Power for Land, Sea, and Air, Vol. 54617, 2011, pp. 359–370.

[3] K. G. Kyprianidis, T. Grnstedt, S. O. T. Ogaji, P. Pilidis, R. Singh, Assessment of Future Aero-engine Designs With Intercooled and Intercooled Recuperated Cores, Journal of Engineering for Gas Turbines and Power 133 (1), 011701 (09 2010).

[4] T. Nikolaidis, S. Jafari, D. Bosak, P. Pilidis, Exchange rate analysis for ultra high bypass ratio geared turbofan engines, Applied Sciences 10 (21) (2020) 7945.

[5] H. Li, H. Huang, G. Xu, J. Wen, H. Wu, Performance analysis of a novel compact air-air heat exchanger for aircraft gas turbine engine using LMTD method, Applied Thermal Engineering 116 (2017) 445–455.

[6] I. Goulos, T. Stankowski, D. MacManus, P. Woodrow, C. Sheaf, Civil turbofan engine exhaust aerodynamics: Impact of bypass nozzle after-body design, Aerospace Science and Technology, 73 (2018) 85-95.

[7] M. Ryemill, C. Bewick, J. Kee Min, The Rolls-Royce PLC UltraFan heat management challenge, 30th Congress of the International Council of the Aeronautical Sciences (ICAS 2016)

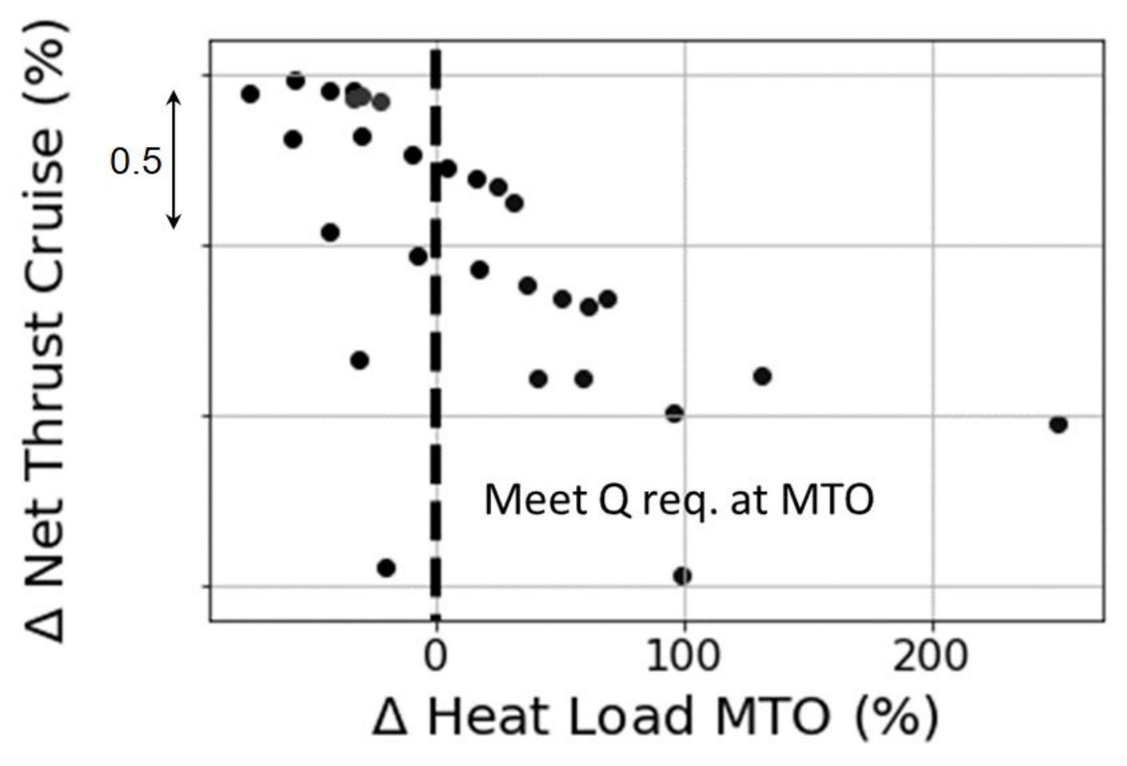

Figure 1 Trade-off between HEX heat load at MTO and engine net thrust at cruise condition.

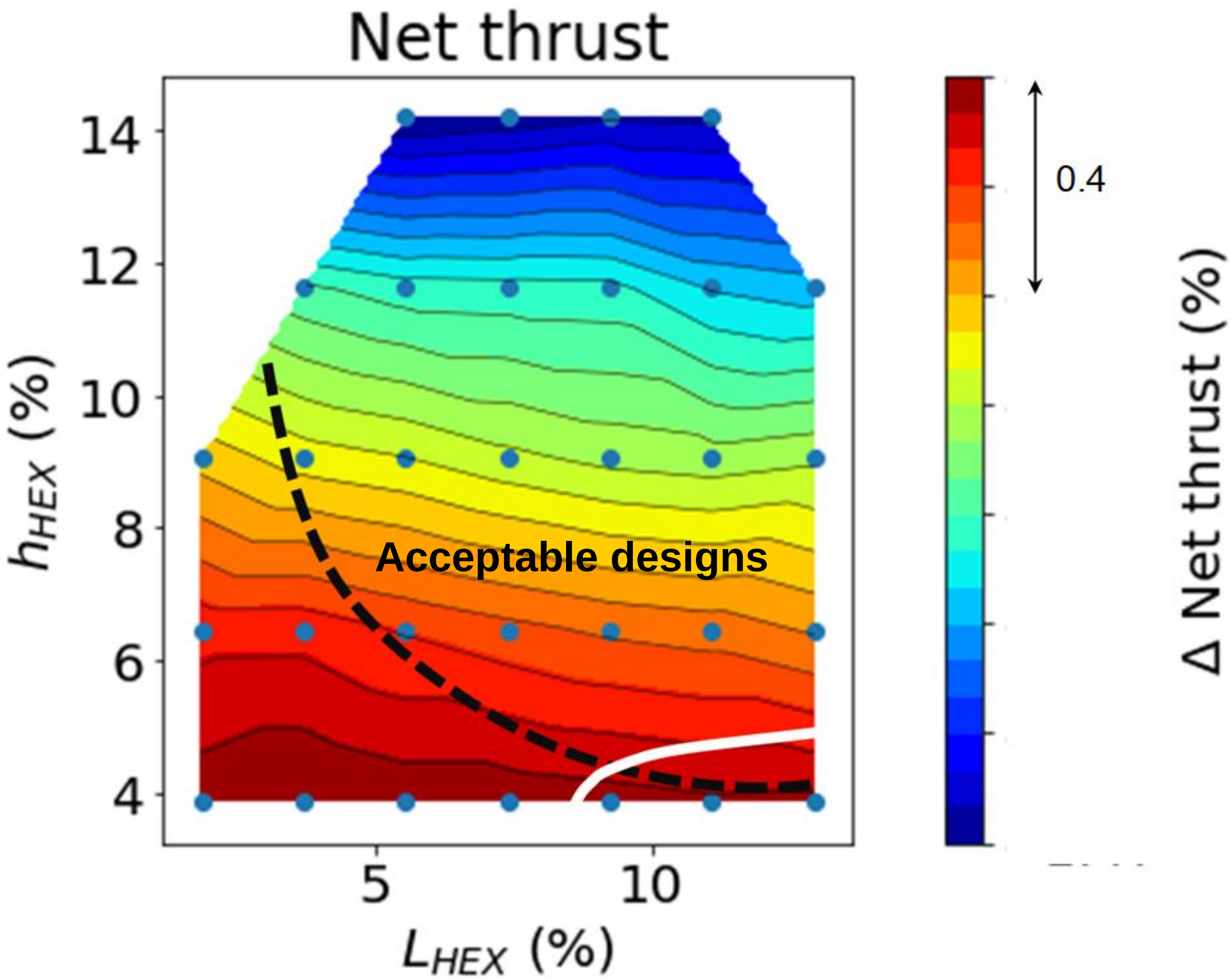

Figure 2 Contour map of loss thrust at cruise with change in HEX height and length.

Dashed black line = design bound for MTO heat load. Solid white line = design bound for intake separation.