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DESIGN OF A COMBINED CYCLE AIRBREATHING HYPERSONIC ENGINE FOR A SIMULATED POINT-TO-POINT MISSION: FROM CONCEPT SELECTION TO DETAILED DESIGN AND OPTIMISATION.

Abstract

In 2013 the University of Sydney aerospace design project challenged engineers to design a Mach 4 near-hypersonic aircraft that could carry a payload of 1800 kg of medical supplies from Sydney, Australia to Denver, Colorado. Student teams allocated subsystem designs amongst themselves, from materials, structures and aerodynamics to propulsion and weights and balance. This paper will present the design of the hypersonic engine to meet requirements for the aircraft, from concept selection to the detailed design and optimisation. A combined cycle airbreathing engine integrated with a ramjet was considered to be the most effective and efficient option considering the urgency of the missions and the lack of relevant operating infrastructure that a rocket based concept would require. Mission studies from the Concorde, LAPCAT and certain fighter aircraft contributed to initial engine sizing and performance estimates. From there engine cycle simulation software was used to generate on-design and off-design performance of the engine and to meet the mission requirements. Finally engine architecture studies were performed to consider the integration of the ramjet with the combined cycle engine. The paper will critically analyse additional options for the engine and include the multi-attribute utility trade-off (MAUT) that was used in coming to the final option as well as detail where the engine performs in relation to similar concepts in terms of operating maps and design point. The paper will also detail the design process, including the design decisions that were made for the required mission and the off-design trade-offs. In particular it will explore differing performance behaviour caused by varying bypass ratio, overall pressure ratio, turbine inlet temperature, variable area bypass and for the ramjet: inlet area and burner temperature. Optimisation studies will also be provided, including fuel burn and engine size. Inlet and nozzle design will also be explored. In addition the integration requirements for the ramjet, the challenges that were faced when attempting to design for this integration and the throttling mechanisms between the combined cycle engine and the ramjet will also be evaluated. The paper will finally present performance maps including the engine deck; on-design performance evaluations of thrust and TSFC compared at various altitudes and Mach numbers of the mission; and off design operating maps. The paper will analyse the assumptions that were made in the complete design process and the viability of the solution for production in terms of cost, manufacturing and the differing requirements for similar aircraft.