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Hypersonic Air-breathing and Combined Cycle Propulsion (9)

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PERFORMANCE ANALYSIS AND OPTIMIZATION FOR A PRECOOLED AIR TURBO ROCKET ENGINE USING DUAL FUEL OF LIQUEFIED NATURAL GAS AND KEROSENE

Abstract

An Air Turbo Rocket (ATR) engine usually employs high temperature fuel rich gas to drive its turbine according to its working principle. If it uses hydrocarbon fuel, the fuel should be rich in hydrogen to avoid the generation of small particles of unburnt carbon, which might damage the downstream flow passage of the gas generator. Liquefied Natural Gas (LNG) is such a fuel consisting primarily of methane CH4 with some mixture of ethane C2H6. It is cooled down to liquid form for ease and safety of storage or transport. However, it must be stored approximately at an atmospheric pressure and a temperature of 162 C. This low temperature inevitably needs cryogenic tank and facilities to evaporate the LNG prior to its entry into the combustion chamber, lowering the engine thrust to weight ratio. In terms of achieving less engine weight, an approach of supplying kerosene in the burner of a LNG ATR engine to reduce the LNG consumption is proposed in this paper. The mass flow rates of the LNG and kerosene should be carefully matched to obtain a desired cycle maximum temperature and a practical turbine expansion ratio for the engine with acceptable performance. Therefore, a performance simulation model for an ATR engine using dual fuel of LNG and kerosene with the assumption of equilibrium fuel rich gas as the working fluid in the gas generator is established. To minimize the weight of the facilities to evaporate the LNG stored in the tanks in a liquid state without external heat sources, an inlet precooler and turbine rotors are utilized as LNG heaters for a compact engine in this model. Then parametric cycle studies are performed with the variation of LNG/air ratio, kerosene/air ratio, compressor pressure ratio and combustion temperatures at the flight Mach number of 0 and 4 respectively. The interrelationships between cycle parameters and their effects on cycle performance are discussed. Based on the parametric analysis, cycle parameters for an optimized ATR engine using the dual fuel are also suggested. The predicted engine performance shows that the ATR engine using the fuel of LNG and kerosene might reduce the consumption of LNG by 42% and increase the engine specific impulse by 11% when compared with the ATR engine only using the fuel of kerosene. It is proved that this dual fuel engine might be a promising propulsion system for high speed air-breathing flying vehicles.