SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic and Combined Cycle Propulsion (5)

Author: Dr. Dajun Xu
Beihang University, China, xdj@buaa.edu.cn

MODELING AND SIMULATION OF RBCC ENGINE CYCLE

Abstract

RBCC engine combine the most desirable characteristics of airbreathing engines and rockets into a single, integrated engine, which could be used as potential propulsion system for aerospace plane. Along a typical SSTO ascent trajectory a RBCC engine operates in five modes: ducted rocket, ramjet, scramjet, scramjet/rocket, and pure rocket. Different engine cycle are needed for various engine operating modes. Modeling and simulation of a RBCC engine cycle were undertaken in this paper. RBCC engines use liquid hydrogen as fuel to propel the aerospace plane ascends in atmosphere. When outside the atmosphere, liquid oxygen and hydrogen are feed into pure rocket which push the vehicle insert orbit. During the ducted rocket mode, the engine's fuel side is powered by a fuel-rich gas generator. The oxygen side is powered by an oxidizer-rich staged combustion cycle. During pure airbreathing modes, the engine's entire oxygen feed system is inactive. The fuel side operates in a expander cycle mode using heat available from required cooling of the engine structure. In the Scramjet/Rocket mode the fuel remains operating in the expander cycle and the oxidized is restarted in the stage combustion cycle. Fuel/oxygen turbopumps, fuel-rich gas generator, oxygen-rich preburner, and pipes were modeled. Balance equations of mass flux, pressure and power were built to determine parameters of each part, include flow mass flux, power, and pressure ratios of turbopumps, etc. Through simulation of engine cycle, several results were concluded. Compared with full rocket engine, RBCC combustor has lower pressure, thus fuel turbopump has characters of smaller entrance pressure and pressure ratio. Fuel absorbs heat from engine and vehicle airframe through heat exchanger in ram/scramjet mode, its temperature increase and pressure decrease, could be injected into combustor directly. In pure rocket mode, fuel turbopump is driven by expander cycle, but pressure of fuel enter rocket combustor is too lower, can't satisfied requirement of combustor pressure 6MPa, thus fuel flow mass flux should be increased. Some advices were given to engine cycle according simulation results. In pure rocket mode, fuel turbopump should be driven by gas generated by oxygen-rich preburner instead of expander cycle. Fuel-rich gas generator only operate in ducted rocket mode, thus could be removed replaced with oxygen-rich preburner gas drive fuel and oxygen turbopumps together. Improved engine cycle can satisfy various engine operating modes and reduces weight of engine cycle system.