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# CYCLE ANALYSIS AND OPTIMIZATION OF THE PRECOOLED AIR TURBO-RAMJET

**Abstract**

With the increased emphasis on enhanced performance of the aircraft and strong need to broader the flight envelope, ATREX (Air Turbo-Ramjet Expander-cycle) was put forward by Japanese scholars. Obviously, as flight speed increases, stagnation temperature of the incoming air sharply increases, so that the temperature is too high for the turbomachinery to work. To solve this problem, precooled ATREX emerged, that means the engine adopts a precooling cycle using cryogenic liquid hydrogen. The high temperature inlet air of hypersonic flight would be cooled through an air-precooler by the same liquid hydrogen used as fuel. Hence, to find out the determinants and value the importance of the heat transfer in the precooled engine, it is necessary to do cycle analysis. Moreover, temperature of the air passed behind the air-precooler is a new parameter that influences the performance and thus needs to be optimized. In this paper, cycle analysis for the precooled engine is provided by applying the first law of thermodynamics to find out the determinants for the cycle work and cycle efficiency. Non-dimensional model with variable specific heat capacity is built to compare the performance of the precooled ATREX and the normal one. Taking the structure differences between those two types of engines above into consideration, the maximum performance under the technology available nowadays is calculated. Furthermore, optimization of parameters of the components is carried out to find the tradeoff between the specific impulse and the specific thrust by applying multi-objective optimization with restraints. This analytical study finds out that heating ratio, precooling ratio and total compression ratio are the three determinants for the cycle work and cycle efficiency, and there is one optimum total compression ratio for a specific engine cycle to reach the maximum cycle work. The comparison work shows that precooled ATREX can equipment fan/compressor with higher design compression ratio, and can gain broader flight envelope compared to the normal one, under the technology available now. While simulating the flight process of the precooled ATREX, results show that the specific impulse will decrease rapidly due to the increase flow rate of the fuel for precooling, if temperature of the air behind the precooler is forced to be a specific constant value instead of a variable value as the flight condition changes. The optimization work shows that phenomenon can be improved significantly by controlling the flow rate of fuel, which changes regularly as the flight condition changes.