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

Author: Dr. Hiroaki Kobayashi
Japan Aerospace Exploration Agency (JAXA), Japan, kobayashi.hiroaki@jaxa.jp

Dr. Hideyuki Taguchi
Japan Aerospace Exploration Agency (JAXA), Japan, taguchi.hideyuki@jaxa.jp
Mr. Takayuki Kojima
Japan Aerospace Exploration Agency (JAXA), Japan, kobayashi.hiroaki@jaxa.jp
Dr. Yusuke Maru
Japan Aerospace Exploration Agency (JAXA), ISAS, Japan, maru.yusuke@jaxa.jp
Prof. Shujiro Sawai
Japan Aerospace Exploration Agency (JAXA), Japan, sawai.shujiro@jaxa.jp
Prof. Tetsuya Sato
Waseda University, Japan, sato.tetsuya@waseda.jp

ALTITUDE TESTING OF THE HYPERSONIC TURBOJET ENGINE AT MACH 2 FLIGHT CONDITION

Abstract

Research on hypersonic turbojet engine with air-precooling system is under development in JAXA for the propulsion system of hypersonic transport. A notable feature of this engine is to use an air pre-cooling device using liquid hydrogen fuel as a coolant in order to protect the turbo-machinery from aerodynamic heating under hypersonic flight conditions. JAXA's recent model of the hypersonic turbojet engine has 0.225 by 0.225 meters square cross section, a total length of 2.67m, and a mass of 134kg. It produces a thrust of 1 kN by firing liquid hydrogen fuel in afterburner, its compressor rotational speed is 80,000rpm and its compressor pressure ratio is six. This engine is developed for a Mach 2 flight test with a balloon-launched missile-like vehicle scheduled in May 2010. This paper reports pre-flight verification test results of the engine in altitude test facility and post-flight analysis. High altitude environment was formed in a combustion wind tunnel facility in JAXA's Akiruno Research Center. The wind tunnel consists of a vacuum chamber and a water ejector exhausting air including air-hydrogen combustion gas. Air flow rate and pressure was regulated properly with flow control valves connected in front of the engine. Hydrogen fuel was supplied from gas cylinders and was regulated with an electromagnetic valve to control turbine inlet temperature of combustion gas. Hydrogen ignitability limit in high altitude environment was obtained. It was found that the engine can be started without electric motor due to wind-milling effect at high altitude condition. Acceleration of rotational speed in flight conditions is very larger than that in sea level condition. This is due to the fact that the turbine chokes immediately after the ignition. In the sea level static condition, turbine pressure ratio gradually increases with compressor rotational speed and pressure ratio, therefore the power for accelerating rotational speed is little at low rotational speed, while the wind-milling engine has plenty of turbine power independently from the compressor status. It was also found that turbine inlet temperature can be reduced by 200 K due to that the turbine power is enough. Turbine inlet temperature margin makes easier to design engine controller for the engine operated in the flight environment including various error factors. Verification tests in the altitude test facility were successfully conducted, therefore we are ready for the first Mach 2 flight in May 2010.