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Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

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DESIGN OF A HIGHLY REUSABLE AIR TURBO-ROCKET ENGINE

Abstract

Fully reusable hypersonic cruise, and single-stage-to-orbit vehicles have remained an engineering challenge for over half a century. Such missions span a wide range of flight speeds and atmospheric conditions under which the different components must operate with sufficient efficiency. Such requirements are especially demanding on the propulsion system. Existing propulsion solutions belong to one of two families: rocket and air-breathing engines. Rocket engines are the best option in the upper part of the atmosphere, where low pressures do not allow for air breathing engines. However, they have a poor efficiency at low altitudes, due to their low specific impulse, resulting from having to carry the oxidizer on-board. Turbojet (air-breathing) engines, on the other hand, have a significantly better specific impulse, since the oxidizer is taken from the atmosphere. However, they can hardly operate in high-speed conditions (beyond Mach 2.5) due to material limitations in the turbine, and the inefficiency of afterburners. Ramjets do not have such material limitations, due to the absence of a turbine, but are unable to operate in low-speed situations where static compression is insufficient. Air turbo-rocket (ATR) engines present themselves as a valid candidate meeting such broad mission requirements. They also feature a dynamic rotating compressor (like turbojet engines) connected to a turbine. However, this turbine is not driven by the hot air flow leaving the main combustion chamber, but rather from a secondary colder flow. This relaxes the turbine's material limitations, allowing ATR engines to operate with a high specific impulse in a range of flight Mach numbers from 0 to 5. ATR engines, fueled by liquid hydrogen, are being developed by Destinus to power their upcoming hyperplanes in the first parts of their missions. This paper covers the development process of such ATR engines. First, different layouts are compared in terms of performance, design complexity, and manufacturability. Then the detailed design process, construction, and testing of the selected configuration is presented, including relevant results from each of these phases.