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FLUIDIC THRUST VECTOR CONTROL FOR RENDEZVOUS MISSIONS

Abstract

The challenge of space debris mitigation and interest in asteroid deflection and mining operations necessitate increasingly complex rendezvous missions. High-precision rotational and translational capabilities are required to successfully approach, dock with, or manoeuvre an uncooperative target. The ability to control the thrust vector of individual attitude control thrusters has the potential to improve manoeuvring precision by minimising the number of required thruster pulses and compensating for thrust misalignment. A fluidic thrust vector control system is proposed to achieve this with minimal moving parts and power requirements.

Fluidic thrust vectoring (FTV) is the control of the propulsive exhaust flow with the injection of a secondary fluid. This can be achieved by flow turning through oblique shock waves if injection occurs in the supersonic section of the nozzle, or skewing of the nozzle throat if injection occurs subsonically at the throat. FTV is potentially compatible with cold gas, chemical, and electro-thermal thrusters, while additional hardware is limited to valves, piping, and optional pressure regulators outside of the primary flow path. The secondary fluid can be identical to the main propellant, eliminating the need for a separate storage tank. With constant nozzle and injector geometry, the thrust vector angle can be controlled in real-time by regulating the injection pressure.

The sensitivity of FTV performance to combustion chamber temperature, pressure, and injector configurations has been examined using three-dimensional computational fluid dynamics simulations. This paper will provide an estimate of achievable thrust efficiency, vector angle, and propellant consumption for a typical attitude control thruster and report transient simulations performed to determine approximate flow stabilisation times for control system implementation. The paper will also present results of experimental validation in the UNSW Canberra vacuum chamber with a biaxial thrust stand and 3D printed FTV nozzles. The performance results will be used to develop a simplified docking simulation to compare the required number of thruster pulses and fuel consumption of an FTV control system to a traditional attitude control system.