SPACE PROPULSION SYMPOSIUM (C4)
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Author: Dr. David Greatrix
Ryerson University, Canada

Mr. Clayton Wozney
Ryerson University, Canada
Mr. Markus Bockelt
Munich University of Applied Sciences, Germany

ALTERNATIVE THRUST MODULATION TECHNIQUES FOR SOLID AND HYBRID ROCKETS

Abstract

Alternative approaches for controlling the thrust level of either an AP/PBAA solid-propellant rocket motor (SRM) or N2O/HTPB hybrid rocket engine (HRE) over the course of a rocket vehicle's flight mission are examined in this substantive computational study. The on-command approach for modulating the thrust of an SRM is based on spinning the SRM about the motor's longitudinal axis at a given rate to deliver the required propellant burning rate increase and corresponding thrust level. The on-command approach for modulating the thrust of an HRE is based on applying different levels of swirl to the incoming head-end oxidizer flow, which in turn delivers the required fuel burning rate increase and corresponding thrust level. Predicted pressure-time and thrust-time profiles are included among the study's results. By applying and varying the spin rate of an SRM, one exploits the well-documented phenomenon of normal-acceleration-based burning-rate sensitivity of solid propellants (effective compression of the combustion zone). As a potential advantage, this technique for modulation of thrust may involve lower flow energy/momentum losses, versus existing SRM thrust-control approaches, like the usage of a pintle nozzle. Applications that may more readily take advantage of the proposed SRM spin technique would be spin-stabilized flight vehicles (complete vehicle under spin) with existing differentially-actuated external aerodynamic control surfaces for controlling the roll of the vehicle, or alternatively via existing internal hot-nozzle-flow thrust-vector-control (TVC) devices. Other applications may require that only the SRM be rotated, with the forward part of the flight vehicle unrotated; this would entail the usage of slip rings, etc., in separating the motion of the two vehicle components. Traditional hybrid rocket engine fuels (like hydroxyl-terminated polybutadiene [HTPB]) at larger engine scales (length, port diameter) tend to have an intrinsically low base burning rate (as a function of the local axial mass flux). It is a distinct performance advantage to utilize only a single central port, rather than going to a multi-port configuration (commonly used in current larger HREs) that might be forced by the slow-burning problem. The well-documented effect of local tangential swirl flow above an HRE's burning fuel surface is to increase the surface regression rate. The proposed technique of applying additional levels of swirl, used in conjunction with increasing the incoming oxidizer mass flow rate via a conventional throttle approach, can help to expand the conventional thrust-range capability of an HRE for a given mission, in addition to potentially allowing for a single-port, cylindrical-grain configuration.