SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Systems II (2)

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CONTROLLABLE SOLID ROCKET MOTOR THROTTLEABILITY AND ACCURATE CONTINUOUS THRUST ADJUSTMENT

Abstract

Controllable solid rocket motors (CSRMs), keeping unchanged the benefits of solid propellant motors, they feature thrust command control comparable to liquid propellant engines. Throat area regulation through a pintle-nozzle may be used to gain controllability of thrust driving variations in combustion chamber pressure, in burn rate, in mass flow and in other motor internal ballistic parameters. CSRMs technological advancements have been mainly directed towards the development of the controlled nozzle and recently CSRMs with lower idles and with faster nozzle actuations have been attained. Having the ability to achieve accurately adjusted high thrust intensity, to manage the propellant consumption, to stop and restart the motor, CSRMs have the potential to be included in future manned space exploration programs as propulsion systems for critical phase operations like rocket landing systems of planetary exploration modules, space vehicles proximity attitude control systems, all-altitude abort mission systems. Requiring a continuous thrust adjustment, such kind of applications lead the CSRMs to operate continuously under transient conditions. Since technologies for high velocity and large excursion of nozzle operations are already proven, the authors consider that a deeper predictive analysis of the continuously adjusted thrust response of the motor is vital. Extending previous works on the CSRM stability, this paper studies the influences of some motor features like chamber geometry, propellant, combustion products, pintle-nozzle geometry and masses and operating point parameters, on transient motor response following continual operations of the pintle-nozzle in terms of error/delay of the adjusted thrust. The study involve the analysis of the continuous unsteady nonlinear behaviour of the CSRM and includes the development of a nonlinear unsteady combustion model able to handle also the unsteady conditions consequent to the large and rapid pressure changes in the combustion chamber following some nozzle operations. Propellant parameters, heat transfer, burning rate, combustion surface, outflow through the variable nozzle and properties of combustion products are taken into account. The grain surface involved in the combustion is formulated with a regression model of the chamber walls, in reliance on the unsteady burning rate and on the grain geometry, and reflects the history of performed nozzle operations. A novel investigation on the hysteresis showed by the adjusted thrust with reference to the propellant unsteady response and some nozzle operation sequences is anticipated.