FLOW FIELD SIMULATION TOOL OF SOLID PROPULSION CONTROL SYSTEMS FOR MISSILE APPLICATIONS

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Abstract

In order to achieve hit-to-kill miss distances against manoeuvrable ballistic missile targets, future generation missiles calls for fast response non-conventional propulsion control systems during terminal homing period in high-endo to exo-atmosphere regions augmenting aero control. Based on advances in thrust modulation controlling throat area in solid propulsion pintle motor, control systems are developed for missile Divert and Attitude Control Systems (DACS) applications using multiple nozzles in pitch/yaw directions connected to common gas generator. Control thrust vector for lateral and attitude corrections is generated with proportional distribution of total thrust in pitch/yaw directions through real time thrust modulation of pintle nozzles Towards development of propulsion control systems based on solid propulsion, prototype systems: Thrust Controlled Motor (TCM) and Divert Thruster Flight Propulsion Control System (DTFPCS) are developed to demonstrate thrust modulation/ control thrust vector generation in solid propulsion and finalize unified controller for various missile control applications. Design & development process of prototype systems calls for flow field simulation tool for parametric design analysis/optimization and generate performance maps/control parameters based on detailed flow distributions. Present paper presents flow field simulation tools with Steady Flow Field (SFF) model and Dynamic Flow Field (DFF) model integrating dynamics of pintle movement with steady flow solver. Parametric analysis of geometrical profiles of pintle/throat regions and effect of pintle speed on system response are presented for system design optimization. Performance maps and controller maps of prototype systems are generated based on flow field distributions for nozzle thrust modulation. Simulated results are compared with open loop hot tests and unified controller parameters are updated for control thrust vector generation. Finally flow field distributions of DTFPCS operating modes: neutral-thrust and lateral-thrust are presented demonstrating the utility of simulation tool in design analysis and system development. Present simulation tool is critical in system designoptimization and unified controller development for various flight control applications with minimum number of developmental tests. Further work of integrating propellant grain geometry variation during motor hot tests, with flow field model is in progress to predict control system performance for various missile control applications.

Keywords: Divert Attitude Control System, Pintle Motor, Thrust Controlled Motor, Divert Thrust Flight Propulsion Control System, Combustion Gasses, Frozen Equilibrium Composition