SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic Air-breathing and Combined Cycle Propulsion (9)

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HIGHLY RELIABLE LIFE TIME EVALUATION APPROACHES FOR RAMJET BOOSTER STAGE OF NEXT REUSABLE LAUNCH VEHICLE

Abstract

Ramjet, TBCC and RBCC may be used as the main booster stages for the next generation launch vehicle characterized by reusability. A system composed of a reusable air-breathing ramjet booster stage plus a chemical rocket second-stage-to-orbit would reduce gross lift-off weight versus a traditional all-rocket system. The use of reusable ramjet booster stage would also reduce operational costs, and move orbital launch systems toward greater overall environmental efficiencies. One of the critical design factors is to estimate the life time of this kind of reusable booster engines. The goal in this paper is to establish the process to quantify/verify life times, and the process is based on the main failure mode identification, precise load spectrum simulation, material fatigue date testing, life time evaluation, and verification of them. A new approach, consists of structure strength examination, micro hardness tests, non destructive evaluation and metallographic analysis, is conducted to determinate the main fatigue mode. High temperature experiments in low cycle fatigue and creep fatigue are carried out, and the fatigue and creep date are described as plots of stress as a function of number of cycles or duration to fracture, which are called stress-life curves. In order to reduce the uncertainty of the stress and strength, the standard deviation method is used to describe stress-life curves in case of high reliability. The multi-physics coupled simulation method is conducted to solve the coupled thermal-fluid-structure response through the whole working processes to establish the load spectrum. Based on experimental analysis method, a life time estimation program has been developed and integrated into finite element method package, and the low cycle fatigue and creep fatigue of ramjet are carried out. Some simulation results are compared with the date measured during engine hot tests, and the agreement is excellent, which verify the numerical method.