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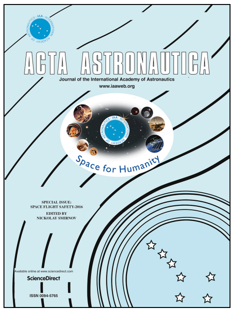

Three-dimensional multi-physics coupled simulation of ignition transient in a dual pulse solid rocket motor

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Three-dimensional multi-physics coupled simulation of ignition transient in a dual pulse solid rocket motor

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Abstract: In this paper, numerical investigation of ignition transient in a dual pulse solid rocket motor has been conducted. An in-house code has been developed in order to solve multi-physics governing equations, including unsteady compressible flow, heat conduction and structural dynamic. The simplified numerical models for solid propellant ignition and combustion have been added. The conventional serial staggered algorithm is adopted to simulate the fluid structure interaction problems in a loosely-coupled manner. The accuracy of the coupling procedure is validated by the behavior of a cantilever panel subjected to a shock wave. Then, the detailed flow field development, flame propagation characteristics, pressure evolution in the combustion chamber, and the structural response of metal diaphragm are analyzed carefully. The burst-time and burst-pressure of the metal diaphragm are also obtained. The individual effects of the igniter's mass flow rate, metal diaphragm thickness and diameter on the ignition transient have been systemically compared. The numerical results show that the evolution of the flow field in the combustion chamber, the temperature distribution on the propellant surface and the pressure loading on the metal diaphragm surface present a strong three-dimensional behavior during the initial ignition stage. The rupture of metal diaphragm is not only related to the magnitude of pressure loading on the diaphragm surface, but also to the history of pressure loading. The metal diaphragm thickness and diameter have a significant effect on the burst-time and burst-pressure of metal diaphragm.

Keywords: multi-physics coupled, fluid structure interaction, ignition transient, solid rocket motor, dual pulse motor

1. Introduction

Solid rocket motors (SRMs) are widely used in military and civil applications due to high performance, simplicity, reliability, and low cost compared with alternative propulsion systems. For the past few decades, SRMs have been extensively developed for different missions. However, the shortcomings of SRM are that the thrust evolution is significantly pre-defined by the initial shape of the propellant grain and the free burning surface, allowing for a lack of freedom regarding thrust management. The implementation of a thrust management system has been proven by a dual pulse solid rocket motor (DPSRM) technology, where the propellant is consumed in two discrete combustion chambers separated by a pulse separation device (PSD). Both stages exhaust through a common nozzle and the delay time between the burnout of the first pulse and the ignition of the second pulse can be easily controlled. The theoretical studies [1,2] have shown that the DPSRM can offer the potential for significant range extension for a given total impulse, increase end game maneuverability and gain terminal velocity for a specified range.

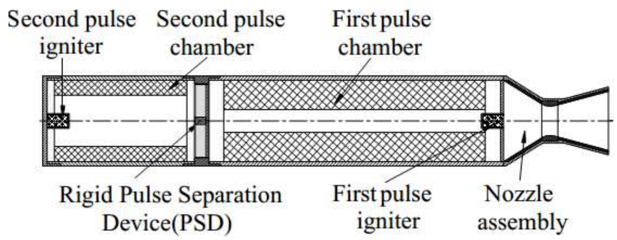

Fig. 1. Schematic diagram of a dual pulse solid rocket motor with rigid pulse separation device

Recently, numerous researchers have advanced the study of DPSRMs. Naumann et al. [3] outlined the benefits and the limitations of DPSRM and gave an overview of the state of the art. The most critical component is the pulse separation device (PSD) which has to protect the second pulse propellant grain during the operation of the first pulse and

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