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Author: Prof. Sterian Danaila
University POLITEHNICA of Bucharest - Research Center for Aeronautics and Space, Romania

Prof. Teodor-Viorel Chelaru
University POLITEHNICA of Bucharest - Research Center for Aeronautics and Space, Romania

ASPECTS REGARDING HYBRID COMBUSTION INSTABILITY CONTROL

Abstract

One of the possible applications of hybrid combustion regards techniques for multi-axis orbit control. In these applications, the control of the magnitude and of the spatial orientation of trust is essential for system operation. Unfortunately, experimental data highlight significant pressure fluctuations in the combustion chamber and the symmetry breakdown, due the combustion instabilities. There are several mechanisms suspected of leading to combustion instabilities, such as pressure sensitivity of the flame speed and the formation of large-scale turbulent structures. While an attempt to suppress combustion instabilities in practical applications has to address all these sources, the current work focuses on coherent structures as the driving mechanism in creating noise. In the present paper, a combined method of large eddy simulations for non-premixed combustion in a turbulent flow coupled with proper orthogonal decomposition of instantaneous velocity, pressure and temperature fields is developed in order to identify the effect of coherent structure and to obtain a reduced order model for control model. Static-control strategies are more robust and need a minimum of maintenance. With static control, a hybrid engine can be designed which is naturally less prone to combustion instabilities. However, to give design guidelines for static control, more information on this type of control has to be gathered. First we investigate the reacting flow using Large Eddy Simulations technique. This physical model is pertinent to internal flows inside the hybrid rocket motors. The regression process at the wall of the solid propellant is modeled by either constant mass flow rate or variable mass flux of the major combustible species of the fuel grain pyrolysis in order to identify the behavior of turbulent structures in vicinity of the wall. HTPB/O2 has been considered as fuel/oxidant pair. The turbulence-combustion interaction is based on a combination of finite rate/eddy dissipation model applied to a reduced chemical mechanism with four reactions. Next, the paper refers to the derivation of a Reduced Order Model (ROM) for the same problem. ROMs are used to obtain fast and accurate results, needed in the areas of flow control. Two cases of interest are analyzed in this paper: constant and variable regression rate. In both cases the flow and thermal fields obtained with ROMs are compared with the ones obtained from the full simulation and an analysis on the number of modes required to achieve the desired accuracy is presented. Finally, a static control technique is proposed.