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ROBUST SLIDING MODE CONTROL OF A MOVING-MASS ACTUATED SUBORBITAL REENTRY BIOLOGICAL PAYLOAD

Abstract

This paper deals with the robust sliding mode control of a suborbital reentry biological payload utilizing moving-mass actuators. Sounding rockets are kind of small rockets, in comparison with satellite launchers, effectively used to conduct experiments in a suborbital trajectory (200 to 700 km) to develop space science and technologies. A typical sounding rocket mission is divided into three different phases: boost phase, experiment phase, and reentry phase. During the boost phase the rocket is accelerated using a motor till separation is occurred in right conditions. Afterward, payload is ready for later phase to perform the specific scientific experiments. Finally, in the reentry phase, the payload reenters the atmosphere and then return to the earth. Cone-cylinder and flat-faced circular cylinder payloads during reentry fall into tumbling, coning and flat spin angular motions due to high density atmosphere. This fact increases the emphasis on requirement for angular rate control of suborbital payloads to ensure that payload containing experimental results will survive during the reentry phase. In a biological payload that is under the study on this investigation, reentry rate regulation is one of the critical issues must be solved. Because of nonlinear time-varying dynamics of these payloads and presence of high aerodynamic disturbances during reentry, choosing an appropriate stability and control mechanism can be an engineering challenge. Moving-mass actuation is an innovative concept introduced recently to control of reentry vehicles. The moving-mass actuation technique offers great advantages over traditional aerodynamic control methods. First, the moving mass actuators are completely enclosed within the geometric envelope of the vehicle which does not affect the efficient aerodynamic shape. Second, these mechanisms use the aerodynamic force and moment in high speed flight to generate required control inputs to stabilize or control of reentry payloads. The present research develops a novel three-degree-of-freedom model of a suborbital biological payload moving in a vertical plane with one moving-mass actuator. In addition, sliding mode control is invoked to regulate the time-varying payload body rates during reentry phase despite inherent uncertainties and aerodynamic disturbances. The moving-mass control system changes the biological payload center of mass relative to the external forces to generate the desired control moments during reentry phase. The asymptotic stability and robustness of the proposed control systems is proved using direct method of Lyapunov. Finally, effectiveness of the proposed moving-mass control system based on sliding mode concept for reentry rate regulation of a suborbital biological payload is demonstrated.