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FEASIBILITY STUDY OF LOADS REDUCTION IN PROCESS OF LARGE SPACE DEBRIS OBJECT CAPTURING WITH ROBOTIC ARM

Abstract

Removing large-sized space debris objects from near-Earth space is a priority in technogenic space pollution control. These objects are a potential source of extremely dangerous small fragments that are difficult to detect and remove. The report studies an active debris removal mission for a group of 10...15 Zenith-2 or Kosmos-3M launch vehicles' upper stages. An original two-stage disposal spacecraft configuration was proposed. A distinctive feature of the spacecraft is a multi-link robotic arm used for the object capturing. Using the approximately 13 m long robotic arm with rotational and translational joints makes it possible to implement a capturing technique similar the traditional 'probe-drogue' docking technique inserting arm's end effector into the stage's main engine nozzle. Such a configuration is beneficial with an extended range of initial docking conditions, since the robotic arm enables to capture a noncooperative body, tumbling with a rate of about 10...20 degrees/sec. Previous studies by the authors provided an estimation of maximum structural loads occurring upon the docking mechanism engagement and arm coming to stop using a simplified spacecraft-robotic arm-object dynamic model. The purpose of the current research is to find the most rational robotic arm control sequences for both the nozzle approach and capture phases. Control laws for both idealized and realistic robotic arm joint actuators were developed using a cluster of ADAMS and Matlab Simulink software. The simulations involved a number of simplifications, i.e. system's motion in a single plane was considered, idealized system kinematic parameters sensor models were used, robotic arm's links were considered to be absolutely rigid. The report contains simulation results for various capturing modes, as well as the analysis of various methods of damping the transients, arising after the docking mechanism is engaged in the nozzle. The damping can be implemented either actively by means of joint actuators or passively by means of shock absorbers incorporated into the robotic arm structure. One of the ways to reduce the loads in process of capturing is coordinating the robotic arm's motion with the motion of the object after the capture. It increases the duration of coupling reaction forces and torques action and, as a consequence, reducing their magnitudes. The robotic arm mass was refined based on the obtained arm actuators power requirements and the mass budget of the disposal spacecraft was updated.