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DOCKING OF A SPACE TUG WITH UPPER STAGE DEBRIS OBJECT USING DEPLOYABLE FLEXIBLE BEAM

Abstract

We propose a new approach for docking of a space tug with a spent non-cooperative orbital stage (debris) by using a deployable elastic beam with high aspect ratio. The developed mathematical model demonstrates the proposed approach and covers all stages of the relative motion of the space tug and debris, including docking stage, beam retraction stage and debris de-tumbling stage.

Often, orbital stages are utilising jet nozzles to create additional forces (with the forces produced by separation devices like spring pushers) for safe separation from the main payload. This separation procedure can lead to the tumbling of the orbital stage at the end of its lifetime, which makes it difficult for docking with the space tug during active debris removal mission. The usage of known methods of docking, using, for example, a manipulator or "probe-cone" mechanism utilising the nozzle of the orbital stage can cause high dynamic loads in the construction of the docking device. It will require an increase in the mass of the mechanisms and complexity of the tug's control system.

We suggest that the retractable flexible docking beam with high aspect ratio reduces the reaction forces caused by the interaction between the elements of the docking device and the debris nozzle. After successful docking the beam deployment mechanism retracts the beam and docks the debris with the space tug. Successful docking refers to the passage of the beam's tip throw the nozzle throat which initiates the triggering of the latches to fix the part of the beam in the nozzle.

To analyse the possibility and effectiveness of using the proposed method the mathematical model of the relative motion of the tug with the elastic beam is developed. All stages of the tug-debris relative motion are considered, including the stage of unconstrained relative motion of the tug and debris, stage when the beam slides along the surface of the debris nozzle, the stage when the tug retracts the beam with the connected debris. The attitude motion of the connected tug and the debris is studied. The possibility of using the docking beam during damping the angular velocities of the tug-debris system is investigated. We consider several simulation cases to demonstrate the application of the proposed device for docking with the large tumbling debris objects like orbital stages.