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ULTRA-SOFT ELECTROMAGNETIC DOCKING WITH APPLICATIONS TO IN-ORBIT ASSEMBLY

Abstract

Docking small satellites in space is a high-risk operation due to the uncertainty in relative position and orientation and the lack of mature docking technologies. This is particularly true for missions that involve multiple docking and undocking procedures such as swarm-based construction. In this paper, an electromagnetic docking system is proposed to mitigate these risks through robust, ultra-soft, propellant-free docking. The system is composed of an electromagnet for controlled approach and a gripping mechanism. The electromagnetic docking phase initiates at a 30-50 cm separation. The electromagnet controllers then pull the two satellites together with decreasing magnetic force until the separation is small enough for the mechanical gripper to complete and rigidize the dock.

Designed with reconfigurable self-assembly in mind, the gripping mechanism is androgynous, able to dock at a variety of relative orientations, and tolerant of small misalignments. The ultra-soft nature of this docking system is also useful for these missions, because perturbations caused by standard docking could induce unwanted motion in the assembling structure, possibly leading to subsequent dock failure. The mechanical and control design of the system is presented and tested in both simulation and on a fleet of spacecraft simulators. The spacecraft simulators employ linear and spherical air bearings and linear actuators to achieve 5 degree of freedom dynamic and one degree of freedom kinematic simulation of spacecraft dynamics. The spacecraft simulators float on the precision flat floor facility in the Caltech Space Robotics lab, the largest of its kind at any university. After standard tests of the docking system, tests are expanded to include unusual docking conditions to determine the magnitude of alignment and actuation error from which it can recover.