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SPACE DEBRIS SYMPOSIUM (A6)
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INVESTIGATION OF ELECTROADHESION TECHNOLOGY FOR ON ORBIT ACTIVE SPACE DEBRIS REMOVAL

Abstract

Space debris is currently a growing threat to future space operations in near Earth environments. With humans and spacecraft present in the region, new solutions for debris control must be investigated and implemented to mitigate this issue.

This research investigates the effectiveness of a high-voltage electrostatic gripper in vacuum to validate the use of electroadhesion as a technique to actively capture and remove debris in space. Conformable single-phase and three-phase powered 6-pole electrostatic chucks were used for vacuum and ambient air tests, respectively. Five linear actuators were assembled to create a five degree of freedom test apparatus inside a small vacuum chamber to examine normal, shear, peeling, and twisting forces. For each actuator, current consumption and position were monitored to determine location and corresponding force profiles for maximum grip strength and grip loss.

Six samples were tested with the single-phase chuck in a 10E-6 Torr hard vacuum. These included aluminum, MLI, volcanic rock, a photovoltaic cell, and beta cloth. Samples were selected to roughly simulate orbital debris and commonly found materials on satellites. Similar testing was conducted in atmospheric conditions to study any changes in peel, pull, and shear modes. Qualitative and measured results suggest the gripper's ability to perform much better, in terms of grip strength, in shear and twist rather than with a pull configuration. Additional findings help characterize the gripper's performance under vacuum with respect to different materials and their properties.

For preliminary hardware simulations, the three-phase gripper was mounted to a robotic arm on a free-floating base with air bearings and thrusters on a frictionless epoxy flat floor environment. Testing was conducted in the Flight Robotics Laboratory at NASA Marshall Space Flight Center with objects including metal and MLI. The gripper was additionally tested in a high purity, low moisture air chamber as a control in order to characterize the effect of ambient humidity on electrostatic gripping effectiveness during simulation runs.

Research conducted has offered practical insight into the application of electroadhesion to manipulate objects in space, indicating potential for this technology to be developed into a platform for orbital debris capture and removal. Drawing from experimental results and lessons learned, this paper will further explore and outline the risks and challenges that the technology will have to overcome to integrate into future space debris removal systems.