A High Fidelity Ground-Based Space Environment Testbed Utilizing Magnetic Levitation for Fully Integrated Small Spacecraft

Abstract

Orbital debris has been, and will continue to be an issue for all space-bound systems and technologies. Small spacecraft are an increasing contribution to this issue with high rates of on-orbit failures. Developing a ground -based planar testbed with a near frictionless, vacuum environment for small spacecraft allows for higher fidelity, 3 degree of freedom (3DOF) testing of fully integrated propulsion systems and control algorithms prior to launch. Ultimately, this provides empirical data at a relatively low cost that can be used to reduce risk of on-orbit failures thereby mitigating contributions of small spacecraft to the growing orbital debris issue. A team at NASA's White Sands Test Facility (WSTF) is investigating the use of high temperature super conducting (HTSC) materials to induce magnetic levitation of a small spacecraft, or a constellation of small spacecraft, to provide this 3 DOF testbed within one of WSTF's existing space environment simulation chambers.

Methods

The team at NASA's White Sands Test Facility (WSTF) currently developing this technology utilizes high temperature super conductor (HTSC) tiles, which when cooled to a critical temperature, induce a magnetic field within the surface of the tiles. A variety of specialized magnetic arrays have been designed, manufactured, and tested in conjunction with the test bed of HTSC tiles. Interactions between the test bed and the magnetic arrays vary for each different magnetic array configuration. An effective, low-perturbation configuration has been established as a baseline and has allowed the WSTF team to characterize the HTSC test bed performance, such as the resistance to translational motion in terms of an effective dynamic coefficient of friction (CoF) for various mass loads. The baseline configuration has been tested under different mass configurations of 0kg, 0.4kg, 1kg and 1.4kg. These load cases were

Methods cont.

performed with half of a 1U CubeSat magnetic configuration and therefore represent only half of the lift capability of the full 1U magnetic configuration. During test trials a linear actuator exerts a constant force onto the sled until its is released, generating a controlled initial dynamic state. Advantages of this methodology include the absence of mechanical tethers required in planar air bearing systems, higher fidelity inertial property representation, sustained representative space-like vacuum levels, and more.

Results and Discussion

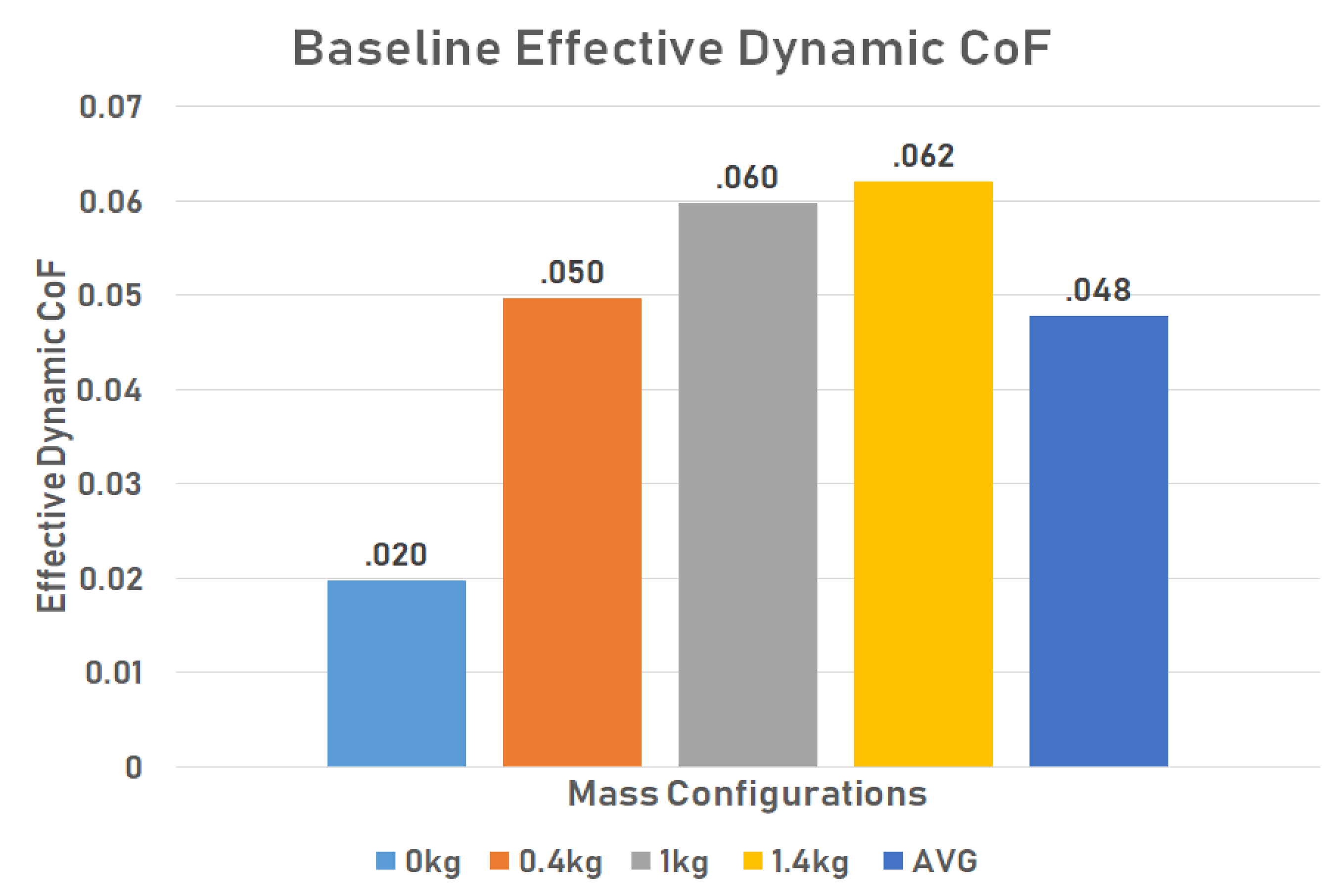

Figure 1: Baseline Effective CoF Graph

A graphic of the test apparatus is shown below with the sled levitating as it translates across the HTSC surface. A graph of the resulting effective dynamic CoF values for the various load cases is shown. With the magnetic configurations tested only representing half of a 1U CubeSat configuration, the results from the 0.4kg and 1.0kg loads were closer to a 1U CubeSat load case. Testing results to this point have indicated that this methodology is capable of providing sufficient levitation of a 1U CubeSat with very low perturbation to its 3 DOF dynamic state. Extrapolation to larger CubeSats, i.e. 2U, 3U, etc. is anticipated to be trivial.

Figure 2: Graphic displaying baseline test apparatus

Conclusion

Based on the data obtained from preliminary baseline examination we arrive at the conclusion that an increase in weight correlates to an increase in the effective dynamic CoF for a given magnetic configuration. We can also observe that the Maglev Testbed is adequately suitable for 1U CubeSat test specimens as their weight is typically under 1.33kg. Accommodating larger small spacecraft can be accomplished by increasing the number of magnets. Thus, the test bed platform is ideal for providing an extensive planar area for dynamic tests for small spacecraft. The NASA WSTF team is continually developing this technology, with space environment simulations within vacuum pressure levels currently in the design process. Additionally, the NASA WSTF team is currently working with local universities to test academic cold gas CubeSat propulsion systems prior to their orbital deployment. Ultimately, the NASA WSTF team anticipates to provide these testing facility to the ever growing sector of small satellites, spanning from academic institutions to commercial partners.

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