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CHARACTERIZATION OF A FLUX-PINNING INTERFACE FOR THE CONTROL OF NANOSATELLITES IN VERY CLOSE PROXIMITY

Abstract

In this work, we propose a system ensuring passive and autonomous station-keeping of a prescribed configuration of two, or more satellites, in very close proximity, which is realized equipping one satellite with a type-II superconductor and the other one with a permanent magnet. It is known that the interaction between two magnets can generate either a repulsive or an attractive force, differently a type-II superconductor and a magnet can show an interaction based on the flux-pinning effect and are therefore named a flux-pinning interface (FPI). The force exchanged by the FPI switches from attractive to repulsive as the two devices approach, therefore it allows binding the relative motion of the satellites while ensuring collision avoidance. To establish the flux-pinning effect, the superconductor must be cooled-down below its critical temperature, a process that can be performed by a passive thermal control system. Theoretical and experimental analyses allow characterizing the FPI and its impact on the stability of the satellite formation. The magnetic characterization of the type-II superconductor, in a sample of granular ceramic YBCO, is performed using a vibrating sample magnetometer. The force exchanged by the FPI is measured using a testbed where the magnet and the superconductor are integrated to air-bearing facilities, which allow recreating on ground the frictionless dynamics of relative motion in space. The two devices are equipped with three-axis accelerometer and gyroscope, used to measure the relative acceleration generated in the FPI by the flux-pinning effect and, therefore, the force exchanged by the two. Once characterized the FPI, a theoretical model of the relative motion in close-proximity under the dominant flux-pinning effect is developed. The dynamic equations of motion are derived using the Hamiltonian formalism and canonical transformations are introduced to rearrange them in a form equivalent to the Hill-Clohessy-Wiltshire equations. In this model, the term responsible for the time drift of the configuration can be isolated, hence bounded solutions, stable in the six degrees of freedom, are characterized by initial states which annihilate the drift term. Furthermore, it is proved that the equilibrium conditions of the FPI can be controlled by changing the magnetic field during the field-cooling process, allowing the selection of the desired configuration.