Controllability and redundancy aspects of a magnetically levitated reaction sphere actuator for satellite attitude control.

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Three-axis stabilized satellites require a device or set of devices capable of applying three-dimensional torques for maneuvering and stabilizing the spacecraft rotational motion. These torques are applied by a set of minimum three reaction wheels, but commonly four of them are used for redundancy and optimization purposes. Common measures to improve the lifetime and reliability of these actuators include the implementation of intrinsic redundancy by duplicating magnetic and winding sub-systems. A Reaction Sphere (RS) has been proposed as a potential alternative to reaction wheels. The RS consists of an 8-pole permanent magnet (PM) spherical rotor that is magnetically levitated and can be accelerated about any axis by a 20-pole stator with electromagnets, making all the three axes of the spacecraft controllable by just a single device.

In the proposed publication, we investigate how the RS controllability is affected in presence of stator coil or amplifier failures. The study of redundancy is performed by considering all possible configurations of operating coils (i.e. coils that are operating normally) for a given number of coil failures. Configurations are computed by using combinatorics and taking into account dodecahedron symmetries. Then, for a given equivalent combination, the study of failure tolerance is performed by monitoring the condition number and the norm of the multidimensional force and torque matrix, which indicate how close the system is to a singularity point. Global optimization has been used in order to search for singularities among all possible orientation of the rotor.

In conclusions, the RS remains controllable with at least 14 operating coils (e.g. a maximum of 6 coil failures are tolerated), which is an interesting self-redundancy characteristics of the proposed RS. As it will be discussed, however, the number of coil failures impacts negatively the torque to power ratio, which in turns reduces the performance of the actuator.

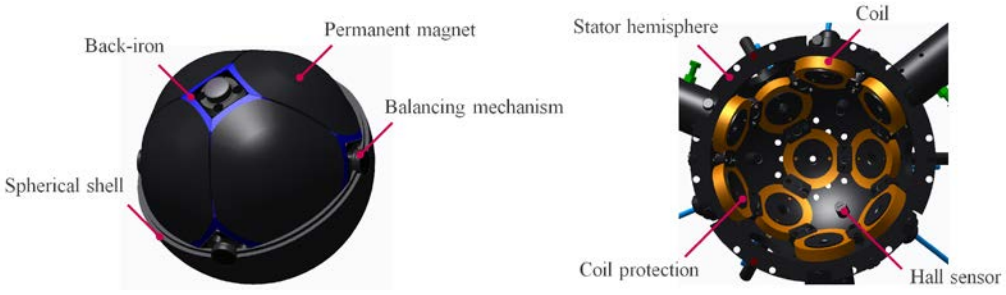

Figure 1. 8-pole PM rotor (left). A half part of the 20-pole stator (right).

[1] L. Rossini, E. Onillon, O. Chételat, and Y. Perriard, “Closed-loop magnetic bearing and angular velocity control of a reaction sphere actuator,” Mechatronics, vol. 30, pp. 214 – 224, 2015.

[2] G. Borque, L. Rossini, E. Onillon, and A. Karimi, “Linear parameter-varying Kalman filter for angular velocity estimation of a reaction sphere actuator for satellite attitude control,” in Advanced Intelligent Mechatronics (AIM), 2017 IEEE/ASME International Conference on.