
 ABSTRACTS (MASTER THESIS)

Optimal Design of High-Temperature Superconducting Coil for Magnetic Sail Spacecraft

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Magnetic sail is an innovative spacecraft propulsion system. The thrust of the sail is produced by the transfer of momentum from the solar wind, which is a plasma flow from the sun, to a strong magnetic field generated by a High Temperature Superconducting (HTS) coil installed in the spacecraft. Since a driving force of the magnetic sail is proportional to a magnetic moment (operational transport current $\times$ the area enclosed by the coil), the magnetic moment must be increased as large as possible. In this study, we perform an optimization study for the HTS coil in order to improve the thrust of the magnetic sail. We firstly developed an analysis method to predict the current transport performance and thermal behavior of HTS coils. We obtained the electric field versus current density as well as heat transfer characteristics of the Bi-2223/Ag tape from experiments using short length samples (30 mm length tape) at conduction cooling conditions. These characteristics of the HTS tape were modeled and analyzed by using the percolation depinning model and the two-dimensional heat balance equation. The percolation depinning model can describe the electric field versus current density of HTS tapes as a function of temperature and magnetic field vector. Next, we investigated the current transport and thermal characteristics of the Bi-2223/Ag double pancake coil. This scale-down model magnet was installed at a cold stage of a GM cryocooler. Only six pieces of aluminum sheets were attached symmetrically at both top and bottom surfaces of the magnet for cooling, taking into account the cooling constraint condition of the spacecraft system. We measured the temperature rises as well as its distribution of the magnet for various operation temperatures from 40 to 80 K, during current applications from 0 to 200 A. In addition, we analyzed the thermal behavior of the HTS magnet under the same conditions as the experiments, on the basis of the percolation depinning model and the three-dimensional heat balance equation. As a result, we showed that the analysis can successfully reproduce the experimental temperature traces for a wide range of operational temperature from 40 to 80 K, and that our analysis can estimate the exact quench currents of the HTS magnet. After developing an analysis method, we design an HTS coil to obtain a larger magnetic moment on the specific constraint conditions of a spacecraft system by using the developed analysis method. As a result, from a point of view of maximizing the magnetic moment for the spacecraft, the racetrack coil is the optimal configuration and the magnetic moment can be increased to 5.3 times larger than that of the former study. This study leads to the possibility of creating the world's first space propulsion system using an HTS coil.

References

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