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STATE OF THE ART REVIEW IN SUPERCONDUCTOR-BASED APPLIED-FIELD MAGNETOPLASMADYNAMIC THRUSTER TECHNOLOGY

Abstract

Magnetoplasmadynamic (MPD) thrusters, particularly of the Applied-Field type (AF-MPD), have long been considered as one of the most promising technologies for high-power electric propulsion of spacecraft. This assessment is based in their unique combination of properties such as: propellant flexibility, high thrust density with respect to other forms of electric propulsion, scalability to very high powers, as well as their throttleability characterized by the ability to operate at high specific impulses and high thrusts. Due to the extreme power consumption of conventional AF-MPD electromagnets, high-temperature superconductors (HTS) have been applied in the development of AF-MPD thruster prototypes in several institutions around the world.

After a recent increase in research interest around Applied-Field Magnetoplasmadynamic thrusters in Germany, Italy, Japan, China and Russia, considerable progress has been made during the past decade. The University of Stuttgart has achieved record-high thrust efficiencies of 62% using a conventional copper coil. Concurrently, several countries have initiated efforts to combine HTS with AF-MPD thrusters as part of their magnetic coils. At two research institutes in China, research activity is ongoing to develop very high-powered thrusters of up to 500kW. In Russia, efforts to develop and test a superconducting 25kW MPD thruster are underway as a cooperation between the National Research Nuclear University MEPhI and the company SuperOx and has produced a working prototype. Furthermore, New Zealand's Robinson Research Institute (RRI) has also launched an initiative to research superconducting MPD thrusters in cooperation with the University of Wellington. In contrast to the efforts of both China and Russia, the RRI focusses on lower-power thrusters with smaller form factors which could be used on small satellites. All three of the previously mentioned programs are at least partly nationally funded. Europe presently has R&D activities ongoing in form of the SUPREME concept from the company Neutron Star Systems, a system designed for a variety of operating powers, for use cases from small satellites up to interplanetary missions.

Due to the emergence of several development programs, including state-funded research, significant progress on superconducting AF-MPD technology is to be expected near-term. National funding campaigns underline the strategic importance of the technology on a global scale. This work gives a critical review on global recent developments in superconductor-based AF-MPD thruster technology. It furthermore identifies problem areas of the technology and assesses and contrasts the approaches each of the development programs have taken and presents the different target use-cases found amongst the programs.