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CONCEPT DESIGN OF AN IN-ORBIT PROPULSION SYSTEM BASED ON MAGNETOFLUIDS

Abstract

A concept design of a novel orbit control system is presented. It is based on the acceleration and subsequent ejection of magnetofluid droplets. Overall, the Gauss gun principle is investigated and extended on the utilisation of ferrofluids. Based on results of the student experiment PAPELL (Pump Application Using Pulsed Electromagnets for Liquid reLocation), the development of this acceleration concept is performed. PAPELL is a technology demonstrator that has been conducted on the International Space Station in 2018. A non-mechanical pumping mechanism has been realised with it, utilising single ferrofluid droplets as working medium to be transported by changing local magnetic fields. A low-maintenance and high-lifetime system can be achieved by the removal of mechanical components, leading to a possible innovative technology for future space transportation systems. With PAPELL, it has been demonstrated that ferrofluid droplets can be transported, split and merged in a microgravity environment. Considering these results, the concept design of the in-orbit propulsion system is based on a multistage Gauss gun. Working with coils acting as magnetic field sources, switched on and off successively to accelerate ferrofluid droplets utilised as propellant, a novel propulsion system is achieved. In detail, the magnetic flux density of each coil generates an accelerating force acting on the propellant. An equation for the estimation of the exhaust velocities for the droplets is derived depending on the ferrofluid type, the coil parameters and the acceleration or respective system length. Possibilities of increasing the exhaust velocity and thus the specific impulse of the propulsion systems are discussed. Additionally, the power supply system for the coils as well as the coil switching control are investigated and a thermal control for the propulsion system is discussed. A storage and feeding concept for the ferrofluid as well as a concept for the formation of droplets for acceleration are presented. A subsequent performance analysis is conducted showing theoretical results of specific impulses in a range of competing electric propulsion systems. However, the specific impulses are limited due to technical feasibility which is investigated further in this paper. Additionally, environmental limits are discussed to assess future applications. The theoretically promising results of the performance analysis lead to the expectation of an extended and more detailed analysis as well as practical tests of the acceleration concept and further validation activities.