PICO-SATELLITE ORBIT CONTROL BY VACUUM ARC THRUSTERS AS ENABLING TECHNOLOGY FOR FORMATIONS OF SMALL SATELLITES

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**ABSTRACT**

The introduction of pico-satellites, in the mass range of 1 kg, is an enabling technology to utilize near Earth space spending limited resources. In the last decade, dozens of spacecraft of this class, mainly Cubesats [1], were launched and many more missions are planned in the near future. One of the main goals of current research is to provide these miniaturized spacecraft with capabilities found in larger spacecraft, such as orbit control. The very limited resources on board a pico-satellite with respect to mass and power budget make conventional propulsion solutions unsuitable. Innovative electric propulsion devices are thus needed to fulfill pico-satellite requirements.

This paper presents recent developments made for the UWE-4 (University Wuerzburg Experimental) satellite project, a demonstration mission for a pico-satellite orbit control by using electric propulsion. Both the mission design and the orbit control strategies are discussed in this paper as well as the hardware implementation.

Orbit measurements of previous UWE satellites have shown that a loose along-track formation with relative distances of 10 - 100 km can be achieved even with limited propulsion capability. We demonstrate using optimal control approach (constrained linear regulator) that the propellant and power requirements for the spacecraft are within reach of a pico-satellite equipped with electric propulsion. Limits are derived for the necessary attitude control accuracy and power availability.

The UWE-4 is based on a modular Cubesat bus that was developed at Wuerzburg University [2]. The UWE satellite includes a comprehensive suite of sensors: sun sensors, magnetometers and rate gyroscopes; two different types of actuators are also included: momentum wheel and magnetorquers. In addition to power management, communication, attitude determination and control modules, slots are available for future use. UWE-4 utilizes these extra slots for accommodating the power processing unit (PPU) of an electric propulsion system. The thrusters themselves are accommodated on the outer structure rails. These rails were originally intended to be used only as interface with the launcher. In UWE-4, however, the rails are modified to contain the thrusters, thus reducing the propulsion system mass.

Comprehensive surveys of micro spacecraft propulsion systems are found in
literature [3]. These indicate that only handful of propulsion systems are available for use today. Among the few, the intelligent vacuum arc thruster (iVAT) - an electric propulsion system, is a promising candidate [4]. The iVAT is a simple and compact device: it has no moving parts and the propellant is in solid state; its performance and mass are suitable for use in pico-satellites. For these reasons it was selected to be used in the UWE-4 demonstration mission.

The iVAT is provided by the University of the Federal Armed Forces in Munich (UniBwM). It consists of the thruster head and the PPU with a control unit. The thruster head comprises two solid electrodes insulated against each other. Applying voltage between the electrodes leads to the production of a plasma plume expanding from the eroded cathode material and therefore to a thrust in the range of μN.

To avoid the need for high voltages the so called “triggerless” ignition is used which allows a discharge at relatively low voltages (few 100 V). Since these voltages are still higher than the satellites power system can provide (~ 4 V) a PPU is required which converts the low d. c. bus voltage into sufficiently high voltage pulses [5].

One key feature is the solid propellant of the iVAT, i. e. the cathode material which in principle could be made of any conducting material. The currently used propellants are tungsten, titanium and copper. The thrust producing erosion of the material requires a propellant feeding mechanism which is currently under development to ensure optimal operation.

To conclude, theoretical and experimental studies, presented in the paper, show the possibility of using a very-low-thrust electric population to control the orbit of pico-satellites in loose formation flying. The UWE-4 project, intended to demonstrate such capability in space, is discussed in details.

References:


