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THERMODYNAMIC ANALYSIS OF STIRLING ENGINE ON FORMATION-FLYING SMALL SATELLITES WITH OPTICAL POWER TRANSFER PLATFORM

Abstract

Formation-flying small satellites is drawing extensive interests, due to its advantages in costs, robustness and reliability. And recent advances in the wireless power transfer results in new classes of formation-flying small satellites whose power is supplied by other spacecraft. Thus an efficient optical power transfer subsystem using high intensity beams of unconverted sunlight with reduced size and low cost becomes very attractive. This paper presents a thermodynamic analysis and design consideration of Stirling engine on formation-flying small satellites with optical power transfer platform.

To begin with, the design configuration together with operating principle of a novel sunlight power transfer platform is described. In this platform, a resource vehicle collects solar energy and distributes it to mission satellites wirelessly, specifically for a free-piston Stirling engine tailored for the thermal-to-electrical conversions. Rather than lasers and microwaves, the optical power distribution using concentrated sunlight avoids multiple conversions of energy from one form to another; the only conversion is at the receiving satellites where sunlight is converted into electricity. Moreover, considering the size of small satellite and missions of formation-flying, the thermal power process employs a micro fabrication of free-piston Stirling heat engine for its high efficiency and use of an external heat source.

In the second section, thermodynamic modeling and numerical simulation of the Stirling engine based power transfer platform on the formation-flying orbits are performed, along with a method for modeling the Stirling engine of a heat receiver, a regenerator and a radiator cooler. A detailed analysis of flow and heat transfer characteristics is given. Furthermore, the thermal-to-electric conversion efficiency has been evaluated, demonstrating a reasonable heat engine performance for a concentrated optical power transfer platform. This unique feature will benefit the operating reliability of Stirling engine based optical power transfer platform for the formation-flying small satellites.