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ATMOSPHERIC DRAG COEFFICIENT CALCULATION MODEL BASED ON DIFFERENT DEORBIT SAIL CONFIGURATIONS

Abstract

As the number of space debris and defunct spacecraft increases, the rising risk of collisions threatens the safety of current and future spacecraft. Effective deorbiting technologies are essential for tackling the growing space debris problem. In Low Earth Orbit (LEO), where debris is common and atmospheric drag is significant, deorbit sails are a promising deorbiting technology. By leveraging the rarefied atmosphere in LEO, deorbit sails reduce spacecraft altitude through increased atmospheric drag.

For the rarefied atmosphere in LEO, the atmospheric drag on a deorbit sail is related to atmospheric density, molecular collision velocity, and the drag coefficient, where the drag coefficient Cd is a key parameter. Empirically, Cd is influenced by factors such as sail configuration, solar activity, wind speed ,satellite attitude, and orbital position. Therefore, Cd varies under different conditions. To achieve accurate deorbit timing calculations, it is essential to establish a Cd calculation model, ensuring precise drag force determination. This study investigates the precise calculation methods for Cd of three deorbit sail configurations: spherical, conical, and pyramidal. The main contents of this paper are summarized below.

1.A calculation model is proposed to calculate the Cd on deorbit sails. The study uses the free molecular flow (FMF) model to calculate the pressure and shear stress on deorbit sail surfaces, simulating collisions between gas molecules and the sail. A modulation coefficient is introduced to account for different gas molecule reflection modes (e.g., specular and diffuse reflections) and their impact on Cd. Additionally, the HWM07 atmospheric wind model is integrated to consider the effects of solar activity on wind speed. Ultimately, this approach results in atmospheric drag coefficient calculation models for different deorbit sail configurations.

2.This paper compares the calculated atmospheric drag coefficients with experimental data to validate the model's accuracy. It analyzes the atmospheric drag coefficients of spherical, conical, and pyramidal configurations to provide recommendations for selecting deorbit sail configurations.

This paper provides an accurate model for calculating the atmospheric drag coefficients of different deorbit sails, offering valuable insights for satellite deorbiting design and space debris management.