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AN ESTABLISHMENT AND TRANSFER STRATEGY FOR FORMATION CONFIGURATIONS BASED ON OMEGA-U TORUS TOPOLOGICAL EQUIVALENCE

Abstract

This paper proposes a topological equivalent formation configuration establishment method based on the coupling relationship between rapidly-changing variable (RCV) time accumulation and slowly-changing variable (SCV) fuel consumption, for the right ascension of ascending node Ω and the argument of latitude u deployment problems. The phase flow (Ω, u) defined by one-parameter transformation groups is identified as the angle variable for a symplectic S^1 action on the union of non-degenerate elliptical orbits. Furthermore, the Delaunay variables are used to derive the geometric relationship of the two torus $\mathbb{T}^2 = S^1 \times S^1$, to obtain the torus plane $\pi_{\Omega \times u}$ spanned by Ω and u.

The fuel consumption of configuration establishment will directly affect the mission's success or failure for formation missions in the same phase and with different orbit planes that differ by around 1° at the right ascension of ascending node. As an application of the new topological equivalence derivation with $\Omega : 0 \to 2\pi$ and $u : 0 \to 2\pi$, through arranging the semi-major axis, which is equal to the derivative of u, the phase flows defined by the $(\mu, \sum J_n)$ dynamical system succeed in establishing the formation configurations after several equivalent substitutions of u. The impulse reaches 132m/s if the conventional orbital normal correction approach is applied, exceeding the control capability of small and micro satellites or the total fuel constraints. Contrarily, through the orbital verification of Yaogan-9 a, b, c, the topological equivalence of the phase flow on the torus $\mathbb{T}^2$, is utilized to achieve "time for fuel", which can save fuel consumption by 22.2kg, accounting for 60-70%.

Hence, the method proposed in this paper is suitable for the task where the formation task has no restriction on the length of time for configuration establishment, or the formation configuration scale is large and the different orbital elements include the right ascension of ascending node. This configuration establishment method using the coupling relationship between the time accumulation of RCV and the fuel consumption of SCV, greatly saves fuel consumption and prolongs the configuration establishment of satellite formation missions and the in-orbit life of long-term constellations.