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Author: Ms. Keying Yang
Beijing Institute of Technology (BIT), China, yangkeying@bit.edu.cn

Prof. Arun Misra
Mc Gill Institute for Aerospace Engineering (MIAE), Canada, arun.misra@mcgill.ca
Prof. Jingrui Zhang
Beijing Institute of Technology, China, zhangjingrui@bit.edu.cn

PARAMETER CHOICES FOR STABLE DEBRIS-TETHER-TUG SYSTEMS

Abstract

The debris-tether-tug (DTT) system is recognized as one of the most promising techniques to remove space debris, especially for large objects like defunct satellites. Surrey University has launched a RemoveDEBRIS platform in 2018, aiming at demonstrating the feasibility of the tether net, harpoon and other key active debris removal (ADR) technologies. However, the deorbiting phase of space debris using tethers has not been performed so far as it requires further exploration about system parameters before going on board. This paper considers the complete DTT system as the main object of study, and analyzes the system dynamic behavior with different choices of parameters.

The DTT system shows significant nonlinear characteristics due to the weak connections between debris and tug using soft tethers. Previous studies have shown that tether tangling, large oscillations, chaotic motions and other unstable phenomena may occur because of the inappropriate inputs, like thrusts, and system parameters, such as tether elasticity, masses of the tug and debris, etc. However, specific ranges or relations have not been presented because the large number of parameters increases the difficulties to determine the desired ranges as one parameter may be affected by others. Thus, it is necessary to reduce the number of parameters using a non-dimensional system dynamics model, and then reveal the specific relationships between non-dimensional parameters and the dynamic behavior of the DTT system, so that general recommendations can be offered to avoid unstable motions when designing the system. The main contents of this paper are summarized below.

1. A non-dimensional model of the DTT system is proposed in which the debris and tug are treated as rigid bodies. The tether is discretized into multiple spring-damper segments, and the tether attachment points on the tug and debris are left arbitrary.

2. The DTT system model is simplified to calculate the analytical solutions. Then, the effects of the parameters are studied using nonlinear methods, such as the multi-scale method, as well as numerical simulation methods by applying various choices of parameters in the complete model.

The results obtained advance the knowledge of the DTT system dynamics, and draw general conclusions of parameter choices desirable for various DTT systems. This work offers reliable reference for DTT system design and also makes contributions towards the determination of the feasibility of an ADR mission using a DTT system.