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Deployment dynamics for rotating space tether systems

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Rotating space tether system (RSTS) is one of the promising methods for removing large space debris objects (referred to as the target) from near-Earth orbits [1]. This approach allows for the use of a push-towing method utilizing space tugs that are based on existing upper stages. For the formation of the RSTS, a tethered autonomous docking module (ADM) separated from the space tug is used. The ADM carries a target capture device, which can be a probe-cone type device, or a net fired from the ADM to the target. The RSTS consists of a space tug and a stack of the ADM with the target connected by a tether with a length of several kilometers. Rotation of the system induces tension in the tether, which allows for the application of thrust from the space tug along the tether, thereby preventing its weakening. The space tug applies thrust periodically, propelling the RSTS towards a disposal orbit. The proposed space tether system utilizes the difference in orbital velocities of the space tug and the target to create rotation of the system [2]. This paper presents the analysis of the RSTS formation as a 3-stage process:

1. Separation of the ADM on the tether from the tug and the capture of the target (the process of target capture using capture devices is considered separately).

2. Tether tension and momentum exchange between the tug and the ADM with the target, transitioning from the autonomous motion of the space tug, debris, and ADM to the motion of the whole system with different motion parameters.

3. The analyses of the tether dynamics to evaluate the overall impact on the RSTS and the angular motion of the space tug, ADM and target relative to the tether. This analysis is crucial for determining the requirements for the control systems of the tug and ADM, which should prevent the tether breakage and stabilize the angular motion of the tug and ADM with the captured target.

This paper presents a model of the RSTS, where the tether is considered as a system of point masses connected by weightless elastic elements. The relative motion of the space tug, target, and ADM is studied before and after the formation of the RSTS under various initial conditions. Methods and algorithms to stabilize the tether's longitudinal oscillations and the angular motion of the space tug and target are proposed. The effect of the space tug engine operation on the system during removal to disposal orbit is also analyzed.

References

[1] Valeriy Trushlyakov, Vadim Yudintsev, Dynamics of rotating tethered system for active debris removal, Acta Astronautica. Volume 195, June 2022, Pages 405-415. doi: https://doi.org/10.1016/j.actaastro.2022.03.023.
[2] Valeriy Trushlyakov, Vadim Yudintsev A method for removing large-sized debris objects and a device for its implementation. Eurasian Patent № 038352 Application № 201900385 от 26.07.2019, Applicant. Omsk State Technical University, Issue date: 12.08.2021.