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# RIGID-FLEXIBLE COUPLING DYNAMICS OF TETHERED SPACE DEBRIS WITH SOLAR PANELS

**Abstract**

Ever since the first artificial satellite was launched in 1957, the number of space debris has significantly increased in the near-Earth space as a consequence of continued space activities. As of 4 March 2017, there are 17995 large objects in orbit around the Earth, including 4420 satellites and 13575 rocket bodies. Kessler Syndrome, proposed in 1978, stipulates that collisions between space debris would lead to an exponential increase of smaller debris. In fact, the collision between Iridium 33 and Cosmos 2251 in 2009 seems to confirm that the chain reaction of collisions between space debris has already been triggered. Since the positive effect of atmosphere on space debris is very limited, active debris removal is the only choice left in order to effectively control the growth of space debris population.

Among all techniques proposed for active debris removal, the tethered tug-debris (TTD) concept may be one of the most promising techniques with advantages of light weight, high flexibility, and tolerance to debris shape. A typical TTD system is composed of a space tug equipped with thrusters, a space debris, and a tether connecting them. In recent years, many efforts have already been made aiming to analyse the dynamics and control of the TTD system. Most of these efforts were devoted to the research of the TTD system which contains a point-mass debris or rigid debris. In fact, most debris in GEO are defunct satellite which have flexible appendages. The dynamics of TTD system is more complex when flexible appendages are considered, and the vibration of them may lead to the instability of the whole system. However, thus far, there has been very few attempt to study the related rigid-flexible coupling dynamics.

The aim of the present paper is to study the rigid-flexible coupling dynamics of a TTD system with solar panels on the space debris. A sub-tether configuration is adopted to approximate a tether net capture. The tether is attached to the tug on one end, and on the other end, it branches into four sub-tethers attaching to the solar panels. The mutual influence of rigid body motion, the elongation and libration of the tether, and the vibrations of the solar panels during towing is investigated. Particularly, instability condition of the system due to resonance is analytically determined. Numerical simulations indicate that the motion of the TTD system is chaotic under some conditions.