USING ELETRODYNAMIC TETHERS TO PERFORM STATION-KEEPING MANEUVERS IN LEO SATELLITES

Thais Carneiro Oliveira[(1)]**, Antonio Fernando Bertachini de Almeida Prado**[(2)]

[(1)]*National Institute for Space Research (INPE), Av. dos Astronautas 1758 Sao Jose dos Campos – SP – Brazil ZIP code 12227-010,+55 12 32086000, thais.tata@gmail.com*

[(2)] *National Institute for Space Research (INPE), Av. dos Astronautas 1758 Sao Jose dos Campos – SP – Brazil ZIP code 12227-010,+55 12 32086000, antonio.prado@inpe.br*

Space tether is a promising and innovating field of study, as many articles, technical reports, books and even missions have been using this concept through the recent decades. An overview of the space tethered flight tests missions includes the Gemini tether experiments, the OEDIPUS flights, the TSS-1 experiments, the SEDS flights, the PMG TiPs and ATEx missions. Space tethered systems can vary drastically from its operating principles and its orbital mechanics. The most studied topics of the space tethers systems nowadays are the momentum exchange tethers, the electrodynamic tethers and the space elevators. This paper analyses the potential and promising concept of using an electrodynamic tether to provide propulsion to a space system with an electric power supply and no fuel consumption. The present work is focused on orbit maintenance and reboost maneuvers for tethered satellite systems (TSS). This type of system consists of two or more satellites orbiting around a planet linked by a cable or a tether [1]. A conductive tether with electrons passing through a magnetic field generates electromagnetic propulsion caused by the induced Lorentz force. The direction of this electromagnetic force depends on the direction of the magnetic field and the direction of the current. The electromagnetic tethers can be used to de-orbit a satellite or/and to generate power if the current flows across the induced electromotive force (EMF). In this case, there is no power consumption if the system is capable of collecting and emitting electrons through the tether. On the other hand, if the current is running against the induced EMF, the direction of the induced Lorentz force is opposite and there is a need to use a battery to drive the current through the tether. The usage of a battery to run a current against the induced EMF produces a thrust that can boost the orbit of the tethered system or help the system to maintain its orbit. The battery can be recharged by solar panels. The control of the magnitude of the induced Lorentz force can be easily achieved with a variable resistance through the tether. The most known proposed tethered mission that includes a battery to reboost the orbit is devoted to the International Space Station (ISS) [2]. For this last proposed mission, it has been proved that the economy on the fuel consumption would represent a cut of two billions dollars over ten years on the budget by replacing the fuel consumed to maneuver the ISS with an electromagnetic tether [3]. The Low Earth Orbits are the most promising orbits to use the electrodynamic tethers, since the disturbing forces like the atmospheric drag and the Jn perturbation constantly drift away the satellite from its nominal orbit, and, consequently, it is necessary to perform station-keeping maneuvers on the satellite. In addition, the electrodynamic tethers are more efficient at lower attitudes, since the magnitude of the magnetic field is more intense. The use of electromagnetic tethers to help the orbital maintenance can be performed by boosting the system, repositioning it rapidly in a higher attitude or by applying small thrust magnitude sufficient to compensate the atmospheric drag and other perturbations. This work will study both of the orbital maneuvers, the rapidly boost of the

tethered system and the low-thrust maneuver to compensate the disturbing forces with the usage of an electromagnetic tether. The study will include the efficiency of the tethers with different tether lengths, attitude, currents, fuel savings analysis, power consumption and other parameters. The analyses of the results will be performed with the help of a practical tool called “perturbation integrals” and an orbit integrator that can include many external perturbations like atmospheric drag, Jn perturbation due to Earth’s non-sphericity, solar radiation pressure and third body perturbation of the Sun and the Moon [4 and 5]. The perturbation integrals are an important key to analyze the magnitude of the disturbing forces as well as the tether magnitude force. The perturbation integrals can quantify the magnitude reduction of the disturbing forces with the electromagnetic tether usage as the orbit propagator can complement the results by performing the maneuver simulations. This work is essential for first analysis mission to guarantee the efficiency of the mission, the economy in the fuel consumption for orbital maneuvers for different parameters of the mission.
In general, the present research has the goal of contributing to the study of orbital maneuvers using electrodynamic tethers to replace propulsion based in fuel consumption and several cases are shown where the fuel savings can be very large.

References

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