Special Issue on Proceedings of International Conference on Materials Manufacturing and Nanotechnology, June 2021. International Journal of Aquatic Science, Vol 12, Issue 03, 2021

REVIEW ON TETHER TECHNOLOGY

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Abstract: Tether Technology is a new and innovative propulsion technique used for launching Spacecraft into its orbit or directing it towards a particular planet which is set as its destination. The principle used is the momentum exchange. This means that the momentum of the spinning tether would be employed to boost the satellite or the shuttle. This tether technology will have a greater impact in future propulsion system.

Keywords: Tether; spacecraft; orbit; momentum

Introduction

Tether technology is also known as Momentum-XchangeElectroDynamicReboost Tether technology (MXER). Tether technology is a new innovative propulsion system. The tethers were derived from a combination of tether concepts including both Momentum eXchange (MX) and ElectroDynamic (ED) designs. A MX tether is a long thin cable or stringer used to couple two objects in space together so that one transfers momentum and orbital energy to the other. Reusable MX tethers require some type of Reboost propulsion due to the fact that orbital altitude (and thus the MX tether's energy and momentum) is "consumed". An ED tether is made of conductive material in order to carry electrical current. Electrical current flowing in the presence of the Earth's magnetic field causes a Lorentz force between the tether and the Earth that results in momentum-exchange—essentially the ED tether "pushes" against the Earth via the magnetic field. This is the same physical principle that causes any electric motor to turn. As such, ED tether propulsion is (ideally) a propellant less space propulsion system that utilizes only electrical power. However, the classical operational range has been limited to regions above the Earth where free electrons are available from the ionosphere (a region approximately 100-km to 1000-km above Earth) to be collected at one end of the 'wire' and then emitted at the other. Thus, the current in the conductor is only in one direction and a net body force is generated along the wire. "The MXER Tether System will serve as a fully-reusable transportation hub in orbit. It's like a 'space railroad',". "It's sort-of like a one-hundred kilometre long fish-net stocking in space, only it's incredibly strong, and it can withstand many years of bombardment by orbital debris"

What is tether?

A Tether is a single, long, thin, high strength cable which is used to make rendezvous between satellite and the space shuttle to be connected. This tether can be extend to a distance of more than hundred kilometers

Principle

In tether technology, cables, miles long, are stationed in an orbit around the earth. On one end there is a shuttle and on the other end of the tether would be a counter mass. This system picks up spacecraft in low orbits and hurls them into higher orbits or towards other planets.

Working

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Tether technology is a technology to use space tethers. When the new satellite or space probe is launched, the spinning tether system captures it and flings it farther from Earth. Now, the principle used is that of momentum exchange. This means that the momentum of the spinning tether would be employed to boost the satellite or the shuttle. So as the tether boosts the body further into space, it itself comes closer to the earth than it was. So after the tether has boosted bodies for a certain number of times, it falls back to earth. It can be demonstrated by a simple example Attach any mass to a string, spin it round and round, suddenly let go of the string and marvel at the speed at which it flies. Well, this precisely explains the principle behind tether technology.

MXER tether configuration

MXER tether facility would consist of a rotating, 100-120 km long tether with a number of masses and mechanisms distributed along its length. At the tether "tip" would be a mechanism to enable a rapid rendezvous between the tether and a suitably prepared payload. Roughly on the other end would be ballast mass, which would probably consist of the spent stage of the launch vehicle that inserted the MXER facility into orbit. The tether itself would be composed of a material with a high specific tensile strength (tensile strength/material density), coated or treated in some fashion to protect it against atomic oxygen and ultraviolet radiation flux. Additionally, the tether would be configured in a multi-strand, cross-linking configuration that would provide redundant load paths in the event that portions were severed by micrometeoroids or orbital debris.

A portion of the high-strength tether, probably 40-80 km, would be integrated with a conductive material, such as aluminum, that would enable this portion of the tether to conduct significant electrical current. Interspersed at regular intervals along this ElectroDynamic region of the tether would be tether "control" stations; smaller spacecraft-like units that would collect solar power and store the energy for use in driving electrical current through the tether during ElectroDynamicreboost operations. The MXER tether facility may then accurately be considered a type of "distributed" spacecraft.

MXER TETHER MOMENTUM EXCHANGE

The MXER tether would normally operate in an elliptical orbit around the Earth. The perigee of the orbit would be in the LEO altitude range of 300-500 km, and the apogee of the orbit would vary from about 5000-8000 km, depending on the specific requirements of the mission scenario. The specific energy of any orbiting object (energy per unit mass) is proportional to the distance between the perigee and apogee of the object's orbit (the line of The MXER tether would normally operate in elliptical apsides or 2x the semi-major axis).

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Therefore, each kilogram of mass in a MXER tether facility in a 400 km x 8000 km orbit has significantly more orbital energy than each kilogram in a payload in a low, 400 km circular Earth orbit. This energy differential is the heart of the exchange of momentum and orbital energy that takes place between the tether and the payload. As the tether passes through the perigee region of its orbit, because of its greater orbital energy, it is moving significantly faster than a spacecraft that is in a circular orbit at those altitudes. A typical example would be a tether moving at 8.9 km/s at perigee versus another spacecraft moving at 7.7 km/s in its low circular orbit. Obviously, rendezvous between the center-of-mass of the tether and the payload would be impossible with this magnitude of relative velocity. But rendezvous is possible with the tip of the tether, if the tether is con**Figure:**d properly In order for the tip of the tether and the payload to rendezvous, the tether must be rotating at such an angular rate that the velocity of the tip of the tether is exactly the difference between the center-of-mass velocity of the tether and the payload's velocity.

Operational methods

Tidal stabilization

An attitude control tether has a small mass on one end, and a satellite on the other. Tidal forces stretch the tether between the two masses, stabilizing the satellite so that its long dimension is always oriented towards the planet it is orbiting. Several of the earliest satellites were stabilized this way, or used mass distribution to get tidal stabilization. This is a simple form of stabilization that uses no electronics, rockets or fuel.

Electrodynamic Tethers

An electrodynamic tether conducts current in order to act against a planetary magnetic field. It's a simplified, very low-budget magnetic sail. It inducts Earth's magnetic field electric force to use as power and produce substantial work. When the conductive tether is trailed in a planetary or solar magnetosphere (magnetic field), the tether cuts the field, generates a current, and thereby slows the spacecraft into a lower orbit. The tether's end can be left bare, and this is sufficient to make contact with the ionosphere and allow a current to flow. The Phantom loop can be used as a circuit in ElectroDynamic tethers. A cathode tube may be place at the end of the tethers, also. The cathode tube will interact with the planet's magnetic field in the vacuum of space. A double-ended cathode tube tether will allow alternating currents.

Rotovators

A rotovator is a rotating tether. A spacecraft in one orbit rendezvous with the end of the tether, latching onto it and being accelerated by its rotation. They separate later, when the spacecraft's velocity has been changed by the rotovator. The momentum of the tether is changed to accelerate the spacecraft. In a planetary magnetic field, a rotovator can be an ElectroDynamic tether, and be charged electrically from solar or nuclear power. Rotovators can also be charged by momentum exchange. In general, rotovator can be charged by using the rotovator to move mass from a place that's higher in the gravity well to a place that is lower in the gravity well. It is possible to use a system of two or three Rotovators to implement trade between the Moon and Earth. The rotovators are charged by lunar mass (dirt, if imports are not available) dumped on Earth, and use the momentum so gained to boost Earth goods to the Moon. One trick for using real-life, weaker materials are to put the rotovator in an elliptical orbit. It would pick up a load at one perigee, and then vary the tether length to throw the load (from the top of the tether) at a later perigee. This splits the speed-exchange into two parts, each contributing half of the final velocity. It reduces the size, strength and weight of the tether dramatically. Rotovators could theoretically open up inexpensive transportation throughout the solar system, as long as the net mass flow was toward the Sun. On airless planets, a rotovator in a polar orbit would provide cheap surface transport as well. An important modification of a rotovator would be to add several latch points, to get different momentum transfers. Another important modification would be to add a linear motor to the rotovator, to accelerate spacecraft. This would permit travel times to the outer planets that were measured in months, rather than years. This is a very valuable option, given that such performance otherwise requires extremely exotic spacecraft propulsion systems**.**

Life time extension

Long-life, damage resistant tether system for extended-duration, high-value and crew-rated missions. The lifetimes of current single-line tethers are limited by damage due to meteorite and orbital debris impactors to periods on the order of weeks. Although single-line tether lifetimes can be improved by increasing the diameter of the tether, this incurs a prohibitive mass penalty. The tether structure composed of multiple lines with redundant interlinking that is able to withstand many impacts.

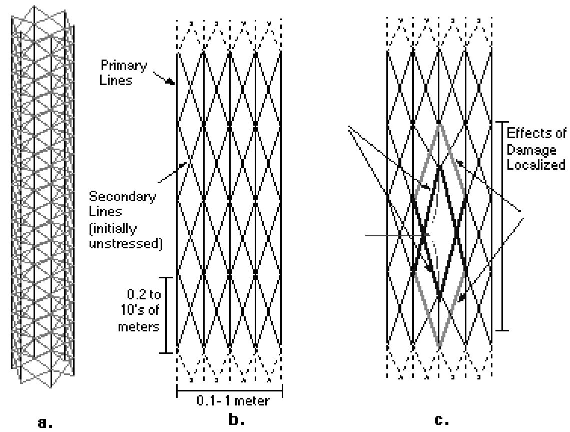

Figure 1: Tether/payload catch mechanism

The development of a lightweight, error-tolerant catch mechanism is crucial for ensuring successful rendezvous between the tether tip and the payload. The tether/payload rendezvous problem differs from both a traditional orbital rendezvous and an orbital intercept. A traditional orbital rendezvous, on the other hand, involves two objects matching position, velocity, and acceleration with each other by assuming identical orbits. They can then approach at an exceedingly low relative velocity and gently connect. The tether/payload rendezvous problem is bounded by these extremes. The tip of the tether, due to its rotation, is able to match position and velocity, but not acceleration, with the payload. Although the tether tip is under centrifugal acceleration, the payload is in “freefall” while in orbit around the Earth. They then can meet at an instantaneous moment of zero relative position and velocity error. The physics are somewhat analogous to a point on the rim of a rolling wheel. That point will make contact with a corresponding point on the ground at zero relative velocity during each rotation of the wheel, however, the point itself is under constant acceleration due to that rotation. Another useful analogy to the physics of the situation is a person standing on a roof or elevated platform. If someone were to throw a tool to them, it would rise and be constantly decelerated by gravity until its velocity reached zero. If done correctly, the person on the platform could reach out and grab the tool when it reached zero velocity and before it started to fall back down again. Due to these unique constraints, the catch mechanism needs to be tolerant of as much position and velocity error as is practical. This desire is countered by the need for the catch mechanism mass to be as low as possible, since the catch mechanism and the payload are both considered the "tip mass". Hence, catch mechanism mass grades directly for payload mass and should be minimized as much as possible. A clear **Figure:**-of-merit for a catch mechanism design then is the volume wherein a catch could take place divided by the mass of the catch mechanism—a type of specific volume. Other important considerations are packaging and deployment, survivability in the orbital environment, any consumables needed by the catch mechanism, and ease of release after the payload has been captured**.**

Advantages

There are so many real time advantages in using tether technology

1. Usage of fuel is almost negligible
2. Cost effective
3. Easy transportation
4. No need for big launch vehicles since the payload is less
5. Many satellites can be launched due to less expense

Conclusion

This system uses a single cable for propelling spacecraft. The tether can be used for many number of times but the rocket can't be used upto that extent once used cannot be reused. Because of so many merits listed above this reusable tether technology will have a greater impact in future propulsion system**.**

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