Electric solar wind sail

ESAIL D23.1
Tether space environment requirements

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Table of Contents

1. Introduction

The E-sail tether is subject to the usual conditions of outer space. In addition, during E-sail operation it is biased to +20 - 40 kV positive potential with respect to the surrounding solar wind plasma, which causes solar wind electrons to bombard its surface. This E-sail specific electron bombardment might hypothetically cause some adverse changes of the tether material. In this document we compile together all the requirements (both generic space requirements and E-sail specific requirements) that the E-sail tether has to satisfy in space.

2. Tether space environment requirements

The parameters affecting the life-time of tether have to be defined and studied in order to guarantee reliable operation and adequate life-time of tethers in the space environment. The parameters and considerations follow.

2.1 Vacuum

The material used for the tether coating, if any, has to be vacuum compatible. If no coating is used, no separate checking is required because the vacuum compatibility of bare or thinly oxidised aluminium is well known.

2.2 Micrometeoroid tolerance

The micrometeoroid tolerance of the tether is taken care of by the hoy-/heytether structure.

2.3 Bombardment of tether by 20 - 40 keV electrons

The tether material has to resist possible wearing and material degradation caused by the E-sail specific electron bombardment.

2.4 Equilibrium temperature

The equilibrium temperature of tether in the adopted radial distance range (0.9 - 4 AU) has to be determined because it may affect the creep, other mechanical properties and life-time of the coating material (if any) and the aluminium backbone. Naturally, the equilibrium temperature depends on the coating.

2.4 Dynamic temperature behaviour

Due to large temperature swings occurring during the space mission (resulting from the spacecraft moving at different distances from the sun and from the rotating motion of the tethers while being inclined with respect to the solar direction), peeling off of the coating material might take place. A proper combination of the coating and tether materials has to be defined in order to prevent the flaking of the coating material.

2.5 UV-radiation

UV-radiation of the space environment can cause fast degradation of coating materials. This property has to be studied.

2.6 Elimination of risk of cold welding

Possible tendency of the tether wires to cold weld among themselves on the storage reel during launch (due to launch vibrations, during the phase of launch when the payload is already above the atmosphere but the booster rocket is still working) should be studied and prevented.

2.7 Creep, static pull

The tether has to withstand the static pull corresponding to weight of 6 g.

2.8 Electrical conductivity

The tether must be electrically conducting. In principle, the higher the conductivity, the better. In practice, steel-like conductivity would be sufficient; aluminium-like conductivity (like in the adopted design) would not be an absolute requirement.

2.9 Spark tolerance

If a tether breaks, the tether gets neutralized in roughly 30 s time by the solar wind plasma. If the broken tether then collides with another tether that still is biased, it is possible that further damage occurs as a result of discharge between the tethers. Consequences of that kind of hypothetical event must be studied.

2.10 Lifetime

The lifetime requirement of tether is defined by the duration of the E-sail mission (adopted 5 years in this project).

2.11 Thermal infrared emissivity

Thermal infrared emissivity of the coating material is an important factor as it defines the equilibrium temperature of the tether for a given solar distance and solar angle. In general we would like the tether to be cold, because that enhances the beneficial properties of aluminium (tensile strength, electrical conductivity), thus if a coating is used, it is desirable if it has high infrared emissivity.

3. Discussion and conclusions

The E-sail tether requirements listed above will be checked (either experimentally or theoretically depending on the case) during the ESAIL project. The list is rather long and hopefully complete. Some of the items are necessary and crucial (such as static pull and electrical conductivity) while some have relevance only in special situations that are hopefully never encountered (such as spark tolerance). We are confident that uncoated or coated aluminium wires provide a tether that satisfies all the requirements. Although stronger materials than aluminium are well known in material science, it is in general hard for a material to satisfy all the tether requirements simultaneously. For this reason, we believe that it would not be trivial (although also not excluded) for someone to come up with a tether concept that would be markedly better (stronger) than the current baseline i.e. aluminium.