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RITD - Adapting Mars Entry, Descent and Landing System for Earth

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Abstract

We have developed an atmospheric re-entry and descent system concept based on inflatable hypersonic decelerator techniques that were originally developed for Mars. The ultimate goal of this EU-funded RITD-project (Re-entry: Inflatable Technology Development) was to assess the benefits of this technology when deploying small payloads from low Earth orbits to the surface of the Earth with modest costs. The principal goal was to assess and develop a preliminary EDLS design for the entire relevant range of aerodynamic regimes expected to be encountered in Earth's atmosphere during entry, descent and landing. Low Earth Orbit (LEO) and even Lunar applications envisaged include the use of the EDLS approach in returning payloads of 4-8 kg down to the surface.

1. EDLS for Earth

The dynamical stability of the craft is analyzed, concentrating on the most critical part of the atmospheric re-entry, the transonic phase. In Martian atmosphere the MetNet vehicle stability during the transonic phase is understood. However, in the more dense Earth's atmosphere, the transonic phase is shorter and turbulence more violent. Therefore, the EDLS has to be sufficiently dynamically stable to overcome the forces tending to deflect the craft from its nominal trajectory and attitude.

The preliminary design of the inflatable EDLS for Earth has been commenced and the scaling of the re-entry system and the dynamical stability analyses has been performed. The RITD-project concentrates on mission and applications achievable with the current MetNet-type, called in RITD as a Mini-1, of lander and on requirements posed by other type Earth re-entry concepts.

2. Wind Tunnel Test to Confirm the Mathematical Analysis

The aim of the wind tunnel tests was the experimental determination of the Mini-1 DV (descent vehicle) damping factors in the Earth atmosphere and recalculation of the results for the case of the vehicle descent in the Mars atmosphere. The Mini-1 lander mock-up model (Figure 1) used in the tests was in scale of 1:15 of the real-size lander as the dimensions were (midsection) diameter of 74.2 mm and length of 42 mm. For wind tunnel testing purposes the frontal part of the Mini-1 DV mock-up model body was manufactured by using a PolyJet 3D printing technology based on the light curing of liquid resin. The tail part of the mock-up model body was manufactured of M1 grade copper. The structure of the dynamic mock-up model provided a CoG relative to the coordinates of the full-scale Mini-1 DV.

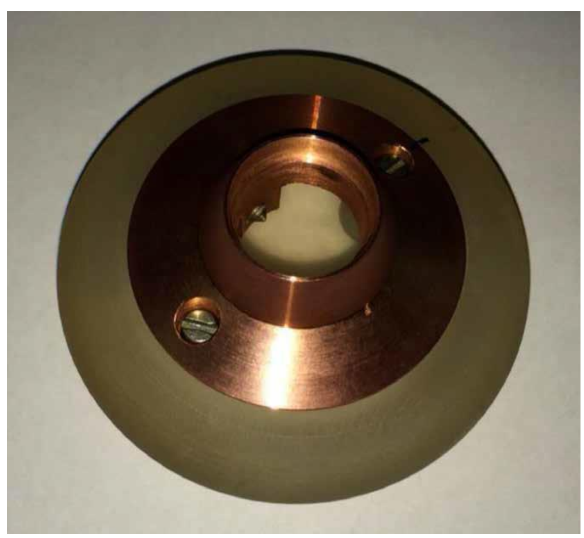

Figure 1: Wind tunnel test mock-up model. Image: LA.

2.1 Wind Tunnel Tests Program of the Mini-1 Mock-up

The Mini-1 DV damping characteristics within the wind tunnel were experimentally determined by the technique of free oscillations of dynamically similar mock-up model installed on the holder with one degree of freedom. The method of testing and damping factor Cmq determination was based on the characterization of the model oscillatory motion with regard to the free oscillation holder's hinge in gas flow within the wind tunnel. The Mini-1 DV mock-up model mounted on the free oscillation holder (Figure 2) was placed into gas flow of the wind tunnel at the known angle of attack. In case the factor of damping moment Cmq value is negative (Cmq < 0) the descending DV rotation will be decreased and the DV will be stable. If its value is positive (Cmq > 0) it will lead to increase of the amplitude of DV oscillations and causes instability.

The wind tunnel test program included the defining of the damping factor Cmq at seven values of Mach numbers 0.85; 0.95; 1.10; 1.20; 1.25; 1.30 and 1.55 at different angles of attack (A_H = 0 degree to 40 degree with the step of 5 degree).

Figure 2: Lander mock-up model inside the wind tunnel during the RITD test program. Image: LA.

2.1 Wind Tunnel Test Results

Using the transonic wind tunnel the factors of the longitudinal damping moment of scaled Mini-1 DV mock-up model were determined experimentally within the range of angles of attacks (A_H) 0 degree to 10 degree at Mach numbers of 0.85 to 1.53.

The wind tunnel tests showed that within the range of Mach numbers 1.1 to 1.53 and angles of attacks (A_H) 0 degree to 10 degree the excitation of self-oscillations and increase of oscillations' amplitude (A_0) up to the value 9 degree to 11.5 degree take place. With that the factor of antidamping varies within the limits of the aerodynamic factor of longitudinal damping moment 0.01 to 0.25.

Within the range of Mach numbers 0.85 to 0.95 and angles of attacks (A_H) 5 degree to 10 degree the damping of oscillations within the limits of the aerodynamic factor of longitudinal damping moment -0.07 to -0.12 was observed.

3. Summary and Conclusions

Our development and assessments show clearly that this kind of inflatable technology originally developed for the Martian atmosphere, is feasible for use by Earth entry and descent applications. The preliminary results are highly promising indicating that the current Mars probe design could be used as it is for the Earth. According to our analyses, the higher atmospheric pressure at an altitude of 12 km and less requires an additional pressurizing device for the in atable system increasing the entry mass by approximately 2 kg. These analyses involved the calculation of 120 different atmospheric entry and descent trajectories.

The analysis of the existing technologies and current trends have indicated that the kind of inflatable technology pursued by RITD has high potential to enhance the European space technology expertise. This kind of technology is clearly feasible for utilization by Earth entry and descent applications.

Acknowledgements

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References

[1] http://ritd.fmi.fi