RITD - Wind Tunnel Test Results

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A new generation of inflatable Entry, Descent and Landing System (EDLS) for Mars has been developed. It is used in both the initial atmospheric entry and atmospheric descent before the semi-hard impact of the penetrator into Martian surface. The EDLS applicability to Earth's atmosphere is studied by the EU/RITD project. It focuses on the analysis and tests of the transonic behaviour of this compact and light weight payload entry system at the Earth re-entry.

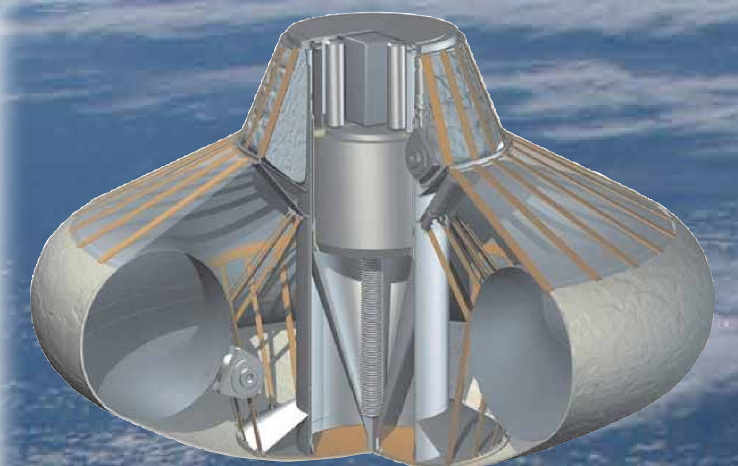

Figure 1: Lander configuration. Picture: LA.

EDLS for Earth

The dynamical stability of the craft is analysed, 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 undertood well. 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 EDLS for Earth will be commenced once the scaling of the re-entry system and the dynamical stability analysis have been performed. The RITD-project concentrates on the current MetNet-type of lander, and on requirements posed by other type Earth re-entry concepts.

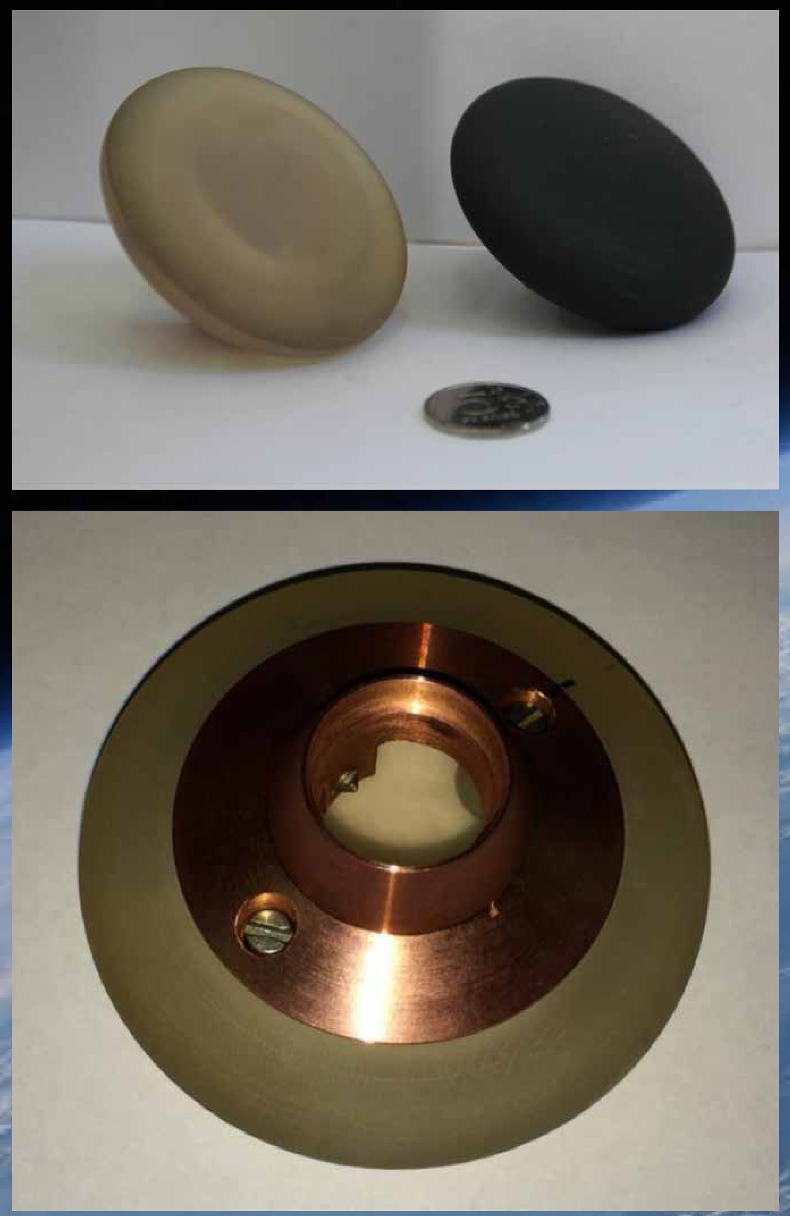

Figure 2: Lander wind tunnel test mock-up. Pictures: LA.

Scaled Mock-up Model of the Lander

The aim of the wind tunnel tests was the experimental determination of the DV (descent vehicle) (figure 1) damping factors in the Earth atmosphere and recalculation of the results for the case of the vehicle descent in the Mars atmosphere.

The lander mock-up model 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 (figure 2). For wind tunnel testing purposes the frontal part of the 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 representative CoG relative to the coordinates of the full-scale DV.

Wind Tunnel Tests Program of the Mock-up

The DV damping characteristics within the wind tunnel were experimentally determined by the technique of free oscillations of a dynamically similar mock-up model installed on the holder with one degree of freedom. The method of testing and damping factor C_{mq} 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 DV mock-up model mounted on the free oscillation holder was placed into gas flow of the wind tunnel at the known angle of attack. In case the factor of damping moment C_{mq} value is negative ($C_{mq} < 0$) the descending DV rotation will be decreased and the DV will be stable. If its value is positive ($C_{mq} > 0$) 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 C_{mq} 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).

Table 1: Conditions of test performance in wind tunnel tests.

Condition number	1	2	3	4	5	6	7
M_∞	0.85	0.96	1.05	1.19	1.25	1.30	1.55
$Re_{\infty D} \cdot 10^{-5}$	1.17	1.26	1.31	1.42	2.35	4.30	6.40
q_∞[kg/m²]	3427	4164	4782	5442	8013	9320	6477

Acknowledgements

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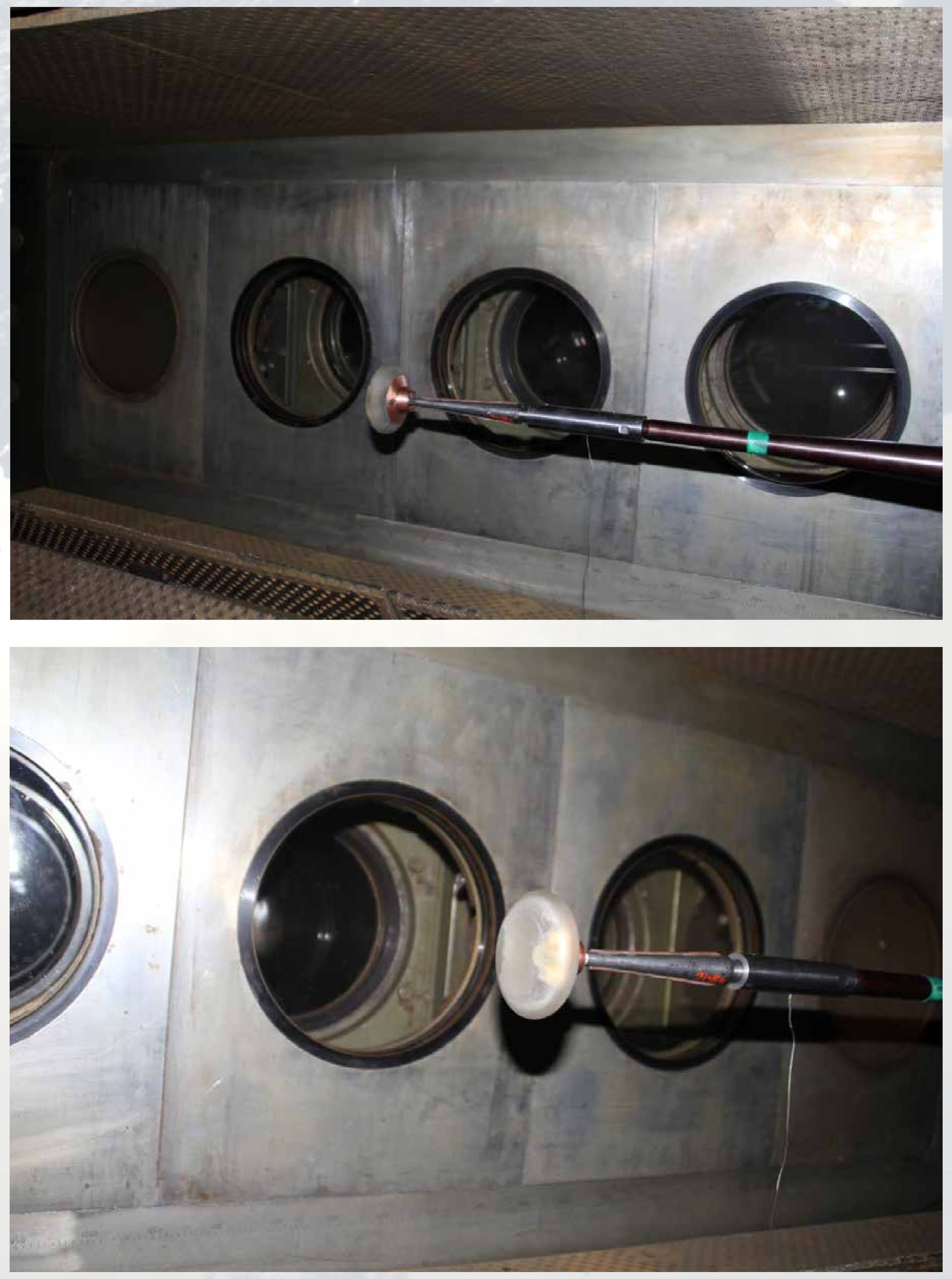

Figure 3: Lander mock-up in the wind tunnel. Picture: LA.

The test program of the wind tunnel tests comprised the following:

1. A nozzle was installed in the wind tunnel in such a geometry that provided an airflow speed in the operating section of the tunnel corresponding to the Mach number of 1.55.
2. The mock-up model was installed in the operating section on the holder with free-oscillation mechanism along the wind tunnel axis; the mock-up model was locked so that its axis had the desired angle with respect to the wind tunnel angle. This angle is the initial angle of attack.
3. The wind tunnel was put into steady mode of operation and (by special drive laid along the holder cavity and led out of boundaries of the tunnel operating section) the mock-up model became unlocked and performed oscillating motion.
4. The parameters of the model oscillating process were recorded.
5. The results were analysed and the value of the damping factor C_{mq} was determined.
6. The nozzle with sliding flaps was installed to the wind tunnel.
7. By bringing of expanding nozzle flaps into a certain position the flow rate corresponded to Mach number 1.30 was achieved.
8. Serial operation of sections 2-5 was implemented.
9. The flaps were brought into the position when Mach number was 1.25 and the whole test program procedure was repeated until the Mach number 0.85 was reached.

Conclusions

Using the transonic wind tunnel the factors of the longitudinal damping moment of scaled 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.

More information from the RITD website http://ritd.fmi.fi