EPSC Abstracts
Vol. 12, EPSC2018-454, 2018
European Planetary Science Congress 2018
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An analysis of the components of the RITD and evaluating alternatives for each component

Vsevolod V. Koryanov, Alexey G. Toporkov, *Bauman Moscow State Technical University, Moscow, Russia (vkoryanov@mail.ru)***, Christian Marian, Dr. Hugo d'Albert,** *Technical University of Munich, Germany.*

Abstract

To collect soil samples from the Mars and bring them back to the Earth a re-entry concept of a landing vehicle must be developed which is fesabale for the Martian conditions as well as for the Earth. This research shows an entry, descent and landing system that has been already developed for the Martian atmosphere and which is adopted to the Earth's atmosphere. Since the parameter of the Earth's atmosphere are different to the Mars, some adjusting must be done but the overall concept is feasible which has been proved already. To develop the best possible concept, some alternatives will be presented and evaluated. The main components will be listed and the current realization of those components will be shown as well as alternative possible solutions. These solutions will be evaluated in the end.

1. Introduction

Different technologies have been developed to collect samples from the Mars and bring them back to the Earth. To realize this, a re-entry, decent and landing module must be developed. This module must meet Martian and Earth requirements.

An entry, descent and landing system (EDLS) was already developed by the MetNet team. This was an inflatable system which makes the touch down on the Mars possible. The continuation of this project was the Re-entry: Inflatable Technology Development project (RITD) which adopted the EDLS on the Earth's atmosphere. A first concept was already developed and presented before. This research should optimize the RITD project and deepen existing concept.

To optimize the existing concept, a systematical approach will be presented in this paper. Based on Lindemann [1], first of all the RITD will be split in each component. In further steps, different requirements on the RITD will be defined. For each component, different alternative concepts will be presented and evaluated. These alternatives will be compared to the existing concept and finally the best concept, which meets the requirements best, will be proposed to continue the project. The goal of this project to develop a small and light (20 – 50kg) re-entry vehicle on the earth [2, 3]

2. State of technology

The entry, descent and landing system (EDLS) was already developed between 2001 and 2009 by the MetNet team and Finnish Institute of Technology (FIM). This developed vehicle was supposed to land on the Mars. The vehicle's breaking process was engineered as an inflatable system. The advantages of the inflatable system were on the one hand the huge mass reduction because heavy shields are not necessary anymore, and on the other hand, the vehicle can be designed a lot smaller than before, since the shields do not occupy as much space as before. [4]

The Russian Bauman Moscow State University (BMSTU) boarded on the project and developed together with the FIM the continuation of the EDLS which adopted it to the earth's atmosphere and named it re-entry: inflatable technology development (RITD). The conclusion of this project was that this inflatable breaking system is adoptable for the earth's atmosphere with some little modifications. [5-7]

Requirements that were focused on the RITD were based on Finchenko [8]:

- the impermeability with respect to the gas
- Integrity after any repeated folding
- Tightness and integrity from the moment of entering the atmosphere until the moment of landing

- No distortion of the CA shape due to thermal effects
- Materials should not have the property of self-burning after termination of external heat flow

In addition to that, an overall cost requirement will be set up for the evaluated alternatives.

In figure 1, the main components of the RITD are listed based on Harri, Pellinen [9]:

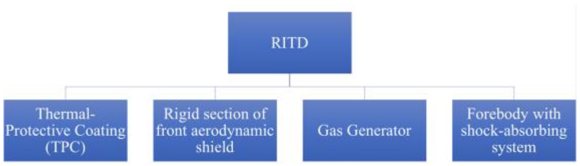

Figure 1: Components and current solution of RITD

3. Method

To approach different potential alternative concepts, a systematical approach will be followed. First of all, the components are analyzed deeply. Afterwards, a brainstorming to reach different potential solutions for each component was realized. These solutions were structurally organized. In the next step, each potential solution for each component is evaluated according to the defined requirements in the chapter before. Tests, simulations, calculations, etc. were used to evaluate the components/functions regarding to those requirements. Before accepting it as an overall solution, no conflicts between each best sub-solution must be ensured.

4. Results

The following figures show the results of two main different concepts. One concept considers a solid body and the other concept considers the inflatable breaking concept.

The figure above shows the pressure (q), the angular velocity of descent relative to the longitudinal axis of the apparatus (ω_x) and the resonance frequency (ω_{rez}) as a function of flight time.

Figure 3 presents the plots of spatial angle of attack (αs), as well as transverse load (qs) for the landing vehicle as solid body in the presence of a set of structural asymmetries (Δy0 =0.001, Ixz0 =0.001, mz0=0.002.).

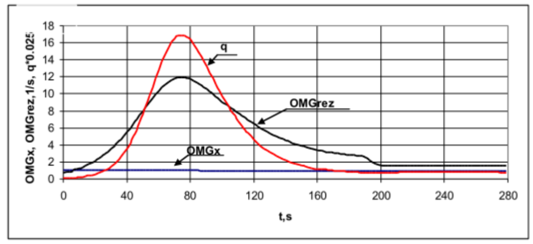

Figure 2: Consider the motion parameters of the landing vehicle as a solid body

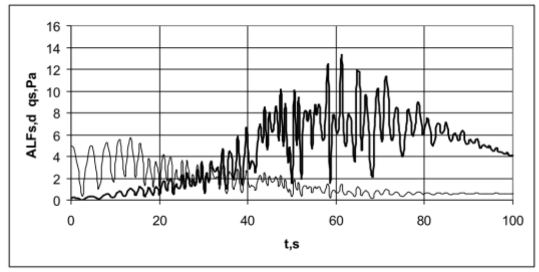

Figure 3: Landing vehicle as solid body in the presence of a set of structural asymmetries

Figure 4 shows a fixed transverse load q_{sf} = 50 Pa an additional value of aerodynamic coefficient of the moment caused by the inflatable braking device exterior shape m_{af} = 0.020.

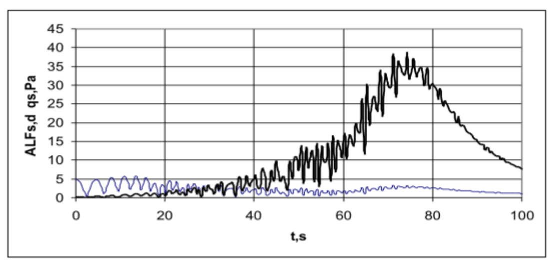

Figure 4: Variation in time of spatial angle of attack and transverse load of the inflatable landing vehicle

The figure above shows the changes in the spatial angle of attack in the presence of complex structural asymmetries and the additional value of the aerodynamic torque coefficient of distortion of the external form of inflatable braking device m_{af} = 0.024 for fixed lateral load q_{sf} = 50 Pa.

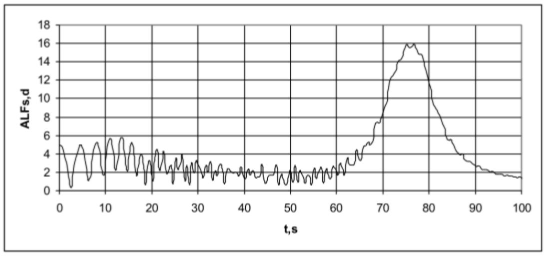

Figure 5: Changes in the spatial angle of attack in the presence of complex structural asymmetries

5. Discussion

It can be seen that under the conditions of an inflatable braking device with m_{af} = 0.024 for fixed lateral load q_{sf} = 50 Pa the solid angle of attack increases indefinitely and landing vehicle loses stability of angular motion.

Thus, depending on the lateral stiffness of the inflatable braking device, the landing vehicle can be both stable and unstable character of angular motion.

However, in this part of the trajectory the value of the velocity head is ten times less than its maximum value, so the presence of strain inflatable braking device leads to a small additional increase in the spatial angle of attack.

6. Conclusions

Since already mentioned, this inflatable braking device, originally developed for Martian atmosphere, can be used for terrestrial conditions. Moreover, the braking device deformation leads, on the one hand, to change the values of aerodynamic coefficients of axial force, the normal force in the plane of the solid angle of attack and the stabilizing of the moment. On the other hand, it leads to the appearance of additional small asymmetry in the form of a lateral displacement of the center of mass, moments of inertia, centrifugal and the asymmetry of the form.

Furthermore, the asymmetry of the external form of braking device in its deformation can lead to significant values of the coefficient of aerodynamic asymmetry. This in turn causes a change in the dynamics of angular motion of the landing vehicle. It is necessary to avoid the occurrence of such modes of motion of the landing vehicle.

Last but not least, the proposed method of investigation of the effect of deformation inflatable braking device on the dynamics of the angular motion of a space capsule enables the design phase to determine the required lateral stiffness of the braking device, which provides steady movement of various space landing vehicle on the entire trajectory of descent.

Acknowledgements

This research was supported by the European Commission Seventh Framework Programme FP7/2007-2013 under grant agreement n°263255.

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