Study of the dynamic of motion landing vehicles in the planet's atmosphere using inflatable braking device

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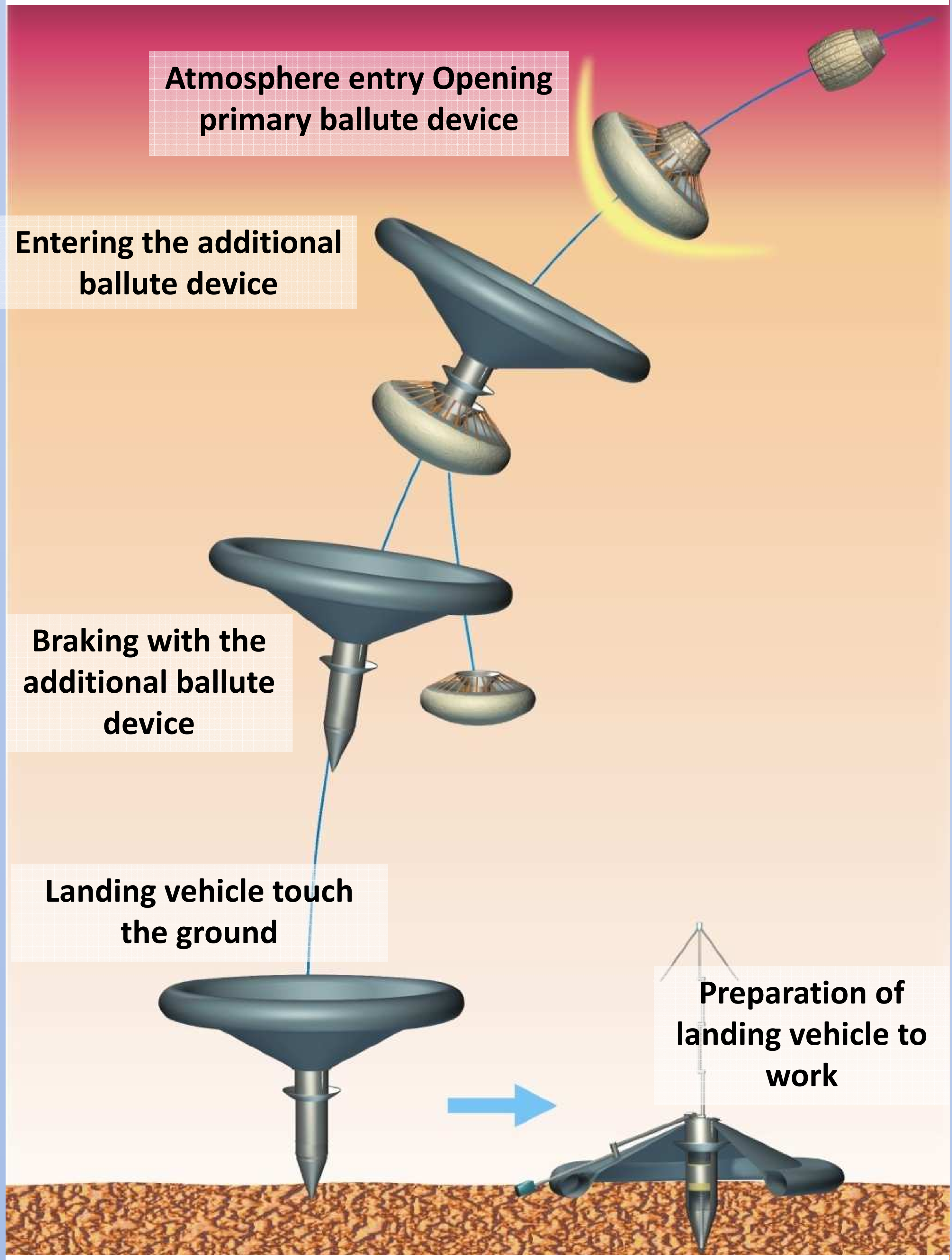
FIGURE 1. DESCENT SCHEME OF LANDING VEHICLE



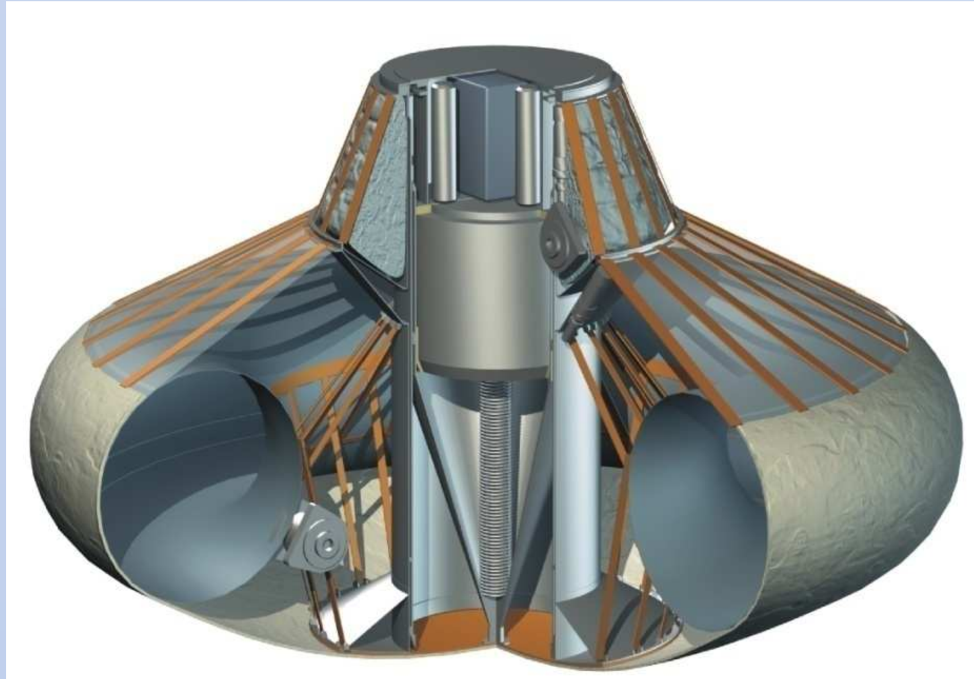
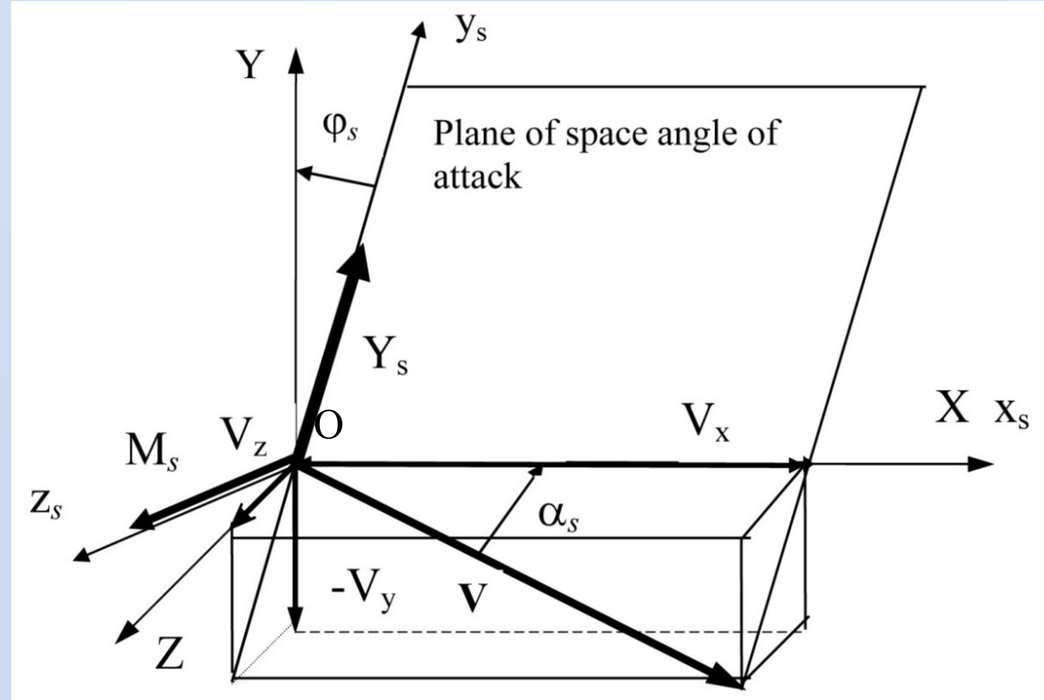


Figure 2. The layout of the landing vehicle deployed with the main inflatable braking device

Constructional features of the landing vehicle deployed with the main inflatable braking device:
S=0.785 m² - Area middle section;
m = 17.0 kg - weight of landing vehicle;
l = 0.585 m - length of the landing vehicle with deployed inflatable braking device

Figure 3. The layout of the landing vehicle to deploy additional inflatable braking device

Input settings landing vehicle deployed with the main inflatable braking device in the atmosphere of Mars:
V = 4559.0 m /s - entry speed into the atmosphere;
ϴ = - 14.8 deg - angle of inclination of the velocity to the local horizon;
h = 120 km - height;
ω_x=1 1/s - angular velocity of descent vehicle relative to the longitudinal axis;
α_s = 10 deg - solid angle of attack.



The mathematical model of the motion of landing vehicle

Figure 4. Coordinate system and the kinematic parameters

At Figure 4. additionally marked with:
α_s - solid angle of attack;
V(V_x, V_y, V_z) – velocity vector and its projection on the axis of a coordinate system related;
$Ox_sy_sz_s$ – spatial coordinate system
φ_s – aerodynamic angle of heel;
Y_s – the aerodynamic force normal to the plane of the spatial angle of attack;
$\mathbf{M}_s$ – vector aerodynamic moment.

$q=0{,}5\rho V^2$- dynamic pressure;

$q_s=q\sin\alpha_s$ – the lateral load on the landing vehicle

In a statically stable the landing vehicle value of the spatial angle of attack decreases gradually and after passing the maximum dynamic pressure is almost zero. Maximum lateral load values are small and occur in or near the maximum value of the velocity head.

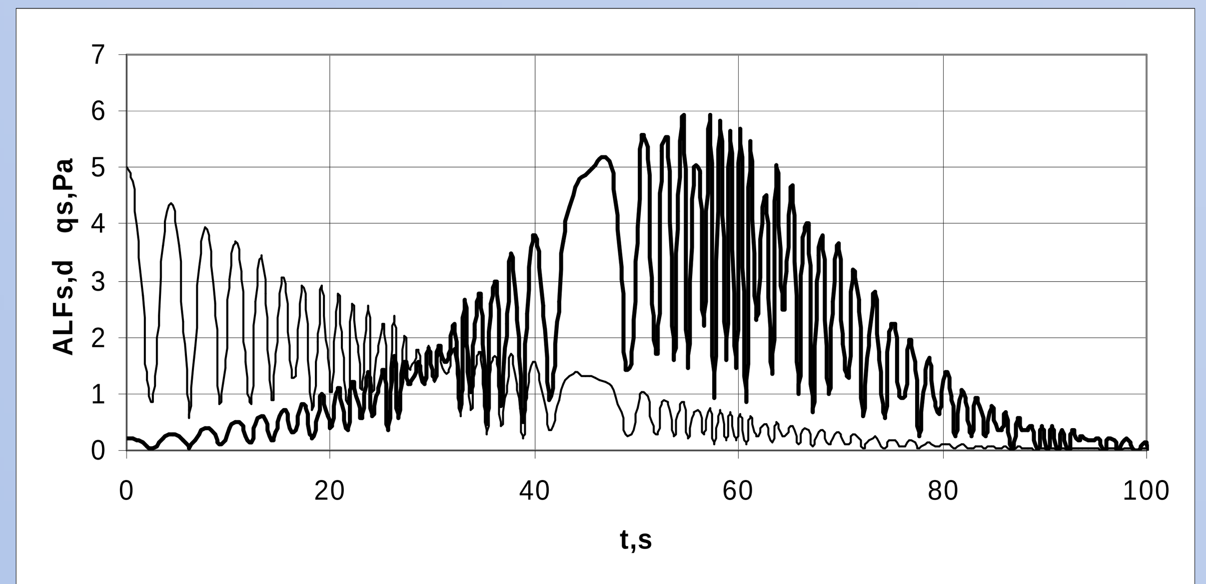


Figure 6. Plots α_s and q_s *vs* time, no perturbations

Figure 7 presents the plots of spatial angle of attack (α_s), as well as transverse load (q_s) for the LV as solid body in the presence of a set of structural asymmetries (Δy_0 =0.001, I_{xz0} =0.001, m_{z0}=0.002.)

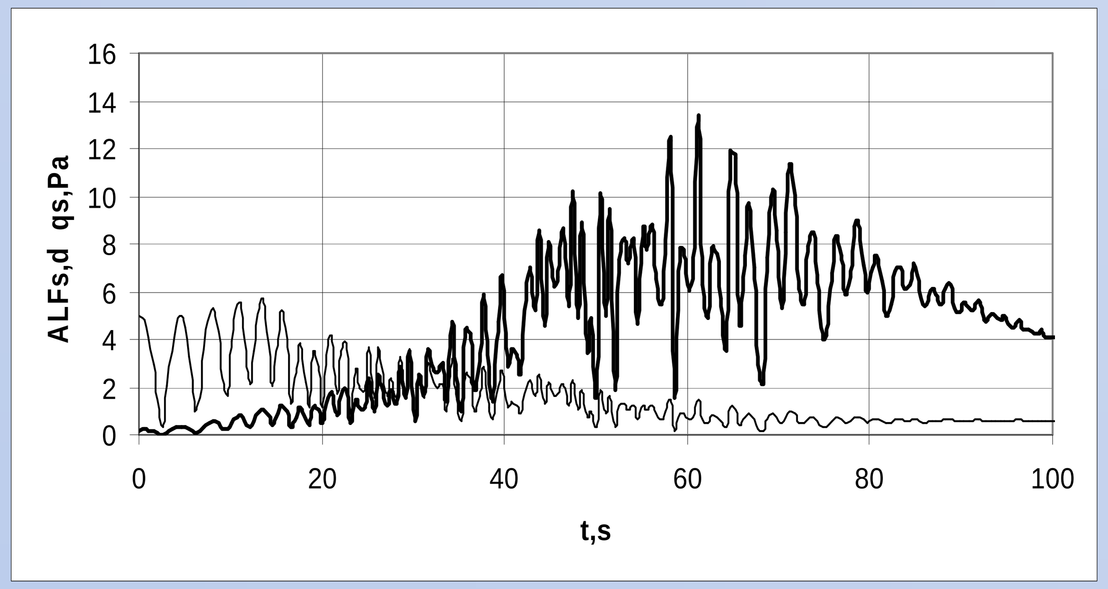


Figure 7. Plots α_s and q_s *vs* time, with structural asymmetries

Figure 9 is a plot 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.

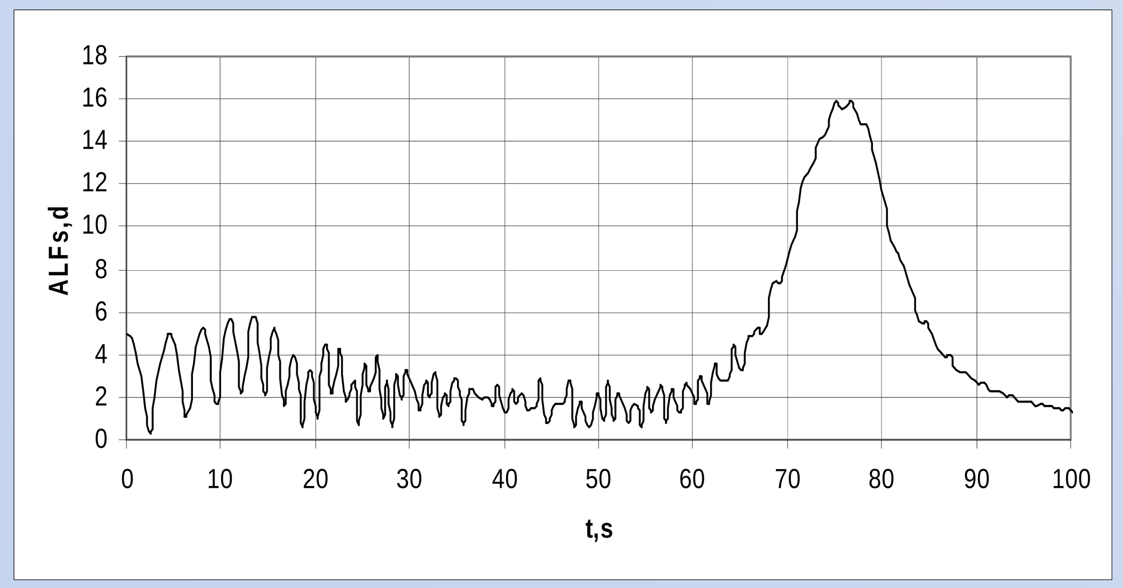


Figure 9. Plot for a spatial angle of attack in the presence of complex structural asymmetries and m_{af} = 0.024.

The curve of spatial angle in-time alteration (Figure 9) indicates sharp increase of maximal angle of attack with the increase of asymmetry due to inflatable braking device non-rigidity. Spatial angle of attach reaches its maximal value at the moment of maximal dynamic pressure.

Conclusions

1. Deformation of inflatable braking device leads to the change of aerodynamic coefficients of the forces and moments, as well as to the occurrence of additional small asymmetries like cog offset, products of inertia, and form asymmetry.

2. Asymmetry of the deformed inflatable braking device exterior shape causes sufficient additional augmentation of aerodynamic coefficient of the moment.

Depending on the inflatable braking device cross-sectional stiffness, the coefficient can tops the values influencing the landing vehicle angular motion dynamics.

In some cases, spatial angle of attack reaches such magnitude that the motion of landing vehicle with inflatable braking device loses stability

3. After passing through the moment when resonance frequency is equal to angular velocity of the landing vehicle rotation about its long axis, when presence of structural asymmetries, the spatial angle of attack begins to increase.

At the same moment, dynamic pressure also increases what defines the inflatable braking device transverse load augmentation. Growth of transverse load results in the enlargement of additional asymmetries caused by the inflatable braking device form distortion.

These additional asymmetries produce sharp increase of the spatial angle of attack.

Calculation results for spatial angle of attack for m_{af} = 0.0245 at q_{sf} = 50 Pa, given in Figure 10, will be analysed.

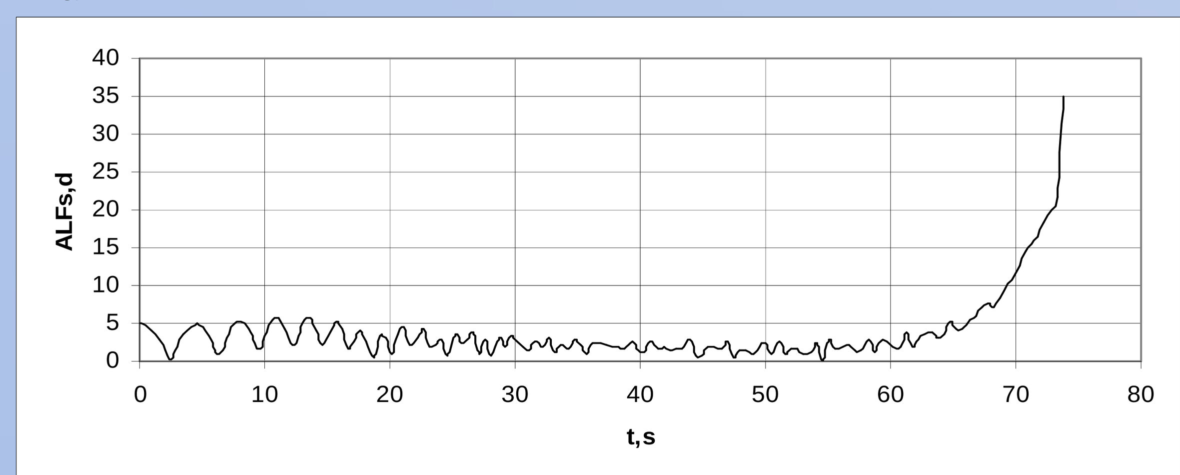


Figure 10. Plot for a spatial angle of attack in the presence of complex structural asymmetries and m_{af} = 0.0245.

It can be seen that under these conditions 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.

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SEVENTH FRAMEWORK PROGRAMME