ASTRODYNAMICS SYMPOSIUM (C1)
Optimization (1)

Author: Dr. Olga Yanova
Central AeroHydrodynamic Institute(TsAGI), Russian Federation, yanova@progtech.ru

Prof. Alexander S. Filatyev
Central AeroHydrodynamic Institute(TsAGI), Russian Federation, filatyev@yandex.ru

THROUGH OPTIMIZATION OF BRANCHING INJECTION TRAJECTORIES BY THE PONTRYAGIN MAXIMUM PRINCIPLE USING STOCHASTIC MODELS

Abstract

The problem of through optimization of space vehicles branching trajectories is considered. Its essential features:

- The motion is considered as branching process. Branches can correspond to both real trajectories (powered ascent, separated parts returning) and imaginary ones, corresponding random factors implementations;

- Constraints on phase/control variables (loads, separated parts fall zones, staging safety, etc.) are defined for each branch;

- Random disturbances are defined by canonical decompositions.

The Pontryagin maximum principle was applied to take advantages of the indirect optimization, e.g. the physical sense of conjugate variables as functional sensitivity functions to phase coordinates variations.

Systematic components of disturbances enter into phase system right parts and are considered at the conjugate system. Random disturbances are considered at uncontrolled trajectory branches only and can result in violation of constraints and boundary conditions ("misses"). At other branches they have to be compensated by the control system.

The method accounting the random disturbances influence in the optimization process is developed. Ideologically it is close to the minimax approach and supposes:

- the event probability is given;

- the greater the miss, the greater the functional loss compensating it;

- random disturbances are small, so their influence can be estimated by the Bliss formula, determining the miss as a linear function of the disturbances and the conjugate system at the optimal trajectory;

- disturbances are considered as an additional control vector-function of "nature" with antagonistic "interests" to injection purposes.

The analytical synthesis of the optimal "nature" control is obtained. Its physical sense consists in the determination of multi-D profiles of the critical (worst) disturbances.

The synthesis allows considering only several worst disturbed trajectories, corresponding to the critical profiles, instead of continuum ones. As a result, the necessary calculations are reduced in 10^6–10^9 times in comparison with widespread engineering approaches, based on the Monte-Carlo method. Additionally, the maximum principle and the linearity of the conjugate system allow replacing the integration of disturbed trajectories by the linear transformation with the nominal transfer matrix.

The described method is realized as the modified version of ASTER codes for the thorough branched trajectory optimization (see AIAA 2001-4391).

The developed technique and codes are applied to the launcher trajectory optimization. It is shown, that the ASTER version allows solving the multipoint BVP automatically even with far initial approximations of variables, as well in presence of singular points and bifurcations.