 Paper ID: 47334
oral

IAF SPACE PROPULSION SYMPOSIUM (C4)
Propulsion System (1) (1)

Author: Mr. Danail Nedyalkov-Höfkes
ArianeGroup, Germany

Ms. Nicole Korus
ArianeGroup, Germany

MODELLING AND CORRELATION OF CRYOGENIC ORBITAL STAGES WITH FOCUS ON PROPELLANT TANKS

Abstract

The present paper deals with a novel approach for numerical modelling of cryogenic orbital stages, used in the development of the Ariane 6 upper stage. The discussed model focuses on the physical phenomena and the propellant behaviour during the ballistic flight phase of the stage and is compared with Ariane 5 experimental flight data.

This propellant behaviour in cryogenic orbital stages - for example sloshing, boiling, heat transfer in the tank and between tank and structure - impacts key performance indicators of the launcher, such as payload capacity, propellant loading and orbital manoeuvring strategy. It drives key architectural decisions, for instance the choice of a reaction control system and propellant management equipment, but also reveals potential problems and even blocking points in the launcher design. Consequently, the mastering of this behaviour is one of the main challenges in the design of cryogenic upper stages.

This challenge is tackled in the Ariane 6 development with the support of a versatile tank model, accurate enough to predict pressure, temperature, mass and heat transfer during the complete mission. In the same time, it is fast and flexible enough to enable analysis of multiple missions with parametric variations to cover all orbital scenarios and find optimal manoeuvring sequences. The model is developed with the simulation platform EcosimPro, used among others for the European Space Propulsion System Simulation library (ESPSS). The tank model itself is part of a complete upper stage model, but this paper mainly focuses on the tank and only briefly introduces the complete stage model.

To correlate this model, Ariane Group has performed three experimental flights (named ECA DemoFlight) to better understand various cryogenic propellant phenomena. Those flights were Ariane 5 missions with an extended ballistic phase incorporating special manoeuvres, such as propellant settling, tank pressurization and depressurization, as well as phases under spin-stabilized control. With support of the obtained direct flight data and CFD analyses of the flights, the versatile tank model could be correlated with the required accuracy.

After correlation, the versatile tank model can solve posed ballistic phase problems by combining analytical correlations with multi-nodal simulation and techniques for experimental data fitting. Its accuracy for system-level analyses, for predictive simulations of the ballistic phase and for quick sensitivity analyses of multiple missions is discussed in detail in the present paper.