CFD study of base drag of the Grot rocket

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Abstract

Propulsion system operation is known to affect the aerodynamic characteristics of rockets. Specifically, the net axial force acting on a rocket in flight cannot be precisely obtained by combining the static thrust with drag values computed for a rocket with an inactive motor. One of the main reasons for this is the influence of motor operation on pressure at the base of the rocket; the drag force component due to this pressure is usually referred to as base drag.

The aim of this paper is to investigate the effect of motor operation on the aerodynamical parameters of the Grot sounding rocket developed by the Students' Space Association, Warsaw University of Technology. Grot is a boosted dart rocket consisting of two stages having a total length of 2 [m]. The first stage is responsible for accelerating the second stage (dart) to an altitude of 2 [km]; at this altitude aerodynamic separation occurs, and the dart continues flight to the altitude of 18.5 [km].

The study consists of two series of axisymmetrical Computational Fluid Dynamics simulations of flow around the rocket — one with the motor being nonoperational and the other with active thrust. In the latter, the exhaust gases are modeled via species transport. The physical properties of the gases are being computed in NASA CEA (Chemical Equilibrium with Applications) with the assumption that they are at a chemical equilibrium state as they enter the nozzle. The freestream Mach numbers considered in the study range from 0.4 to 3.0, matching the flight envelope of the Grot rocket.

In the postprocessing phase, the axial force acting on various components of the rocket is computed, with an emphasis on the base and boattail sections. Quantitative and qualitative differences between the cases with and without active thrust are highlighted and discussed. The obtained results are compared to previously available data on the Grot rocket and semi-empirical models found in the literature. Finally, a semi-empirical base drag model is proposed for use in Grot flight simulation.

Keywords

Base drag, Computational Fluid Dynamics, rocket aerodynamics, sounding rockets, solid rocket propulsion