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Title

Computational Fluid Dynamics of a Supersonic Rocket's Ascent

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Abstract

The goal of the present study was to simulate the ascending portion of a supersonic rocket's flight by using Computational Fluid Dynamics. More precisely, it was necessary to evaluate the impact of accurate atmospheric properties on the aerodynamic performance of the rocket. Therefore, these steady-state axisymmetric simulations considered the change in atmospheric properties with increasing altitude, as per the International Standard Atmosphere (ISA) model.

Four launch situations were then modelled for the expected Mach number range (M0.3 to M1.8). The first launch case considered an external flow with a constant static pressure (1 atm) and temperature (300 K) for each Mach number increment (~M0.05), serving as the least accurate scenario in terms of varying air properties. The remaining launch scenarios implemented the ISA model to account for the varying pressure and temperature in function of altitude. Furthermore, the time to reach top speed was different for each of these remaining scenarios, i.e. t_c1=10 seconds, t_c2 = 7.5 seconds, and t_c3 = 5.0 seconds (constant accelerations were assumed for all launches). Specific tools, such as ANSYS Fluent's parametric study feature and Desktop Studio's clusters, were used to greatly facilitate the planification, execution and computation processes of the large batch of steady-state simulations.

In terms of results, it was found that the wave drag of a supersonic rocket can be minimized by delaying the transition to supersonic speeds as much as possible in time. In other words, aerodynamically efficiency significantly improves when supersonic speed is reached only at high altitudes due to the lower atmospheric pressure, leading to weaker compressibility effects (lower maximal density and total temperature). While previous studies investigated different methods to minimise the drag through component shape optimisation for supersonic speeds, the present study demonstrates that drag can also be minimised through an adequate selection of the supersonic rocket's flight profile.

References

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