Mitteilung

Fachgruppe: Hyperschallaerothermodynamik

Parametric grid fin design study for the T3 vehicle within SALTO

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1. Introduction

The reuSable strAtegic space Launcher Technologies & Operations (SALTO) project, funded by the European Union, aims to increase the technological maturity of reusable launchers in Europe. As part of this project the pre-design of the Themis T3 demonstrator is being analysed and improved. The T3 is a notional reusable first stage. Its aerodynamic control surfaces are to be designed as grid fins within the framework of SALTO.
The concept of grid fins was first described in 1985 by Belotserkovsky et al. [1]. They are becoming increasingly relevant for reusable launchers and promise to be a good solution for these vehicles due to several reasons. Grid fins show good efficiency over a wide range of flight speeds, especially in the supersonic and subsonic regime. They show a delayed stall behaviour and are effective at high angles of attack compared to regular fins. Grid fins require comparably low hinge moments and they can be folded to reduce drag during ascent.
On the T3 vehicle the grid fins will unfold for the descent phase. During this time, they have to fulfil two primary tasks: Enable efficient trim and controllability of the vehicle during the aerodynamic phases. Once these requirements have been met, the design should be improved with regard to other criteria. These include primarily the reduction of mass. In this study, a systematic overview of various geometrical parameters is given concerning their influence on the control forces generated along the trajectory, as well as their effects on the mass of the grid fin. The parameters will be compared to a baseline configuration.
Other factors such as the aerodynamic drag that arises when folded during ascent, aerothermal loads or structural integrity are also relevant for the grid fin design, but are not analysed further in this study.

2. Methodology

To evaluate different grid fin designs CFD studies were performed. The DLR Navier-Stokes solver TAU [2] was used for these calculations. This second-order finite-volume flow solver was used, while applying a one-equation Spalart-Allmaras eddy viscosity model [3]. The AUSMDV flux vector splitting upwind scheme was used for the entire trajectory.
The simulations only consider the grid fin to reduce computational costs. The influence of the remaining vehicle was ignored, as it is assumed that its influence has a similar effect on all of the investigated geometries.

3. CFD Results

An excerpt of the overall results is shown in this section. One of the gouverning parameters in grid fin design is the internal cell spacing s. In Figure 1 three different geometries are compared to the baseline grid fin. The spacing s is varied between 50%, 133% and 200% of the baseline value. Additionally, the cell numbers in y and z direction Ny and Nz were changed, to keep the

original width and height of the grid fin mostly constant. The figure shows the Mach numbers plotted against C_{fy}, the force coefficient in y direction. The investigated Mach numbers cover most of the descent trajectory ranging from supersonic, transonic to subsonic speeds. The deflection angle of the grid fin is 10°.
Using 0.5s shows lower C_{fy} values for all Mach numbers analysed. Therefore, this geometry does not lead to an improvement in aerodynamic controllability. Doubling the spacing, results in lowered C_{fy} in the subsonic and supersonic regime, when no flow choking is present. It increases the resulting force for transonic speeds and for Ma=1.45 and Ma=1.79 (the flow is strongly choked for these two trajectory points). The same increase, but less pronounced can be seen for 1.33s. It also shows a smaller decrease at subsonic and high supersonic velocities.
The 0.5s version increases the weight of the fin by 83.6%, while the 1.33s and 2s versions reduce it by 18.8% and 40.5% respectively.

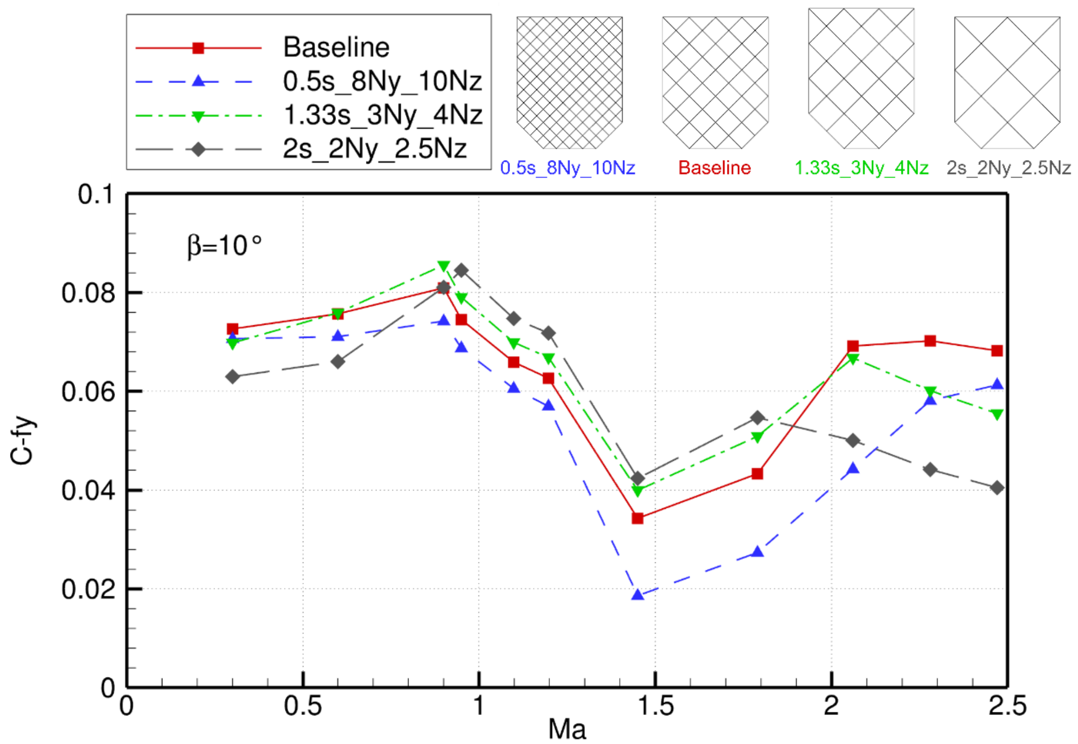

Figure 1: C_{fy} over Ma for different cell spacings s, while keeping outer dimensions approximately the same.

Acknowledgements

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Literature:

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