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Title

Temporal Evolution of Transition Onset along Trajectories of Generic Flight Vehicles

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Abstract

During the design of flight vehicles, quite some uncertainty exists about the onset of the laminar to turbulent boundary layer transition. In [1], it was highlighted that pending on the exact location of the transition onset, the vehicle weight could differ with a factor of two. Additionally, for future reusable spacecraft, the location of transition onset is equally important to estimate accurately the heat load at each position to size the thermal protection system accordingly. A lot of correlations exist to estimate the transition onset, but they usually require information like the displacement thickness, momentum thickness … which are not calculated by standard CFD-tools. Therefore, a tool [2] was developed to post-process the data of a CFD-simulation in such way that the existing correlations can be applied. In this paper several improvements on the existing tool are presented as well as a further development allowing to visualize the temporal evolution of the transition onset and length throughout the flight trajectory of a vehicle.

A first improvement is the parallelization of different parts of the tool. The parallelization allows simultaneous streamline tracings as well as mesh interpolation for different points simultaneously. Using parallelization allows to use linear interpolation of the point cloud using Delaunay triangulation, even for very large meshes. This possibility drastically improves the accuracy of the analysis compared to the reconstructed nearest neighbor interpolation, used previously. Additionally, an improved method for the initial boundary layer edge detection is implemented. To discretize the boundary layer, an initial guess is made. Therefore, an analysis is performed in the wall normal direction, ranging from the wall to the edge of the domain, using a fixed number of points. When the boundary layer is very thin with respect to the domain, the initial guess can be far from the actual boundary layer thickness. To improve this, a method using multiple searches is developed. One can assume that boundary layer thicknesses much larger than the 90th percentile are wrongly detected. Different searches are then performed, every time on a more refined region, until an acceptable boundary layer thickness distribution is reached. Doing this does not only improve the accuracy but also eliminates problems for blunt bodies, in general improving the capability of the tool.

To determine the evolution of the transition location throughout a flight, a wraparound is developed which allows to process different transition analyses along the flight trajectory. Doing these simulations allows to visualize the evolution of the start and end of the transition zone on the vehicle throughout the complete trajectory. Test cases on trajectories of expandable and reusable launchers will be assessed.

References

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