Simulation of Missiles with Grid Fins using an Unstructured Navier-Stokes solver coupled to a Semi-Empirical Actuator Disc

Philippe Reynier[1], Erich Schülein[2] & José Longo[1]

Institut für Aerodynamik und Strömungstechnik,
[1]DLR, Lilienthalplatz 7, 38108 Braunschweig, Germany
[2]DLR, Bunsenstraße 10, 37073 Göttingen, Germany

This study focuses on the numerical simulation of supersonic and hypersonic flows around a missile with grid fins. The advantages of lattice wings, called also grid fins, as aerodynamic controls are well-known. The very small hinge moments reported in several experimental investigations, which can reduce the size of control actuator systems, make them very attractive for hypersonic vehicles. During a long time, the relatively high drag levels were the main concern which restricted the application of this technology. Some recent studies showed that the drag can be easily reduced using frame shaping with only a minimal impact on lift and other aerodynamic properties. Today this technology is used on Soyouz space ships as rear stabiliser for the emergency rescue system.

The objective of the present study is the numerical prediction of the performances, in term of forces and moments, of a vehicle with lattice wings. In order to reduce the computational cost, the actuator disc concept has been chosen to model the effects of grid fins. For a missile with lattice wings the application of this method consists in replacing the lattice wings by boundary conditions where the forces involved by the grid fins are accounted for in the transport equations. This actuator disc has been incorporated in the TAU unstructured code developed by DLR. To compute the forces involved by the grid fins the solver has been coupled with a numerical procedure based on the semi-empirical theory for lattice wings. The forces are calculated with semi-empirical relations as functions of flow conditions and geometrical parameters. These relations valid for subsonic, transonic and supersonic flows have been validated and adapted using experimental data.

The final tool has been already tested on an isolated lattice wing to proceed to an extensive validation of the tool for a wide range of Mach numbers (from 1.8 to 4) and angles of attack (up to 20 degrees). The numerical results for the force coefficients have been successfully compared with theoretical and experimental data. Here, the numerical tool is applied to the prediction of flow around a missile with lattice wings. Numerical results have been obtained for different Mach numbers (from 1.8 to 4) and angles of attack (up to 20 degrees). In the final paper, the predicted force and moment coefficients will be compared to experimental data obtained for the same configuration. In order to evaluate the impact of the actuator disc approach on the results, the body alone has also been numerically investigated. The analyse of the results will provide an estimate of the tool capacity to model the grid fin effects and particularly the interactions between the body and the lattice wings.

The approach presented in this paper is based on the integration of experiments to develop an actuator disc valid for grid fins. The use of an actuator disc reduces by one order of magnitude the computational time for such a configuration. Moreover, so far the lattice wing configuration (number of wings and position) remains constant no additional time is necessary for mesh generation and for testing different lattice wing geometry's in the procedure. The approach presented in this study has a high potential as tool for vehicle design.