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Geometrical Discretization of the Computational Domain for Computations of Axisymmetric Supersonic Flows

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Abstract: The construction of single structured grids for complex geometries is not always possible and it can be a high time consuming part in Computation Fluid Dynamics (CFD). The governing equations for computations of supersonic flows are nonlinear and, in general, do not admit an analytical solution. Thus, numerical techniques are indispensable for obtaining the full-scale solution of these equations. In many cases, computational difficulty stems from the inherently complex geometry and boundary conditions of the problem, which excludes the use of high-accuracy global methods.

Therefore, both multi-zone and multi-block methods for complex geometries can be very important tools. These techniques allow us to use various numerical schemes and governing equations in each region of the computational domain and also, multiple regions of structured grid can be joined together to form the optimum grid for the simulation of flow over a complete body. Thus, these abilities increase both the efficiency of the numerical schemes and the accuracy of the results.

By the use of composite-region grids, the computational domain is subdivided into several subdomains bounded by four curves (in two dimensional). Within each subregion, the grid is generated separately and also the numerical solutions of governing equations can be implemented in all rectangular computational subdomains separately. This allows the solution of large problems, requiring many mesh points, by keeping only the information needed to solve the governing equations in one region in the computer RAM while storing the information of remaining regions in the hard disk. In the multi-block method, the blocks can be had complete communication of flow information across their connecting interfaces, While in multi-zone method, transferring the information of flow variables is done only in streamwise direction.

In practical supersonic aerodynamic calculations, the flow contains various regimes, flow separation regions and strong interaction between inviscid and viscous layers. Thus, the Full compressible Navier-Stokes (FNS) equations or the Reduced Navier-Stokes (RNS) equations such as the Thin-Layer Navier-Stokes (TLNS) and the Parabolized Navier-Stokes (PNS) equations have to

be used in these computations. The numerical solution of the TLNS and PNS equations requires less computer memory and calculation time than the FNS equations. Therefore, in order to predict supersonic flowfields around/in complex configurations, one can choose an appropriate algorithm which uses the TLNS, the PNS equations or the combination of the TLNS and PNS equations along with multi-zone or multi-block schemes to reduce the complexity of grid generation, the computational efforts and required storage.
In this talk, the computations of axisymmetric steady compressible flow which performed over/in complex geometries to determine the aerodynamic characteristics are presented. The present work is to show the ability of the multi-zone and multi-block methods to simulate the external or interaction of internal-external compressible flow. The numerical scheme used to solve the TLNS and PNS equations in the generalized coordinate system is an efficient, implicit, finite-difference factored algorithm of the Beam and Warming. To limit the generation of wiggles and overshoots near shock waves due to inherent behavior of central differencing method, nonlinear artificial dissipation terms (combination of second and fourth order terms) are added to the numerical method. The present results including surface pressure and temperature are compared to other numerical results and experimental data.

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