VOL. 25, NO. 10, OCTOBER 1988 J. AIRCRAFT

Zonal Grid Generation Method for Complex Configurations

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An efficient grid generation scheme has been developed for realistic aircraft configurations. The scheme is based on a zonal approach that simplifies the grid generation process and permits greater flexibility in modeling three-dimensional geometries. In the present scheme, the computational space around a multicomponent aircraft configuration is divided into a number of non-overlapped blocks whose boundaries define the configuration surfaces and the limits of the computational space. H-type grids are generated independently in each region using a hybrid two-dimensional elliptic/algebraic grid generation algorithm. The block grids are then smoothly patched together along common surfaces to ensure proper transition from one block to another. Examples of the generated grids for fighter aircraft demonstrate the effectiveness of the zonal grid generation scheme in modeling complex configurations.

Introduction

ALTHOUGH there have been significant developments in grid generation methods,[1-5] difficulties in constructing computational finite-difference grids often still arise due to the increasing gemetric complexities of modern aircraft configurations. In addition, the continuing improvements in the development of Euler and Navier-Stokes algorithms for complex aerodynamic configurations have increased the need for fast and flexible grid generation methods that can allow for efficient steady and unsteady flow analyses. Currently, several three-dimensional grid generation methods exist for complex aircraft configurations. The majority of these methods employ a zonal approach by which the grid around a multi-component configuration is established by generating a number of block grids, each containing a part of the configuration. The generated block grids are then joined along common boundaries or allowed to overlap[4-8] to establish the grid for the complete configuration. In the present study, a novel zonal scheme is developed to provide efficient grid generation capability for realistic aircraft configurations.

Zonal Grid Generation Scheme

The present grid generation method is based on a hybrid differential/algebraic zonal scheme and an H-type grid topology. The grid for a multicomponent configuration such as a wing/fuselage/tail/canard combination is constructed by dividing the computational space into a number of zones. Each zone contains either a single component or several components depending on the configuration complexity. The boundaries separating the different zones are arbitrary and depend on the configuration geometry; all the zones, however, share common boundary surfaces. Once the zonal boundaries are defined, separate grids are generated in each zone using two-dimensional differential and/or algebraic algorithms for a defining series of planes normal to the coordinate directions. Between each of these defining planes, linear or cubic interpolation is used to generate the additional computational planes. Three-dimensional effects, including sweep, twist, and dihedral, are then incorporated for each zonal grid as needed using a sequence of coordinate rotations and translations. The zonal girds are then patched together to produce the grid for the entire configuration. The patching process involves grid smoothing to ensure proper transition of the grid lines from one zone to another.

Applications

The grid for a given fighter configuration is generated in three consecutive steps. First, the wing/canard/tail/block grid is generated, followed by the fuselage/inlet/vertical fin block, and then the different blocks are smoothly patched to establish the final grid. The grid for the wing/canard/horizontal tail zonal block is generated by solving a set of two-dimensional elliptic partial differential equations of the Poisson type for a specified number (4–5) of span stations that define the wing/canard/tail surfaces. Additional spanwise stations are generated using linear interpolation. The required source terms in the elliptic equations are computed directly from the surface grid point distribution as described in Ref. 9. Clustering of grid points near regions of large flow gradients is accomplished by using exponential stretching. Since most of the computational work is performed for a few defining span

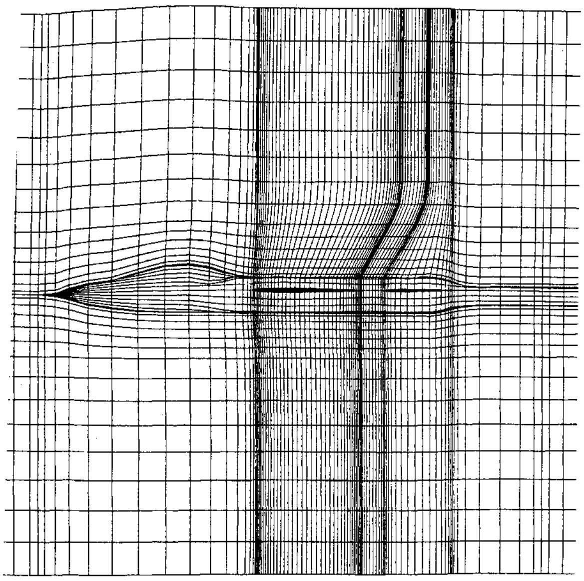

Fig. 1 Plane of symmetry grid for a fighter configuations with vertical tail.

Presented as Paper 87-0276 at the AIAA 25th Aerospace Sciences Meeting, Reno, NV, Jan. 12–15, 1987; received Feb. 26, 1987; revision received July 14, 1987.

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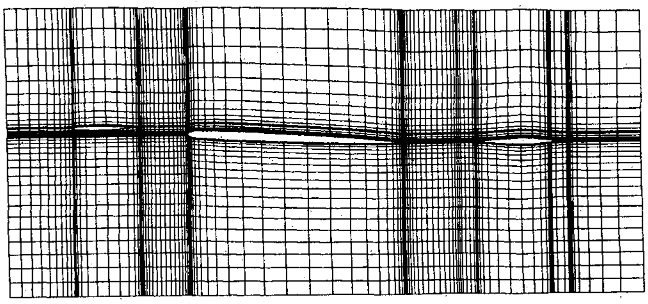

Fig. 2 Side view of field grid for wing/tail/canard configuration.

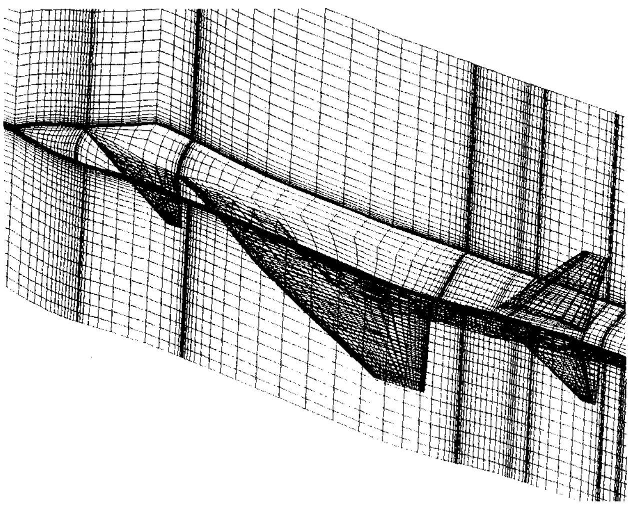

Fig. 3 Plane of symmetry grid for a fighter configuration.

stations, the execution of the grid generation scheme is very fast, especially for medium and coarse grids. In many cases, however, adequate resolution of viscous flowfields requires the generation of very fine grids. For such cases the present grid generation algorithm, like most differential methods, tends to exhibit slow convergence. Consequently, when very fine grids are needed, an algebraic algorithm employing quintic polynomials is used to generate the two-dimensional grids for all the spanwise stations. To preclude the possibility of grid lines crossing, the slopes of the grid lines near the surface are constrained to have a monotone variation in the streamwise direction. The algebraic algorithm provides more control of grid line spacing and slopes near the surface than does the differential technique.

The block grids for fuselages and inlets are generated from the input geometry using cubic polynomials for a series of two-dimensional planar cross sections in the streamwise direction. In each cross section, the slope of the grid lines at the surface is monitored to prevent grid lines crossing and excessive skewness. The vertical fin is embedded into the fuselage grid either in the vertical plane of symmetry or at any desired inclination. As a result of patching different blocks whose grids are generated indepedently, and because of the rotation and translation applied to each block to achieve proper grid point spacing and distribution, the final three-dimensional grid for a given configuration exhibits slope and curvature discontinuities, especially near the common boundaries of the different blocks. These discontinuities are smoothed out using Bezier and quintic polynomials.

The effectiveness of the present zonal method in modeling complex aircraft configurations is demonstrated in Figs. 1–4.

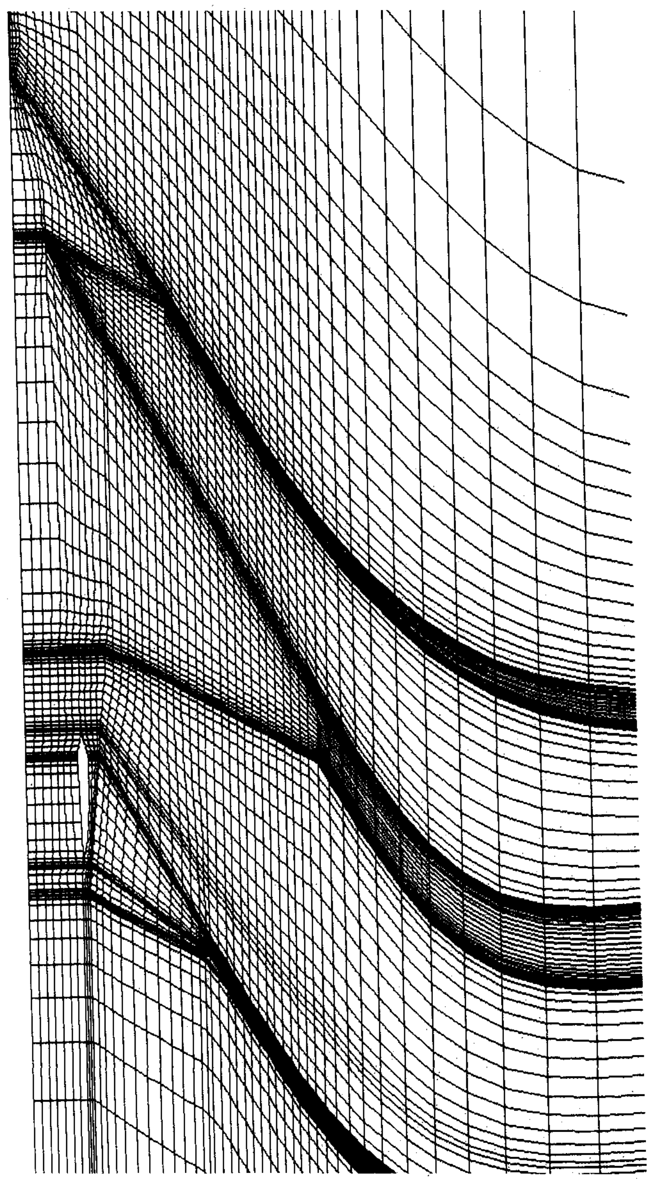

Fig. 4 Plan view of grid for a wing/canard/fuselage/tail configuration.

Figure 1 displays a side view of the plane of symmetry grid for a fighter configuration. The figure clearly shows that regions of high surface curvature and lines of component intersection are modeled properly. Additionally, effective grid point distribution and clustering have been established throughout the field grid. Figures 2–4 display several views of the grid for a highly complex fighter configuration with closely coupled nonplanar lifting surfaces, a rectangular fuselage, a V-shaped vertical fin. In spite of the geometric complexity of the configuration, the grid exhibits good smoothness and continuity properties. Furthermore, regions of large flow gradients such as the fuselage nose and the leading and trailing edges of the wing/tail/canard surfaces have been properly resolved.

Conclusions

An efficient grid generation scheme has been developed for realistic aircraft configurations. The zonal structure of the gridding scheme combined with the use of an H-type topology provide a high degree of flexibility and allow the grid generation scheme to be used for isolated components or complete configurations. The key elements of the scheme are:

1) Adoption of a zonal strategy whereby the field grid about about a muilticomponent configuration is divided into a

number of patched, non-overlapped, block-structured grids.

2) Selection of the H-type topology for each grid block.

3) Application of a two-dimensional differential/algebraic numercial algorithm to generate three-dimensional grids.

Examples of the generated grids for fighter aircraft demonstrate the effectiveness of the present grid generation scheme in modeling highly complex configurations.

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