AN INTERACTIVE MULTI-BLOCK GRID GENERATION SYSTEM

T. J. Kao and T. Y. Su
Aerodynamics Research, Engineering Division
Boeing Commercial Airplane Group
Seattle, WA

Ruth Appleby
CFD Computing
Boeing Computer Services
Seattle, WA

SUMMARY

A grid generation procedure combining interactive and batch grid generation programs has been put together to generate multi-block grids for complex aircraft configurations. The interactive section provides the tools for 3D geometry manipulation, surface grid extraction, boundary domain construction for 3D volume grid generation, and block-block relationships and boundary conditions for flow solvers. The procedure improves the flexibility and quality of grid generation to meet the design/analysis requirements.

INTRODUCTION

The process for conducting a computational fluid dynamics (CFD) analysis usually follows four steps:

- Geometry modeling
- Model discretization (2D and 3D)
- Flow analysis
- Result interpretation.

As the flow codes become more reliable and easy to use, the flowtime for acquiring a solution becomes relatively small when compared to the pre-processing step of geometry modeling and discretization, the most difficult and time-consuming aspects of the process.

This paper describes a multiblock grid generation approach in which geometry continuity is maintained and the required surface grids and block definition are prepared using the Boeing-developed Aero Grid and Paneling System (AGPS)[1,2], and the block-block relationship bookkeeping and boundary conditions are achieved using an interactive graphics interface program, BCON[3].

A unique feature of AGPS is that it is a *geometry programming language*. It allows users to create command files to perform specific tasks. This has allowed us to develop a collection of command files specifically for grid generation problems. This grid generation package contains geometry manipulation tools, various gridding functions, and graphics utilities for generating surface grids and defining block topology. And most importantly, the surface grids in AGPS are based on the actual mathematical surfaces, not approximations.

BCON is a menu-driven graphics interface program. BCON input consists of strings or arrays of points generated from AGPS or another CAD tool/surface geometry source. It generates input files that contain the block definitions, the block relationships and the block boundary conditions required for a multi-block volume grid generation and flow solver.

The combination of AGPS and BCON provides an effective means of producing surface and field grids for arbitrary three-dimensional configuration. In the following sections, we discuss some of the results in applying current procedures.

METHOD/APPROACH

The current approach is to use AGPS to define lines, curves, and surfaces at the block or sub-block boundaries and then to extract the edge and surface grids on these lines, curves, and surfaces. After the edge and surface grids are defined, BCON interactively combines those edge and surface grids into blocks, then writes out block data for 3D volume grid generation and block-block relationships with boundary conditions for an Euler or Navier-Stokes flow solver [4]. We are currently generating 3D volume grids with the Eglin Arbitrary Geometry implicit Euler (EAGLE), a batch-oriented algebraic/elliptical grid code[5]. Figure 1 shows the relationships of each step. It should be noted that this approach is not limited to a particular 3D grid code.

AGPS CAPABILITY

A 3D surface geometry system, AGPS was designed by aerodynamicists primarily for aerodynamics applications. AGPS is a useful tool during the preprocessing and postprocessing steps of the CFD process because of its ability to model both general and complex geometric shapes. It allows for double-valued curves and surfaces and has a variety of surface and curve types, including bicubic, biquintic, conic, interpolated, non-uniform rational B-spline (NURBS), and ruled. It generates surface intersections easily and accurately and has a unique *subrange* surface capability that allows surfaces to be broken or trimmed into smaller regions while keeping the exact mathematical definition used in the original. AGPS-generated surface lofts can be checked thoroughly for flaws using shaded graphics, curvature plots, and various other methods, helping the user achieve a surface with the desired characteristics.

Most importantly, AGPS is more like a geometry programming language than a program itself. The command files make it easy to repeat tasks. In addition, a playback feature is available to interactively record the steps followed.

With the AGPS user-accessible menu (Figure 2) and command file structures, we have developed a grid generation *package* that includes data I/O, geometry manipulation, various gridding functions, and graphics utilities. Inexperienced users need only limited CAD or geometry training and do not need to understand internal data structure or remember a multitude of object names during the operations. With some experience, users can tailor the package to fit their particular needs.

Currently, the primary function of the grid generation package is to define block edges and faces for a multiblock structured grid. As shown in Figure 2, the package allows users to

1. Input AGPS geometry and extracted grids
2. Manipulate curve and surface geometry
3. Extract curve and surface grids
4. Output grids in a specified format
5. Manipulate graphics displays and a geometry database

These functions give engineers a set of highly interactive graphics tools in a single environment to generate geometry, distribute points, and interface with a particular 3D grid generator and/or flow solver.

After preparing the block layout topology, including the number blocks, shape and size of each block, and location of the blocks, the user then creates the block layout interactively by defining lines,curves, and surfaces at the block and sub-block boundaries. Next, the edge and surface grids are generated. The points are extracted directly from the curves and surfaces and lie precisely on the original mathematical definitions.The user can also control grid distribution and perform grid manipulations such as merging and splitting.

BCON CAPABILITY

BCON is a menu/mouse-driven, interactive graphics interface program written in C and using NASA-Ames Research Center's PANEL Library for a graphical user interface on the Silicon Graphics Inc.'s IRIS graphics workstations. The user first prepares the geometry surface definition and decides on the block topology, as well as surface grids, with AGPS. With BCON, the user then defines blocks, block-block relationships, and boundary conditions for input to the volume grid code (currently, EAGLE) and the flow solver. BCON accepts input in the form of strings or arrays of points from AGPS or other geometry/surface grid generation sources. It is highly modular, which allows new features to be incorporated easily.

Major functions BCON provides are

1. Input
2. Define block
3. Define i, j, k index system for each block
4. Impose boundary conditions
5. Write EAGLE run stream and input data deck
6. Write block-block relationship and boundary conditions input files for flow solvers

To simplify the data preparation and reduce redundant data, unique edge/face is required and each block should be represented by as many edges/sub-edges as possible. In cases of original geometry, or when it is necessary to preserve the distribution of interface points, blocks are represented by faces/subfaces. Once a face is defined, no edge associated with that face needs to be prepared; BCON code can identify the edge from the related face.

Each block can be formed by a combination of edges/sub-edges and faces/sub-faces.For a simple face, only two edges need to be defined. For a simple block, only two opposite faces need to be defined. If a block has complex faces, these faces need to be defined first. Similarly, if a face has complex edges, the edges need to be defined first . BCON picks up the remaining simple edges/faces automatically and forms the block.

BCON lets the user interactively select the origin from one of the block vertices and define the directions of the local indices i, j, and k for the first block. The code will propagate these indices throughout all the blocks defined in the blocking process. The block-block relationship is established during this process. Once the blocking process is finished, only the faces without neighbor blocks are displayed; on these faces, the user can impose a variety of boundary conditions, i.e. solid wall, symmetry plane, inlet, exhaust, and far-field. Output files include the EAGLE run stream and input data deck for 3D volume grid generation, as well as block-block relationships and boundary condition input files for flow solvers.

APPLICATIONS

To demonstrate the capability of the present procedure, we have studied several test cases, from simple two blocks wing/body to full configuration four-engine transport airplane. Figure 3 shows the surface grid of a wing/nacelle/strut configuration. The complete flow field consists of 20 blocks (Figure 4) with a total number of 60,000 grid points. An H-type grid is used for all external flow field, and a cylindrical grid is used for nacelle inlet and exhaust flow. Figure 5 shows the isobars of Euler analysis on the configuration surfaces.

Figure 6 shows surface grids for the body/wing/strut/nacelle twin-engine transport model. The volume grid contained approximately 1.2 million grid points and was composed of 26 to 32 blocks, depending on the nacelle simulation. The entire flow through nacelle configuration (with pylon, wing, and fuselage) is modelled with 32 blocks (Figure 7). Fifteen of these blocks are used for the flow-through core and fan cowls. Figure 8 shows constant K plane field grid with part of the surface grid of a fan cowl. Figure 9 shows a comparison of computed wing Cp with wing tunnel data for nacelle installed at eta=0.34, at M=0.77 with Cl=0.55.

The third case is the high speed civil transport (HSCT). Figures 10 shows a symmetry plane and surface grid for cruise configuration with vertical tail. Figure 11 shows the surface grids for high-lift configuration without a vertical tail. The general block layout for high-lift and cruise configuration is shown in Figure 12. It used 10 blocks for a cruise case and 18 blocks for a high-lift case. Figure 13 shows the surface streamlines for both cruise and high-lift cases.

The last case is a four-engine 747-200 full configuration for Navier-Stokes analysis. The complete flow field consists of approximately 45 blocks with over 2 million grid points. Figure 14 shows the complete geometry surface grids. Figure 15 shows a layout of some blocks near the configuration. For this case, the viscous calculation was limited to the wing. It took 14 blocks to cover the boundary layer region. Figure 16 shows viscous blocks near a wing/body junction.

CONCLUSION

The combination of the AGPS Grid Generation Package and the BCON program significantly reduces the flowtime required for generating and pre-processing 3D multiblock grids. The long term goal of this effort is to merge these two capabilities with 3D volume grid generation into one integrated environment, giving users timely, accurate 3D grid generation.

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4. N. J. Yu, H. C. Chen, T. Y. Su, and T. J. Kao, "Development of a General Multiblock Flow Solver for Complex Configuration," Proceedings of the Eighth GAMM Conference on Numerical Methods in Fluid Mechanics, 1990.
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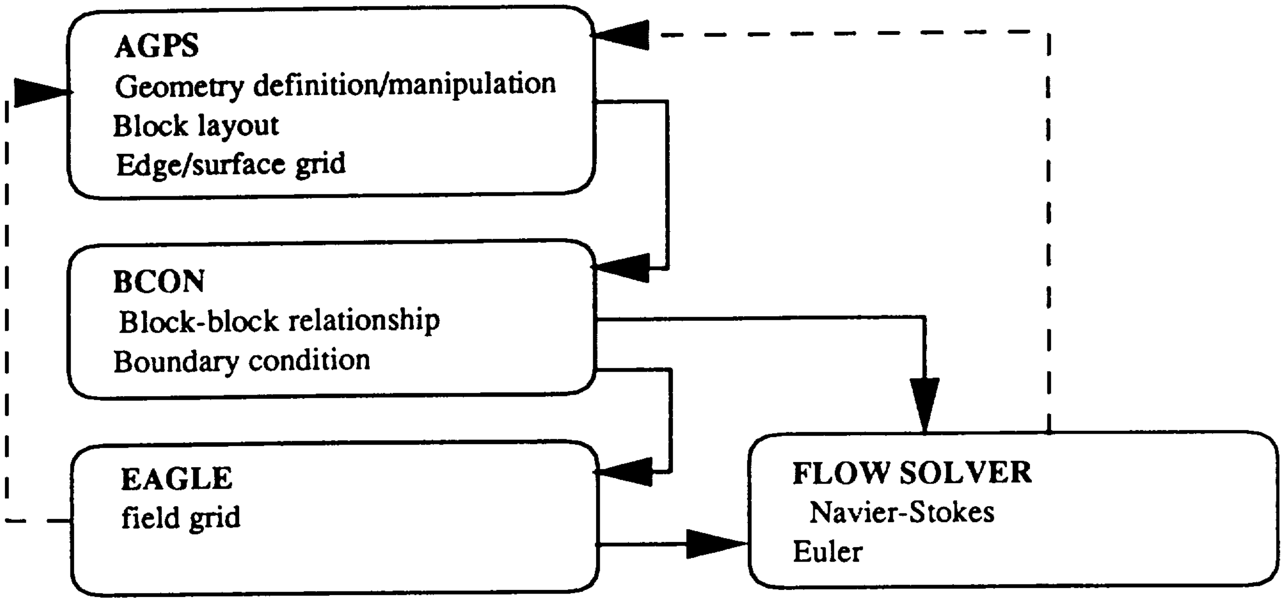


Figure 1. Multiblock grid generation process.

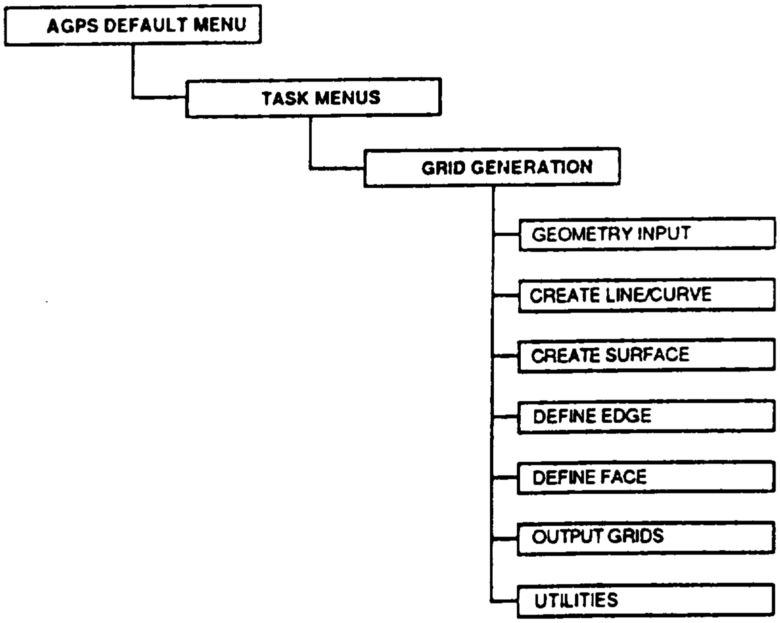


Figure 2. AGPS user-accessible menu.

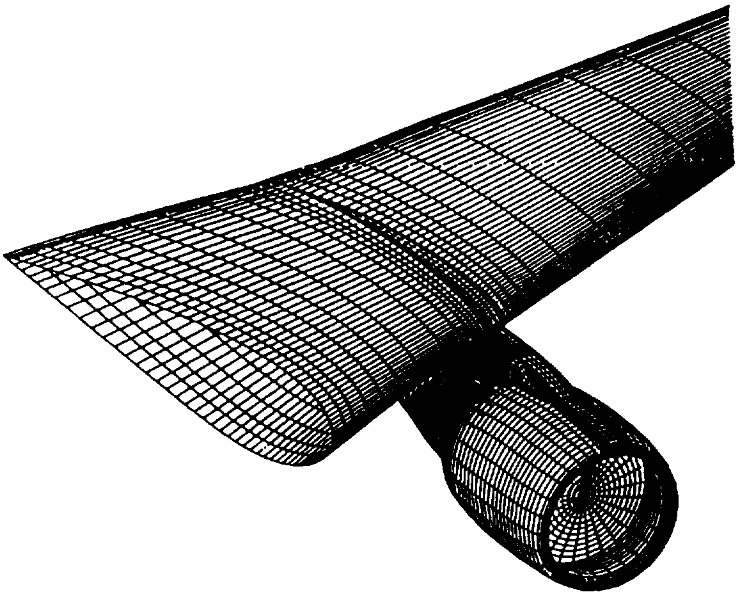


Figure 3. Surface grids for a wing/nacelle/strut.

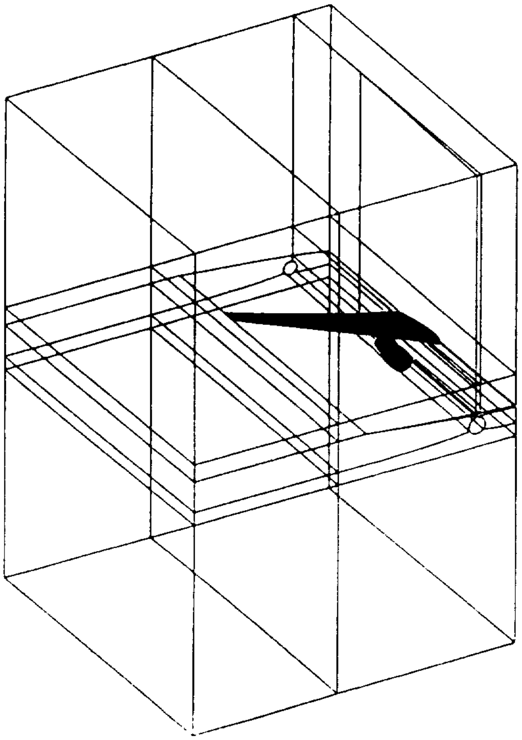


Figure 4. Blocks layout for a wing/nacelle/strut.

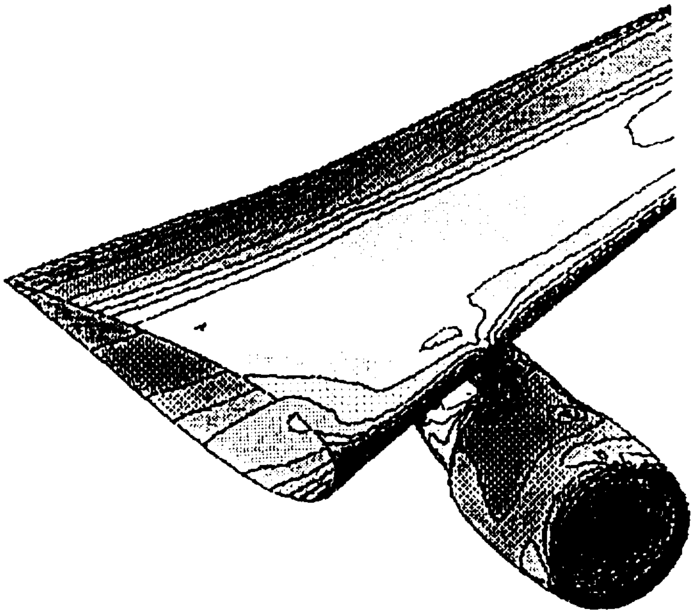


Figure 5. Isobar for a wing/nacelle/strut configuration at Mach=0.8, Alpha=2.0.

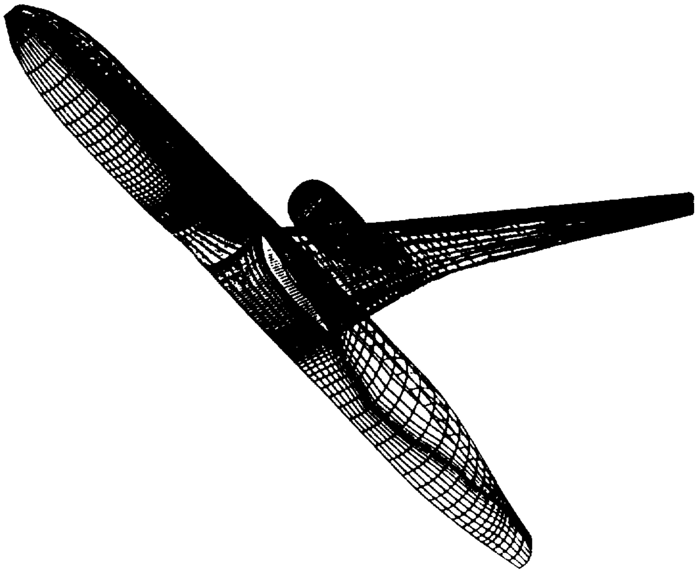


Figure 6. Surface grids for a body/wing/nacelle/strut.

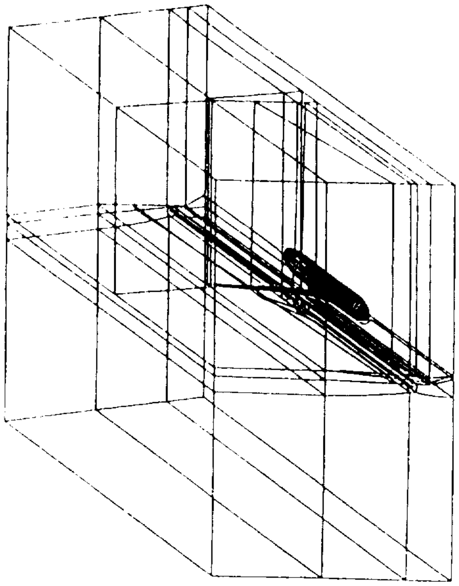


Figure 7. Blocks layout for a body/wing/nacelle/strut.

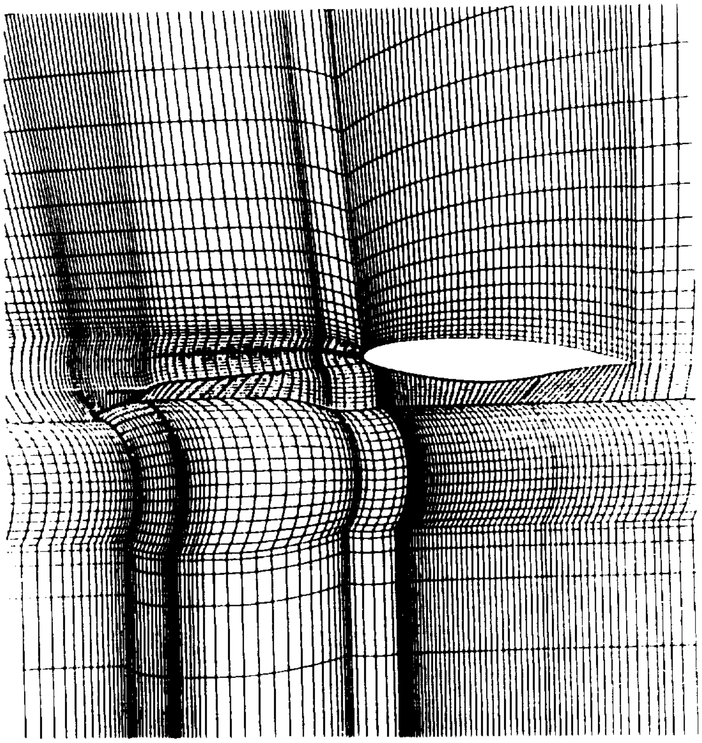


Figure 8. Constant K-plane field grid with fan cowl surface grids.

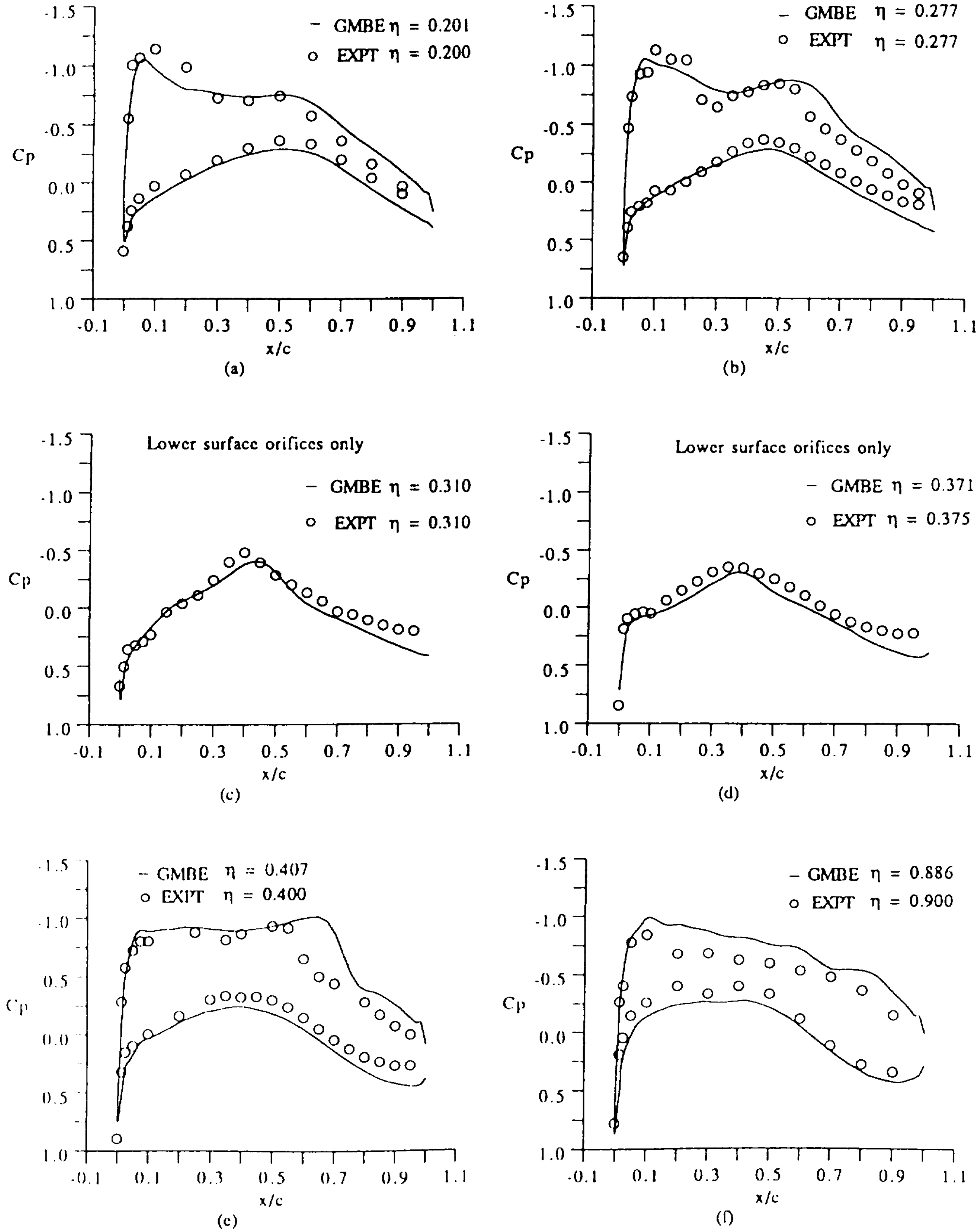


Figure 9. Comparison of computed wing Cp with wing-tunnel data.
for nacelle installed at η=0.34, Mach=0.77 with Cl=0.55.

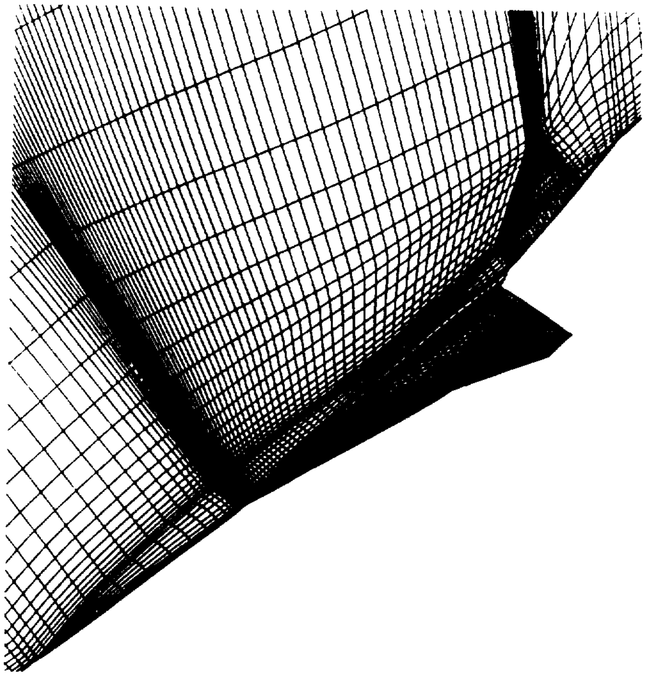


Figure 10. Surface grid and symmetry plane for HSCT cruise configuration.

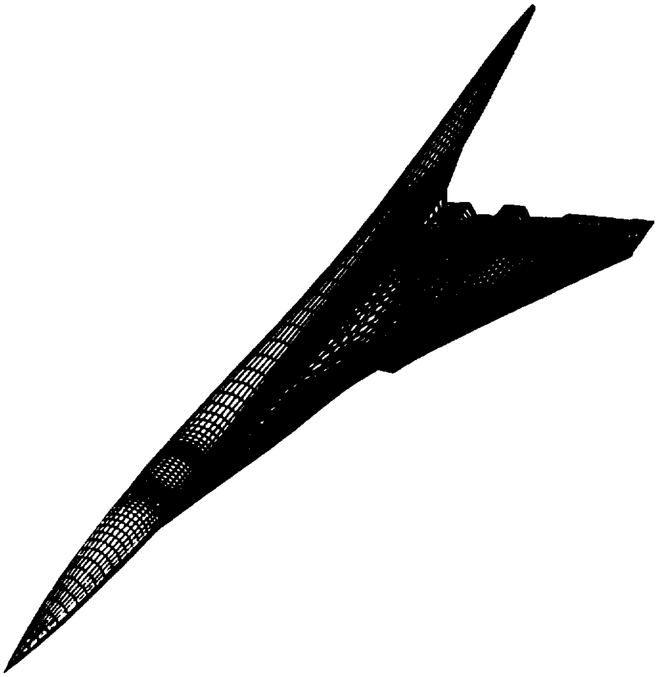


Figure 11. Surface grid for HSCT high lift configuration.

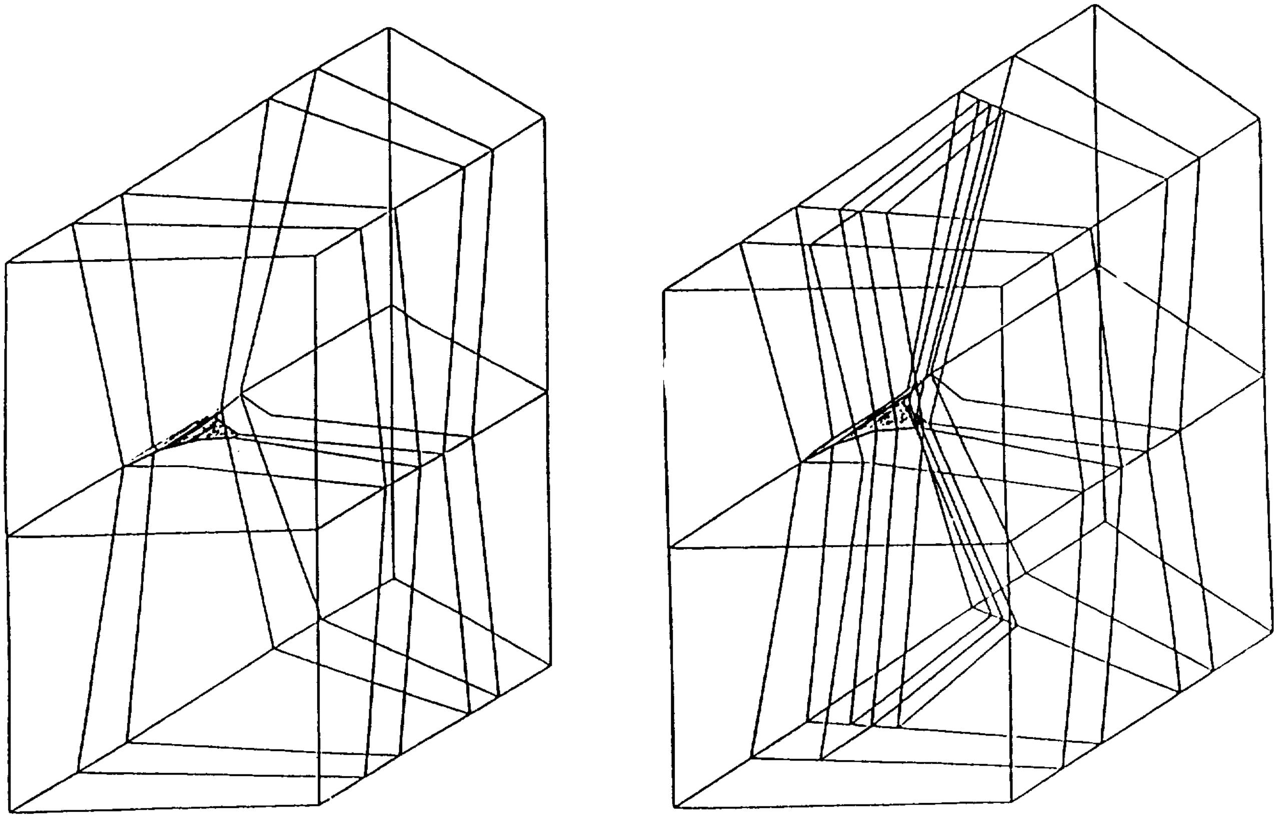


Figure 12. Blocks layout for HSCT cruise (10 blocks) and high lift (18 blocks) configurations.

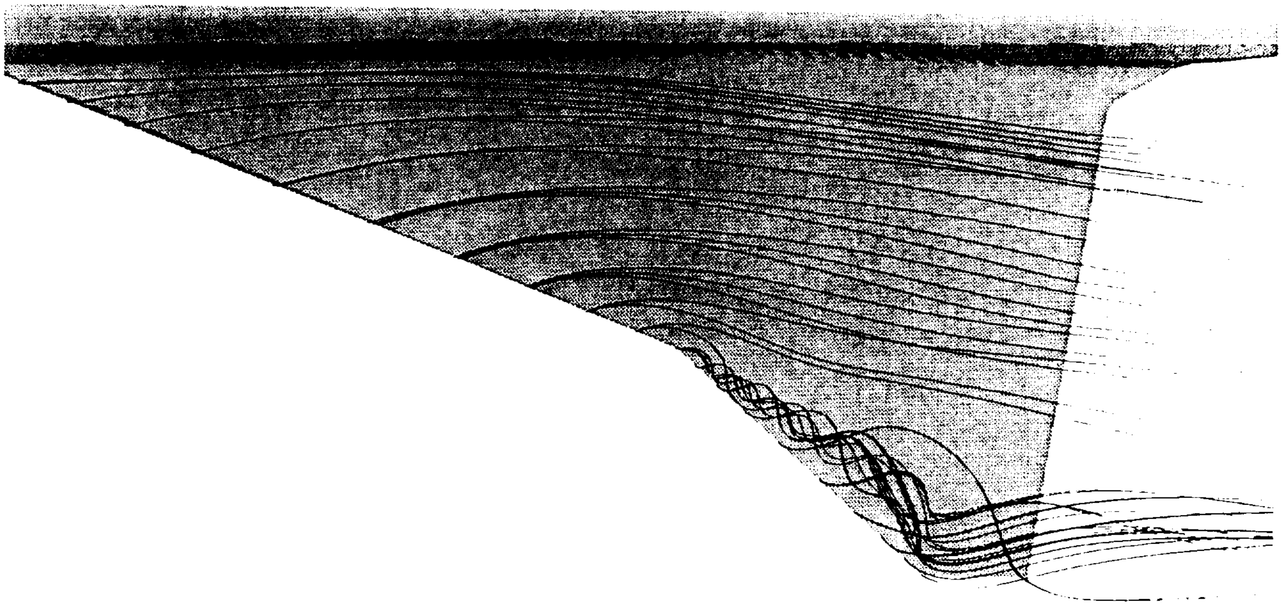


Figure 13a. Streamline traces for HSCT cruise configuration.

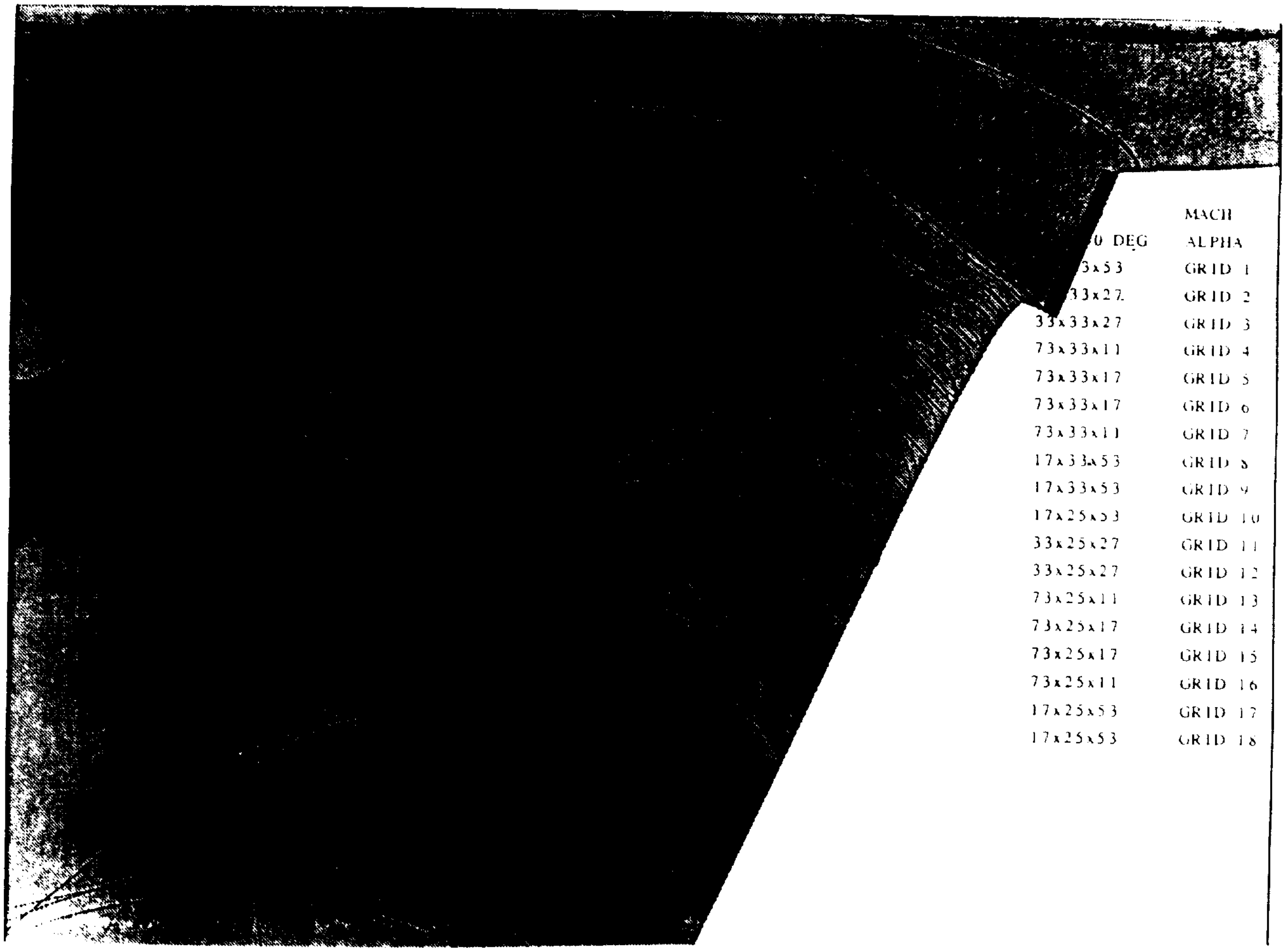
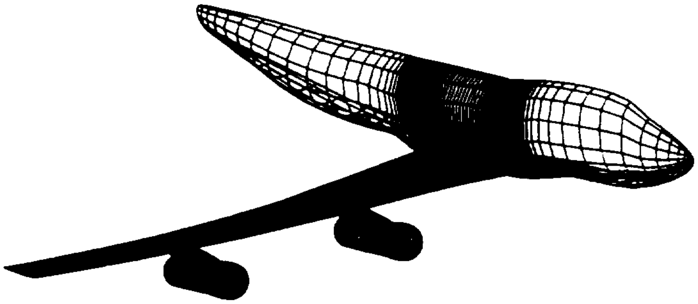


Figure 13b. Streamline traces for HSCT high lift configuration at L. E. flap.



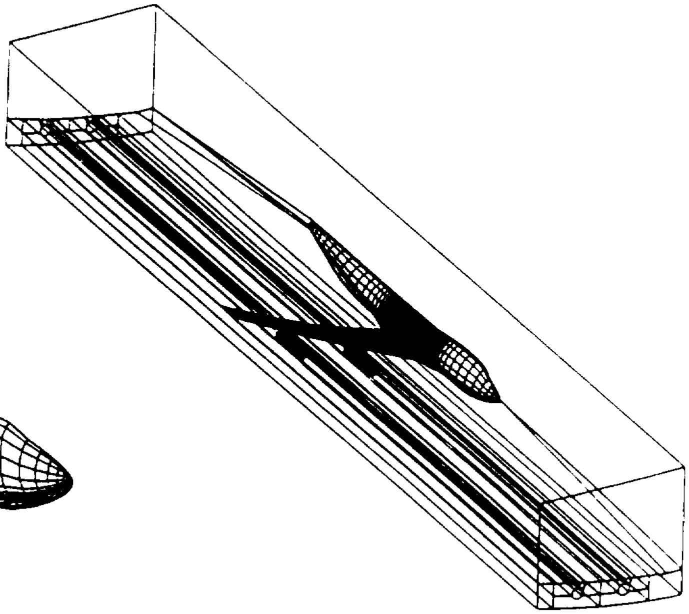


Figure 15. Near field blocks layout for four engines 747-200

Figure 14. Complete surface grids for 747-200.

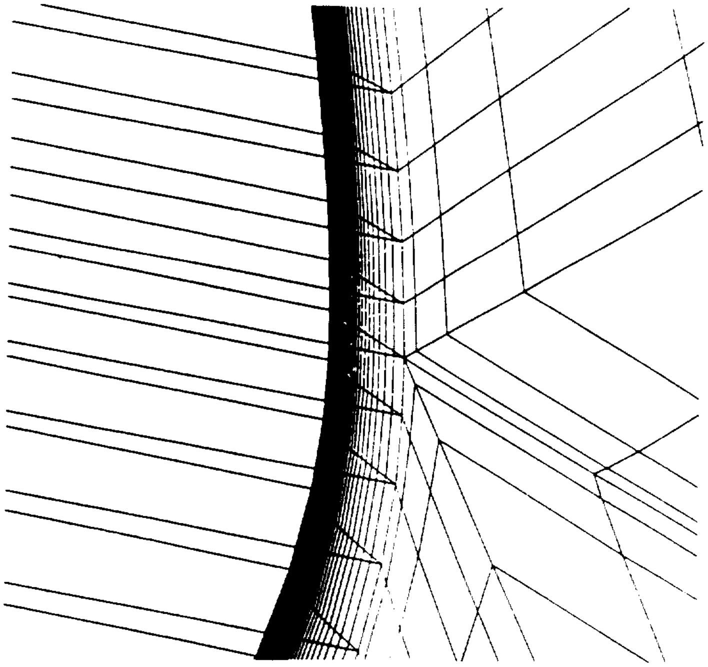


Figure 16. Viscous blocks near a wing/body junction.