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SOME ASPECTS OF ADAPTING COMPUTATIONAL MESH TO COMPLEX FLOW DOMAINS AND STRUCTURES WITH APPLICATION TO BLOWN SHOCK LAYER AND BASE FLOW

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The present paper treats several practical aspects connected with the notion of computation with flow oriented mesh systems. Simple, effective approaches to the ideas discussed are demonstrated in current applications to blown forebody shock layer flow and full bluff body shock layer flow including the massively separated wake region.

The first task in constructing an adaptive mesh is to identify the gross flow structures that are to be captured on the mesh and to work out a grid topology that conforms to them. Among the properties the mesh topology ought to admit are both computational accuracy and algorithmic compatibility. Both these properties are served by grids that feature large connected segments of natural or computational boundaries fitted by mesh surfaces or curves of constant coordinate. But it is neither necessary or always desireable that the entire surface of a particular boundary feature be fitted by a single surface segment of one family of coordinates. For accuracy, convenience, and particularly from the point of view of modern algorithms that embody such features as vector organization, spatial splitting, and implicit solution, it is very desireable that the mesh be composed of identifiable continuous grid

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lines, not necessarily of homogeneous coordinate type, that run from boundary to boundary.

These notions are illustrated in the application to high Reynolds number full bluff body flow in axisymmetry. Here the basic structure of the turbulent flow is well known, Figure 1. The computational mesh that we have adapted to the flow is shown in Figure 2.

We note that in the mesh shown the computational boundaries — axis of symmetry, bowshock, body, and outflow plane - are all fitted by continuous grid lines. The mesh is so constructed as to be flow aligned over the four principal regions — forebody shocklayer, base recirculation, outer inviscid wake, and inner turbulent viscous wake. We note the wrap around mesh provides continuity of the boundary layer and shear layer in the aft expansion zone. The continuity of the mesh coordinate topology is broken in the recompression zone which embeds a saddle surface of the turbulent flow solution at the interface of the recirculant base flow and downstream viscous wake. The singular topology of the mesh in the base recompression zone is illustrated in Figure 3. The viscous wake core box of the mesh, which provides continuity across the viscous-inviscid wake shear layer, can be regarded as a separate sheet of the topology with a cut taken along a line from the singular point down through the recompression zone to the wake axis.

The cut forms part of a set of construction lines embedded in the mesh, Figure 4. It is central to the method described that these lines which largely define the base mesh structure are also representative of the flow structures which the mesh is to fit. Thus in the approach presented here the construction lines serve the role of supplemental imaginary boundaries along which mesh nodes are distributed according to the usual criteria on ordinary boundaries. The resulting bounded domains can then be filled in with computational grid by any of a large variety of means, for example[1,2,3,4].

The particular grid shown in Figure 2 is quite adequate in concept, though not optimized in detail, and was simply constructed in a single pass using one dimensional distributions along straight coordinate lines between boundary points. Where non-uniform distributions have been required they have been conveniently accomplished using a universal stretching function due to Vinokur[5]. In the program, for the stretching function as we have adapted and use it, the total interval along the coordinate line and the (approximate) first mesh spacings from either end of the interval are specified. The function then returns the distribution between boundary points. As convenient, the stretchings are done variously in X, Y, or S (arc length). The actual X and Y coordinates of mesh points are then found by the functional relationships of points on the given coordinate curve, which of course can be piecewise defined. Where fictitious boundary lines are to be embedded in the mesh, actual boundary points are defined on the connecting coordinate lines at half-first-mesh-cell intervals away from the fictitious lines.

A virtue of meshes constructed of distributions along analytically defined coordinate curves, and particularly straight lines, is that differential displacements of boundary points are readily functionally transformed through kinematic relations into corresponding displacements of the intervening grid points so as to leave invariant the relative distributions of mesh points along the given coordinate curves. For the mesh shown in Figure 2, we presently use this property to analytically deform the outer flow portion of the mesh in relative conformity with the moving, fitted bowshock.

In a similar manner it is intended in future work to differentially adapt the interior base mesh to the changing flow solution by moving the underlying construction lines. A central requirement to do this is to define relationships tying the construction lines to the base flow solution. In this regard it is intended that the X coordinate of the mesh singularity correspond to the axial location of maximum wake pressure. Presumably, the Y coordinate of the singularity which lies on the construction line through the viscous-inviscid wake shear layer ought to be determined from a fit to the axial velocity gradient.

Along the same lines, however, we have developed an adaptive mesh for the blown forebody shock layer which is intended to represent flow over an ablating body. Here we wish to distribute points in predetermined ways in the blown layer, the shear layer interface, and in the outer flow region. In this case a construction line demarking the interface between the blown and outer flow regions can readily and unambiguously be fitted to the zero of the stream function based on mass flux and this is what we have done.

We note in connection with the blown shock layer that the associated flow has regions of steep gradient in density, velocity, mass flux, and temperature and that these properties by no means vary together. We take it that an accurate calculation ought to resolve all these features. Thus we think for this application a mesh distribution approach based on the integral of gradient of a single flow property such as Dwyer[6] has demonstrated is not evidently optimum. A similar distribution based on weighted gradients is certainly feasible but this would appear to be more tedious to implement than a compromise _ad hoc_ distribution tied to key features of the flow structure as we have done. In the paper we shall present curves showing the variation of relevant flow properties across a blown shock layer and show how the simple _ad hoc_ distribution approach we use results in satisfactory resolution of all properties.

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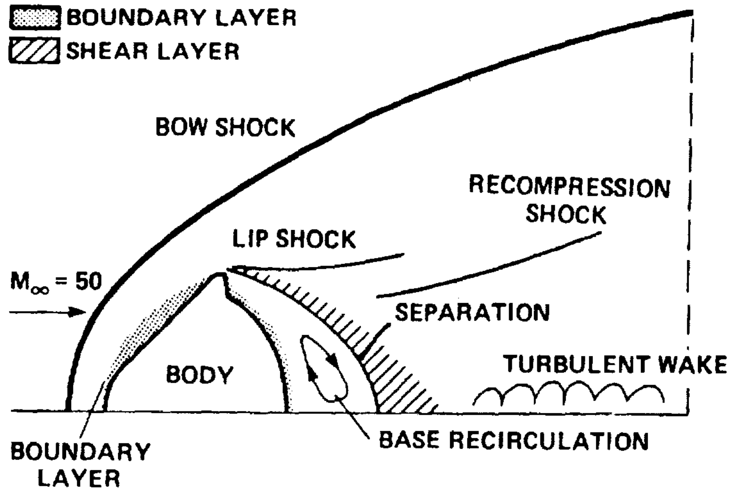

Figure 1.- Geometry and principal structure of full bluff body flowfield.

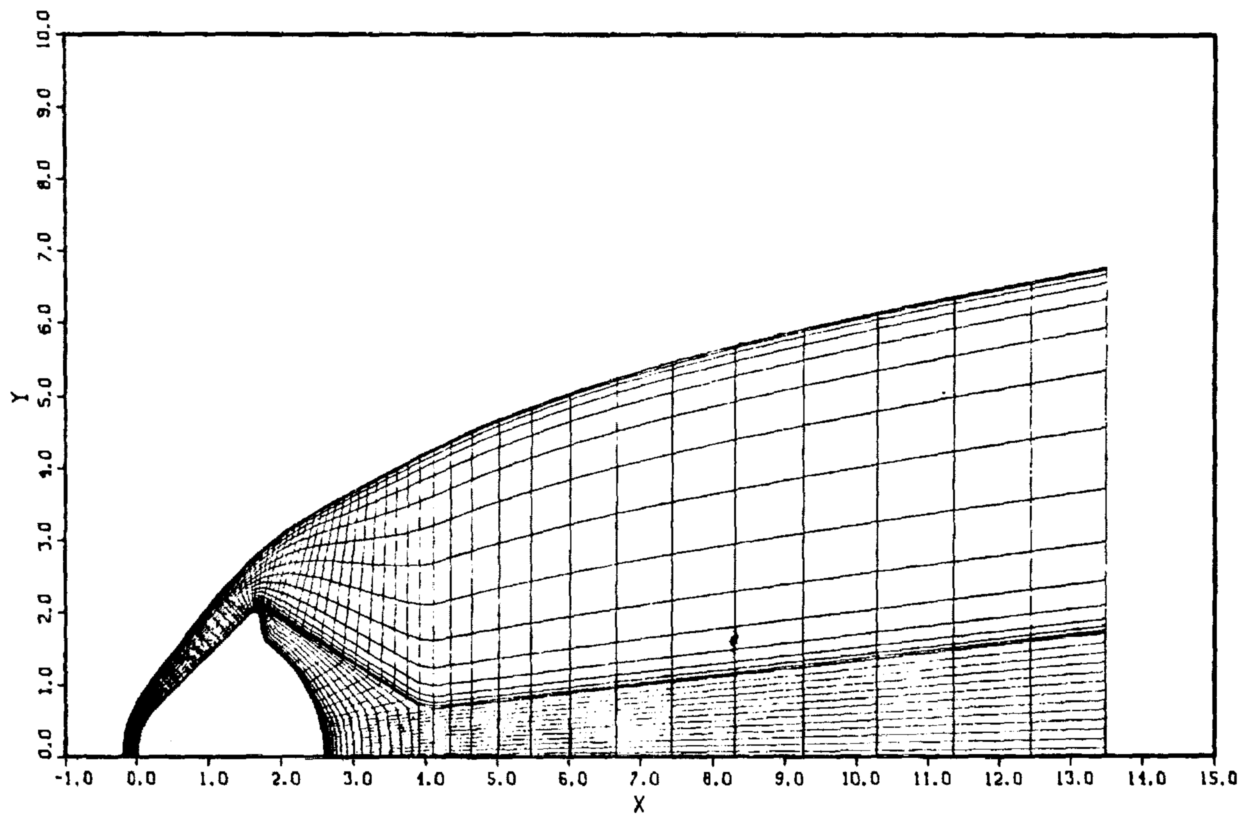

Figure 2.- Full bluff body mesh.

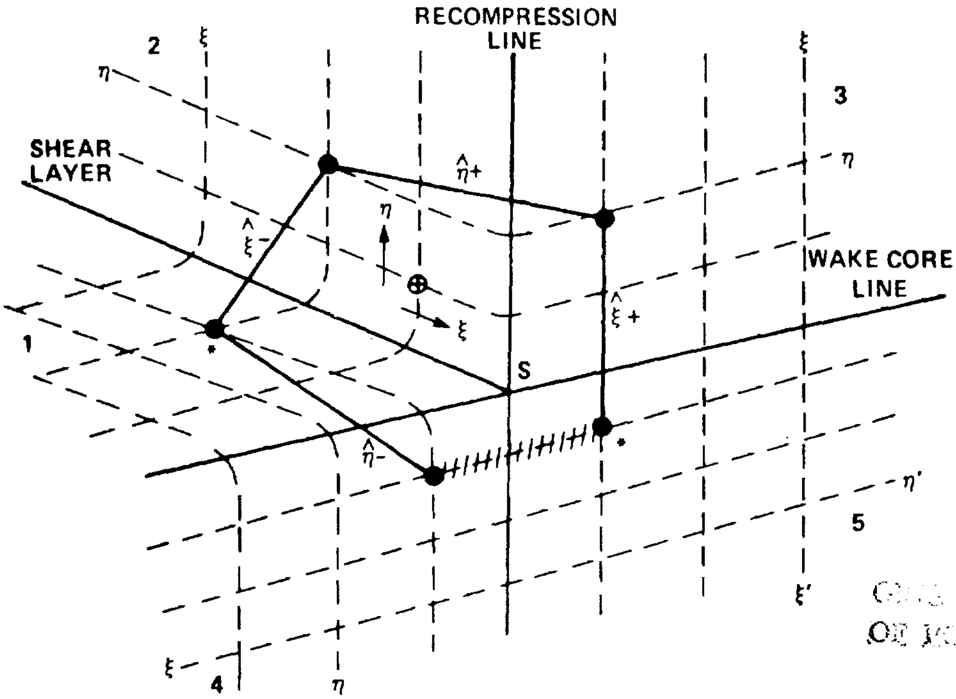

Figure 3.- Base region mesh detail showing topology of the coordinate lines in the vicinity of the singular point s.

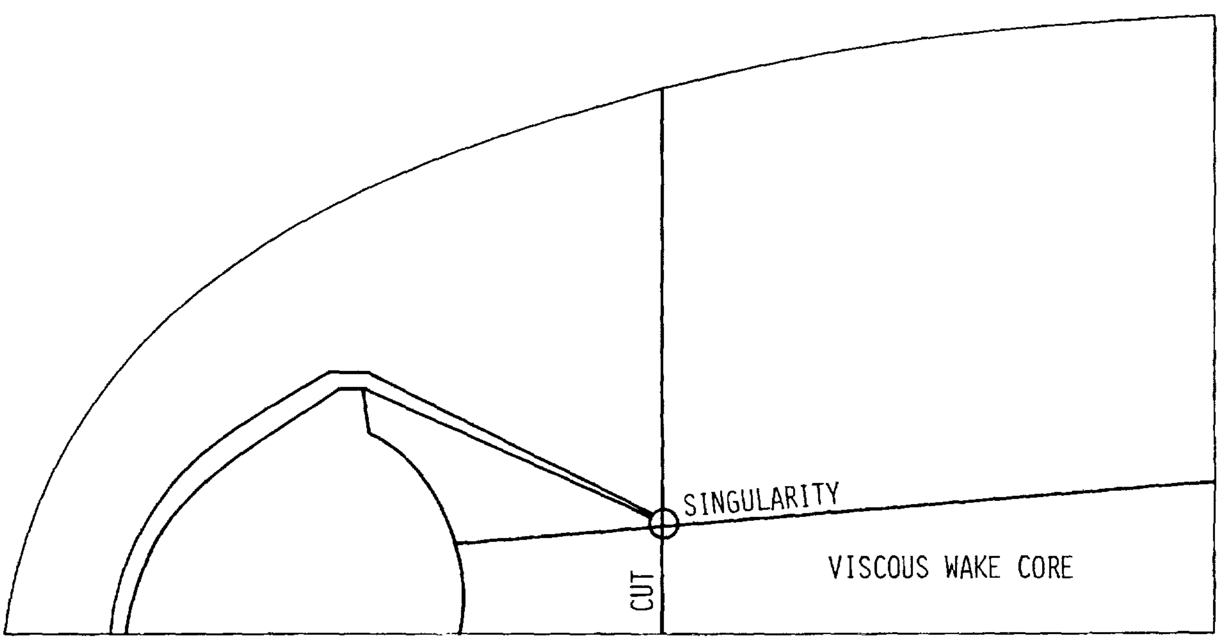

Figure 4.- Mesh construction lines.