THE 5th ASIAN COMPUTATIONAL FLUID DYNAMICS
BUSAN, KOREA, October 27~30, 2003

TRANSITION LOCATION EFFECTS ON DRAG REDUCTION FOR AIRSHIP BODIES

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A special and effective aerodynamics calculation method for viscous incompressible flow around a body of revolution has been coupled with Genetic Algorithms to find optimized airship bodies for various Reynolds number regimes. The aerodynamics calculation starts with the body profile calculation, which is described by a first order continuous axial singularity distribution. The solution of the direct problem for potential flow then gives the radius and inviscid velocity distribution. The viscous resistance to these bodies is usually calculated from the boundary layer solution, which requires the knowledge of the velocity distribution obtained from the potential flow solution.

A Finite Volume Method (FVM), which is consistent to the geometric and physics of the problem, has been applied for calculating the laminar and turbulent boundary layer equations for airship hulls. The governing equations are derived in form applicable to incompressible, axisymmetric turbulent boundary layer in curvilinear coordinate system. The transverse curvature effects of solution domain are also considered, which become quite important when the radius of the body is small compared with the boundary layer thickness. In order to eliminate Reynolds shear stress term, one of the most frequently used two equation turbulence models is employed. In very complex flows for example flows with pressure gradient, the determination of length parameter in mixing-length models is very difficult and two equation models such as $k-\varepsilon$ model are preferred. In this model, two turbulence quantities, the turbulence kinetic energy k and its dissipation rate ε are calculated from transport equations solved simultaneously with those governing the mean flow behavior. The equations are discretized and solved based on the conservative finite volume approach. Second order central difference is used to approximate the cross-stream direction diffusion terms and hybrid scheme is used for convection terms. The formulation is implicit in the stream-wise direction and since the type of the boundary layer equation is parabolic, the forward marching was used in the stream direction, which means the solution domain consists of strips of control volumes.

The transition region is considered as a point where the velocity profile and its properties such as shape factor change from the last value in the laminar boundary layer to the initial value for the turbulent boundary layer. Laminar to turbulent transition is one of the most difficult problems in the field of fluid mechanics. In order to predict the onset of transition during the aerodynamics design process, a strongly simplified theoretical approach is needed. Because of their computational efficiency, empirical local criteria are often employed, but a wide range of predicted transition location can be found with different criteria. In this study the transition location effects for optimized body shape in different Reynolds number range are investigated and the results are compared with those obtained from a semi-empirical e^n criterion based on the linear stability theory presented by Lutz-Wagner.

Separation point can be found from velocity profiles and by avoiding those profiles, which result in separation of the boundary layer, the drag coefficient is determined which takes the skin friction and form drag of attached boundary layer into account. The drag coefficient calculation plays an important role in shape optimization process and it means that accurate boundary layer calculation with reasonable transition location and separation criterion is required to find correct drag coefficient and also real optimized body shape.

For Shape optimizations of airship hulls, a powerful optimization procedure called Genetic Algorithms is performed to minimize the drag coefficient for different Reynolds number regimes. Since the Genetic Algorithms (GAs), represents a special artificial intelligence technique for large spaces, it's one of the best optimization methods for such multi-dimensional, multi-model and nonlinear objective functions.