CASTS Talk

Numerical Perturbation Algorithms, High-Order Accurate Positive Finite Volume Scheme and Its Applications to CFD.

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"The PNS method is in very widespread use; indeed, it forms the basis of an industry-standard computer program, which is used by virtually all major aerodynamic laboratories and companies." (John D. Anderson Jr. American aerodynamicist 2006). There are several PNS equations with different slightly viscous terms, these PNS were suggested by several authors between the late 1960s and the late 1970s. F.G. Zhuang (Academician, China) called the simplified NS equations suggested by Z. Gao in 1967 as first PNS. In early studies of PNS, it is not very clear what kind of basic flow is described by PNS equations, there is no basic fluid theory corresponding to PNS. The senior author presented a PNS's fluid basic theory: viscous/inviscid interacting shear flow (ISF) theory. Main points of ISF theory and inferences are as follows. ISF consists of viscous shear layer and neighboring inviscid outer flow. The basic characteristic of the viscous shear layer flow is convection-diffusion competitive in its normal direction, while it is convection-dominant in its streamwise direction. The optimal coordinates describing ISF is a fitted-surface (This surface indicates zero normal velocity V=0 flow surface) orthogonal coordinates, the equations of motion governing ISF are PNS equations in the optimal coordinates. The PNS equations can be simplified further and the resultant equations are called v=0 surface criteria, the v=0 surface is zero normal velocity flow surface. An important special case of the v=0 surface criteria is the Wall-Surface Criteria. We proved that twelve exact solutions of the Navier-Stokes equations for incompressible flows satisfy exactly the wall momentum criteria. So NS numerical solutions also ought to satisfy the wall momentum and energy criteria (WMC and WEC), which are proved numerically by some computations of 2-D incompressible stagnation flow, shock/boundary layer interacting flow, compression ramp and cylinder flare. People can obtain NS grid independent solution by operation of NS numerical solutions satisfying progressively the WMC and WEC. Especially, this criteria can evaluate the departure of NS

numerical solutions from NS true solution by just one time NS calculation on one set of grid, and based on that some people suggest that the WMC-WEC method may be used as an ingenious substitute for the grid convergence analysis method in common use and that the WMC-WEC method and ISF theory are called Gao's Criteria Method and Gao's ISF Theory, respectively. The evolution laws of physical scales (i.e. length scales and velocity scales) of ISF's viscous shear layer flow are given and it is shown that local small spatial scales can generate in all normal, streamwise and sidewise directions. These local strong viscous/inviscid interactions do cause local sudden increase of several physical quantities such as heat flux and pressure gradient, etc., which are considered as "unknown-unknown" phenomena by some people. Numerical calculations of hypersonic flows over complex bodies are still a challenge subject.