In The Name of God

Dual-Code Thin Layer, Parabolized Navier-Stokes Solutions for Supersonic Flows Over Spinning Wing-Body Configurations

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Thesis

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To

My Mother, My Sisters

And

My Brothers

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Abstract

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In this study, an earlier developed Parabolized Navier-Stokes (PNS) code is combined with Thin Layer Navier-Stokes (TLNS) code to solve supersonic flows around the non-spinning and spinning wing-body combinations. The purpose of this dual-code strategy is to decrease the required memory and computer time for solving 3-D supersonic flow over complicated geometries. The process of the matching between two codes is done by a linearized interpolation subprogram. The flow field around the nose is solved by TLNS code and for the remainder of the body, before wing's juncture, PNS code is applied. The modeling is switched from PNS to TLNS in the vicinity of wing.

Explicit time marching technique with finite volume approach is used to implement the code. The three dimensional Thin Layer Navier-Stokes (TLNS) algorithm is based on Roe upwinding scheme for the discretization of inviscid fluxes and central differencing for viscous terms. The code can be employed in laminar and turbulent flow as well, in which the Baldwin-Lomax turbulent model is used. To compute the flowfield around spinning wing-bodies, the capability of solving the equations in both inertial and rotating frame of references is included in the code.

To validate the code firstly, laminar hypersonic flow with Mach number 7.95 around a cone at incidence angles of 20° and 24° are compared with experimental data. Then, the results of turbulent flow around a tangent-ogive with incidence angle of 6° and a secant-ogive with incidence angle of 10° at Mach

number 3 are compared with existing experimental data and Euler solution. The obtained results were acceptable.

Numerical results of dual-code strategy are presented in two sections. At the first section, this strategy is applied for non-spinning and spinning bodies. The numerical results of a supersonic flow over secant-ogive at Mach number 3 are compared with the experimental data and full TLNS results. It is found that the dual-code computer time is one order of magnitude less than that of TLNS code at comparable accuracy; thus, provides a useful tool in preliminary design of spinning bodies. Furthermore, it is shown that the final results are not much sensitive to the stream wise position of the matching plane.

At the second part, the dual-code procedure is applied for wing-body combinations. Two types of wing-bodies with sweepback and rectangular wings are considered. The comparison of the dual-code results with experimental data and full TLNS results shows that the matching plane should be located small distance before the wing juncture, especially for the sweptback wings. The pressure distribution on the body and wing surface for sweptback wing and normal force coefficient for rectangular wing are compared with the experimental data, which showed a reasonable accuracy. Finally, the dual-code strategy is used for a rotating wing-body combination with rectangular wings. The results show that the matching process works quite well.

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Nomenclature

C	Speed of sound
C_p	Coefficient of pressure
C_n	Normal force coefficient
D	Diameter
E	Total energy
E, F, G	Inviscid fluxes
E_υ , F_υ , G_υ	Viscous fluxes
$\widetilde{E}, \widetilde{F}, \widetilde{G}$	Fluxes in general curvilinear coordinates
f_c	Coriolis force
f_{ce}	Centrifugal Force
F_{Kleb}	Klebanoff intermittence factor
F_{Wake}	Wake function
J	Jacobian of transformation
h	Enthalpy
K	Thermal conductivity
M	Mach number of the free stream
n_x , n_y ,n_z	Components of surface vector
q_x , q_y , q_z	Heat conduction terms
Q	Primitive variable matrix
P	Pressure
P_e	Free stream pressure
Pr	Prandtl number
R	Radius
Re	Reynolds Number
R^i	Right eigen vector