Chimera Grid Simulation of Supersonic Unsteady Open-Cavity Flow

Yong-Hyun Yoon*
Department of Aerospace Engineering
Korea Air Force Academy
P.O. Box 2 Cheongwon-gun, Choong-buk, 363-849 Republic of Korea
E-mail:yoon@afa.ac.kr

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ABSTRACT

Open cavities are typically short and deep with a length-to-depth ratio(L/D) less than 10. Open Cavities on flight vehicles exposed to supersonic flow, such as weapon bays and missile separations, produce complex unsteady flow fields that are of fundamental physical interest and pose a significant practical concern in aerospace applications. Several issues remain to be understood for open-cavity flow field. Flowfield characteristics appear to depend primary on the shape of the cavity and the Mach number. Those flows are usually dominated by the unsteady effects. The flow characteristics of the unsteady flows are very different from those of the corresponding steady flows. The measurement of field properties within the cavity is difficult experimentally because of the unsteady nature[1-5].

In this study, a numerical analysis is presented for the unsteady flow over a rectangular cavity at a freestream Mach number of 4.0. The governing equations are taken to be the unsteady compressible Navier-Stokes equations. Several types of grid system are tested to get the better results.

In the category of structured CFD methods, it is usually necessary to use multizonal patched or overlapped(Chimera) grids with moving grid capability. The Chimera approach is much more versatile in that almost any relative motion between zones is allowed because zonal boundaries can intersect each other in an arbitrary manner. Since the computational mesh is moving all the time, this modules need to be executed at every time step and they can cost several times more CPU than the flow solver itself. The density-based flow solver, CFD-FASTRAN, was used for this study. CFD-FASTRAN solves the full Navier-Stokes equations in a general curvilinear coordinate system. The flow solver including the 6DOF and automated-Chimera capabilities are all controlled through an easy-to-use graphical user interface[6].

Each block has the number of grids as shown in Fig.1.

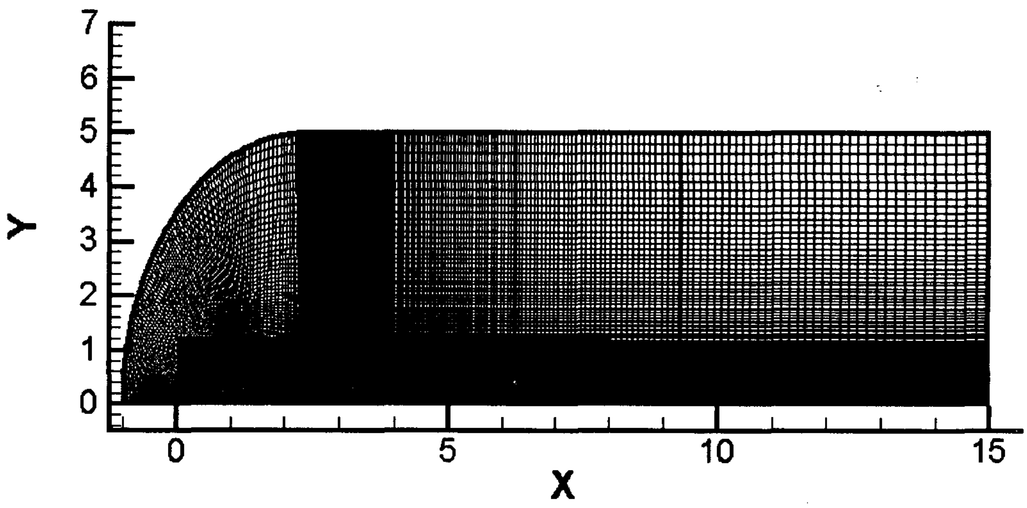


Fig. 1 Chimera Grid System

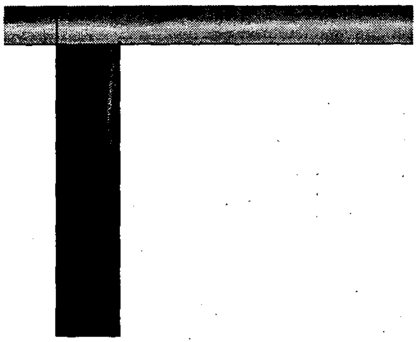
Zone	Grid system	Grid
Zone 1	121 X 161	19,200
Zone 2	321 X 241	76,800
Zone 3	81 X 81	6,400
Zone 4	361 X 361	43,200
Zone 5	121 X 81	9,600

To perform the parallel calculation of flow solver, the 8-node cluster (Pentium 4) called Supercomputer Thunderbolt are used. The solver conditions are Roe 's FDS scheme, k-turbulence modeling, and fully implicit point Jacobi iteration. 4 cases are tested as listed in Table 1.

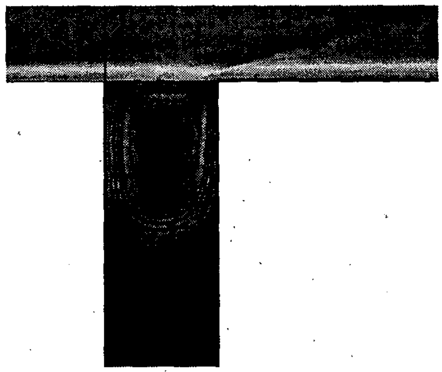
Table1. Test conditions

Cases	Grid	Shear Layer zone	Inner Iteration	Spatial Accuracy	Time Step
1	$7.0x10^6$	Zone	60	2nd order	CFL=0.01
2	$1.5x10^7$	Zone	60	2nd order	$1X10^{-5}$
3	$1.5x10^7$	Zone	100	1st order	$1X10^{-5}$
4	$1.5x10^7$	One	100	1st order	$1X10^{-5}$

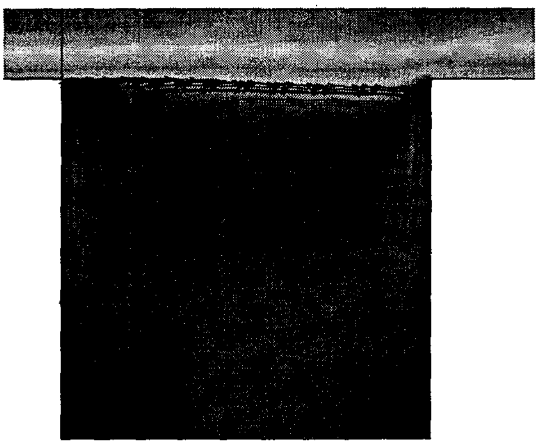
In the current computations, the vortex structures inside the cavity are captured.(see Fig. 2) The characteristics of cavity flow can be represented by pressure coefficients.



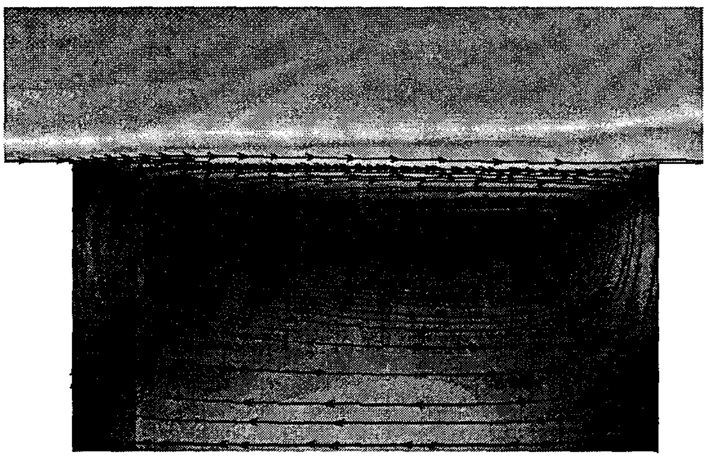
(a) 0.1 D



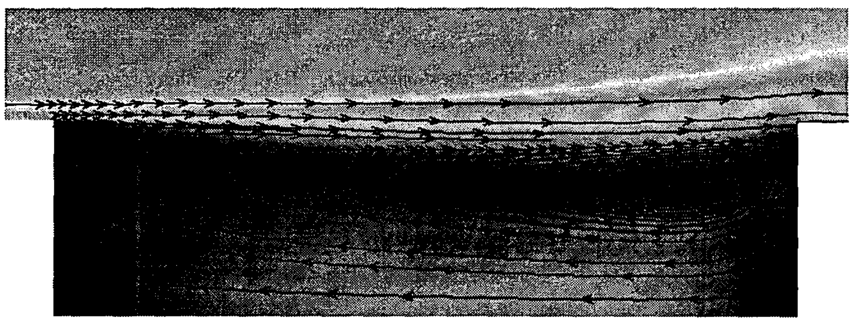
(b) 0.2D



(c) 0.5 D



(d)1.0 D



(e) 1.9D

Fig.2 Unsteady Vortex Structures

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