Impact of Spatial and Temporal Resolution on the Aeroacoustic Wave from a Two-dimensional Impinging Jet

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Abstract: Impacts on the spatial and temporal resolutions are discussed through the two-dimensional model problem of jet impinging which is proposed by Housman et al.[AIAA paper 2011-3650,2011] and the present authors. The result shows that the high-resolution schemes improve the resolution of fine structure of vortices while conventional scheme can predict the blast waves well.

Keywords: Numerical Algorithms, Computational Fluid Dynamics, Aeroacoustics.

1 Introduction

When rocket launches, there appear to be two severe acoustic loads on the pay-load. One is the ignition over pressure (IOP) which is a kind of blast wave generated when the rocket engine starts. The other is turbulent/shock noise generated by a rocket plume. It is important to predict both of them, accurately. Recently, the computational fluid dynamics starts to be used for the prediction of strength of those acoustic waves. It is important to clarify the spatial and temporal resolution of the computational scheme/grid adopted in the simulation for the prediction of such an unsteady simulation. Thus far, the two-dimensional model problem of IOP is established by Housman et al. and the present researchers, and the series of analysis are conducted to understand the spatial and temporal resolution. Housman et al. [1] showed the criteria of number of the sub-iteration, tolerance of residual, and CFL for the accurate simulation, based on the database of the series of computation using three different grid resolution and conventional upwind scheme. It should be noted that they uses the Cartesian based computational grids and clearly discussed the grid resolution effects. Their analysis is very interesting and extension of their discussion to the high-resolution scheme, which is often used in the aero-acoustic and turbulent simulations, sounds very important.

Therefore, in this paper, we will present the effects of the spatial and temporal resolution of the computational schemes and grids on the resulting acoustic fields of the two-dimensional problem, whereas both of the conventional scheme and high-resolution scheme are examined. The difference in spatial resolution between conventional and high-order schemes is mainly discussed in this paper.

2 Problem Settings

The geometric configuration and prescribed pressure history at the nozzle inlet are shown in Figs. 1 and 2. The curvilinear grids are used as shown in Fig. 3 for representing these geometric configurations.

3 Numerical Setup

Two computational codes developed in Japan Aerospace Exploration Agency are applied to this problem, whereas one code is UPACS(-LES)[2], and the other is LANS3D[3]. Both of them has high-order options, where UPACS has compact scheme with localized artificial diffusivity (LAD), and

LANS3D has weighted compact nonlinear scheme(WCNS). See References for more details.”

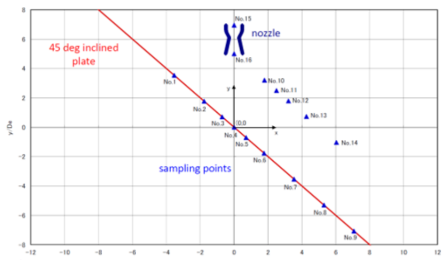

Figure 1 Computational geometry and numerical probes

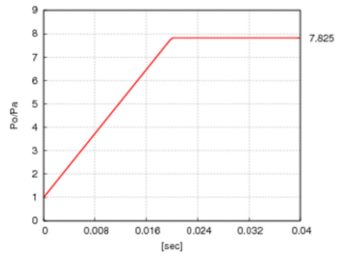

Figure 2 Time history of prescribed pressure inside the nozzle

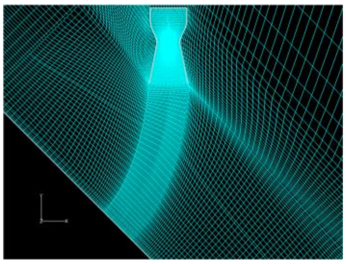

Figure 3 Computatinal grid.

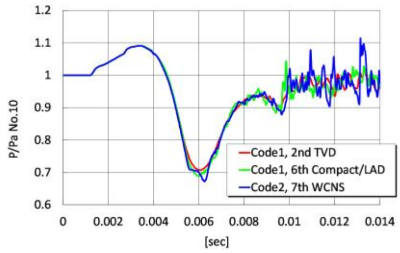

Figure 4 Pressure history at No. 10 with differnt schemes

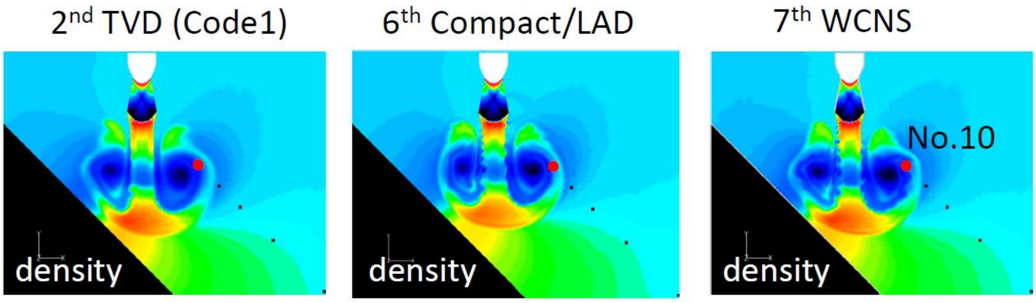

Figure 5 Instantaneous flow fields with different schemes (Code1 denotes UPACS, compact/LAD is computed by Code1 and WCNS is computed by Code 2)

4 Results and Future Work

The time history of pressure at the numerical probe No. 10 is shown in Fig. 4. The first maximum corresponds to IOP and first minimum does to the negative pressure region generated by the starting vortex. Compared with the 2nd order TVD, high-resolution computation gives us finer structure of vortices while the IOP are well-captured even with 2nd order schemes. Here, the finer structure leads to the larger fluctuations in Fig 4 after 0.012 [sec]. A high-resolution scheme improves the resolutions of such fine structure of vortices. In the final paper and presentation, we will also present the temporal resolution with changing the time-step and sub-iterations.

References

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