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On Grid and Scheme Resolution for Supersonic Jet Acoustics

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ABSTRACT

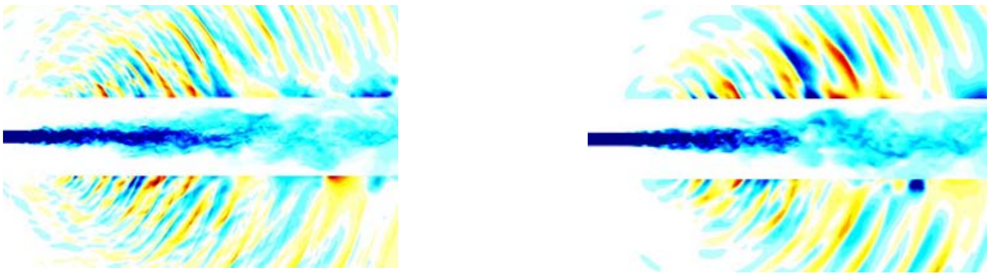
It is known that a rocket plume emits very laud noise which may be harmful to the pay-loads of the rocket such as artificial satellites because they are very light and fragile. Thus it is necessary to predict acoustic waves from the rocket plume accurately for the reduction of level of them. In order to predict noise from a rocket plume, a semi-empirical method based on experimental and the actual launch data, which are reported in NASA-SP8072,[1] has been used in worldwide. However, it is known that there is significant difference between actual acoustic waves measured on Japanese rocket and predicted ones. In addition, though these semi-empirical methods are based on huge past data, mechanisms such as noise-emission, noise-directivity and noise-source have not been well-discussed due to the difficulties of handling the experimental or the actual launch data. Therefore a new prediction method based on a more accurate jet acoustic model is needed. In order to build a new model, it is necessary to obtain detailed information of the flow fields and acoustics fields. Therefore, LES (large eddy simulation)-like methodology, which is recently developed and shows good results, is being applied to clarify the basic acoustic wave emission and propagation. However, LES methods needs very fine grid and high resolution scheme, where required resolutions must be investigated for each problem.

In general, LESs are conducted with linear high order scheme, such as compact scheme. However, a rocket plume is of supersonic jet condition in which shock waves are present. Therefore we must use shock capturing scheme. In this study, Weighted Compact Non-linear Scheme is adopted, which is combination scheme of compact scheme and WENO. The resolution of WCNS is slightly higher than WENO and WCNS has some advantages to WENO such as capability of various flux evaluation methods, etc. However, shock capturing scheme has not been used in aero acoustic computations. Therefore grid convergence study must be carried out. In this abstract, some examples of our results are briefly presented.

In this presentation, first, results of grid convergence study are described and the resolution for the supersonic jet acoustics is discussed. With 10 million grid points and 7th order WCNS[2], solution of supersonic jet flow and acoustic fields are converged very well. This point will be discussed more in detail in the final paper. In addition, cut

off frequency which indicates the reliable limit in frequency domain will be discussed.

So as to investigate effectiveness of WCNS, same problem is solved with MUSCL scheme with the same grid. Figure. 1 shows the instantaneous flow-fields of Mach 2.0 supersonic jet solved WCNS and MUSCL. Clearly, WCNS can resolve very short waves while MUSCL can not resolve them. In addition, spectrum of the acoustics waves solved with MUSCL and WCNS at point D in right side of Fig. 2 are shown in left side of Fig. 2. The result solved with MUSCL has higher peak level at low frequency and lower level at high frequency than that with WCNS. This seems due to that with MUSCL scheme we can resolve only very large vortices and over-predict sound pressure level from them, while we can not resolve high frequency acoustics. Therefore, we should be carefully to use lower resolution schemes because results of the lower scheme (here, MUSCL) does not show simple trend such as under-predicting in all frequencies, but shows complicated trend such as over-predicting acoustics level of lower frequency and under-predicting that of high frequency.



(a) solved with WCNS **(b) solved with MUSCL**

Fig. 1 Compasion of results with WCNS and MUSCL. Center:*x*-velocity distibution (white to dark blue). Top and bottom: acoustic pressure whose threshold is set to -0.01$P_{ambinet}$(blue) to -0.01$P_{ambinet}$(red).

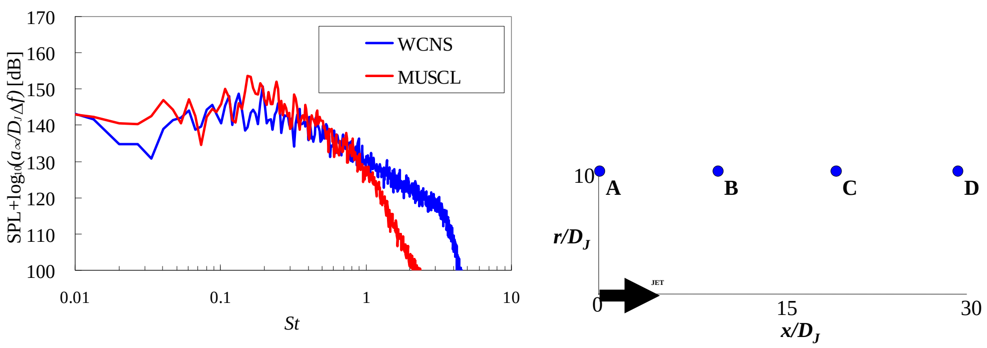


Fig. 2 Comparison of spectrum at point D

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