THE 5TH ASIAN COMPUTATIONAL FLUID DYNAMICS
BUSAN, KOREA, OCTOBER 27~30, 2003

Noise Reduction of Blade Vortex Interaction Using Tip Jet Blowing

Choongmo Yang, Jehyun Baek [1]***, Shigeru Saito, Takashi Aoyama*** [2]
1.Dept. of Mechanical Engineering, Pohang University of Science and Technology, KOREA
2. Rotary Wing Research Group, National Aerospace laboratory, JAPAN

Abstract

Nnumerical investigations of the tip vortical characteristics were conducted with lateral tip blowing to reduce Blade-Vortex Interaction (BVI) noise. The predictions of BVI noise were performed using a combined method of an unsteady Euler code with an aeroacoustic code based on Ffowcs-Williams and Hawkings formulation. A moving overlapped grid system with three types of grids (blade grid, inner and outer background grid) was used to simulate BVI of helicopter with two OLS-airfoil blades in forward/ descending flight condition. The calculated waveform of BVI noise, which is characterized by the distinct peaks caused during blade vortex interaction, clearly shows the effect of lateral blowing at tip to reduce BVI noise

Keyword: *Blade Vortex Interaction Noise, Tip Jet Blowing*

1. Introduction

As one of active control method to reduce the BVI noise, method of jet-blowing from a blade-tip, as shown in Figure 1, has been tried by many researchers. The idea of mass injection to control the tip vortex started in the area of fixed wing. For the application to helicopter rotor blade, Tan et al. conducted wind tunnel test to reduce BVI noise by blowing compressed air from blade tip of helicopter rotor. They showed that the vortex intensity is reduced while the vortex location is moved outward which resulted in lower BVI noise level. Yamada conducted parametric study using three-dimensional compressible Euler code to calculate the effect of blowing air from blade tip on the tip vortex of single fixed or rotary blade at the various free stream velocities and blowing conditions, such as injection angle, mass flow rate of jet blowing. Yang et al. conducted comprehensive numerical and experimental investigation of the lateral tip-blowing to reduce BVI noise. The results showed that blowing from the wing-tip can diffuse the tip vortex and displace it outward causing the increased 'wing-span'.

Main objective of this research work is to study on lateral tip-jet blowing as one of method to reduce BVI noise using compressible flow solver with overlapped grid system. For this purpose, first numerical analysis technique will be constructed to solve the BVI phenomena of the helicopter rotor in forward flight. Quantitative calculation will be compared with experimental data. Then using the code developed, BVI analysis will be conducted with various jet blowing conditions to construct database of predicting optimal condition.

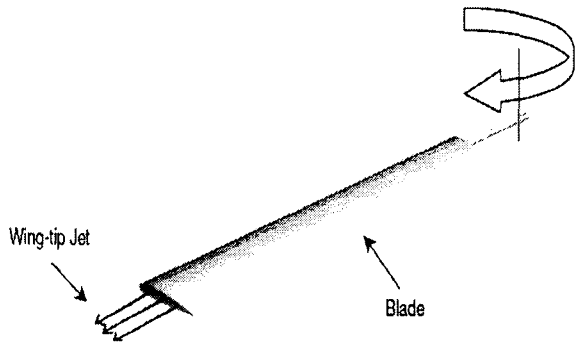
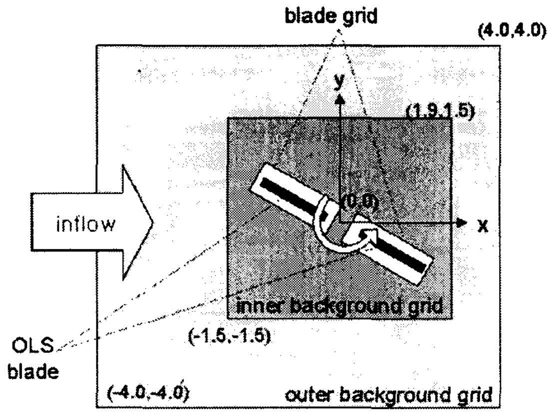


Figure 1. Diagram of wing-tip blowing jet of rotor



Unit = Rotor radius

Figure 2. Geometric dimensions of computational domain of inner and outer background grid

2. Numerical Method

2.1 Overlapped grid system

A moving overlapped grid system with three types of grids (blade grid, inner and outer background grid) was used to simulate BVI of helicopter with two OLS-airfoil blades in forward/ descending flight condition [1]. Figure 2 shows the computational domain for three types of grid and the geometric dimensions for whole domain. The inner background grid is placed around the rotor disk. The outer background grid covers whole computation region with a sparse grid density. The flow data are exchanged between inner and outer background grids. The body-fitted blade grid in O-H topology moves with the blade motion including rotation, flapping, feathering, and lagging. The number of grid points in span-wise direction is considerably increased to match the grid density of the blade grid with that of the inner background grid. The size of the blade grid in normal direction is nearly equal to the chord length.

2.2 Ffowcs-Williams and Hawkings formulation

The prediction method of the far field acoustic pressure is based on the combined method of CFD technique with acoustic equation solver. The prediction method of rotor noise is composed of tree steps: calculation of sound pressure of the noise source, acoustic prediction computation at the observer position, and post-processing of the noise data in the way of sound level, visualization or audible converting. Several prediction methods are available. Direct computation can be used to get the noise solution directly from the flow calculation with CFD based methods, but this is available only near field, and best way is the coupled with integral method for far-field prediction. Acoustic Analogy, which is re-arranged in to Ffowcs Williams–Hawkings Equation and Kirchhoff formula were widely used and still under construction for better applications. Retarded time solution to Ffowcs-Williams and Hawkings equation, neglecting quadruple noise, can be written in the following equations as the form of ***Formulation1a*** [2]

3. Results

Figure 3 shows the comparison of sound pressure level (SPL) histories for one revolution of rotor blade according to the jet conditions. Compared to the results of single fixed blade calculation, the solutions of different jet condition show not so much difference with each others. The reason of small effect of jet blowing can be thought of a numerical dissipation in the inner background grid, which is sparse to project the tip vortex core correctly. The numerical dissipation causes this result in spite of using higher accuracy numerical scheme.

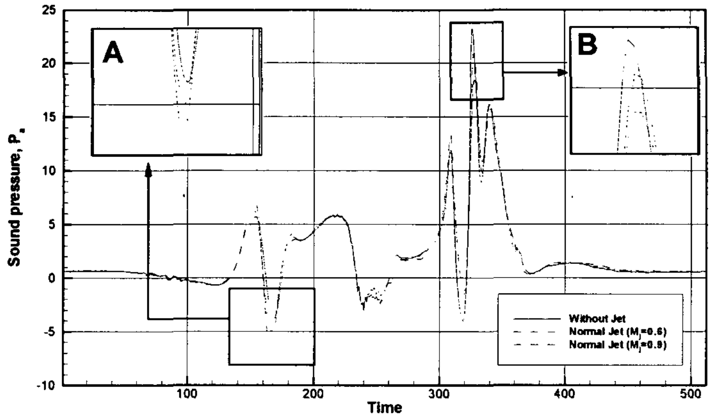


Figure 3. Comparison of sound pressure level (SPL) between cases with overlapped grid system

References

[1] Boxwell, D.A., Schmitz, F.H., Splettstoesser, W.R. and Schults, K.J., Helicopter model rotor-blade vortex interaction impulsive noise: scalability and parametric variations, J. of American Helicopter society Vol.32, No.1

[2] Farassat, F. and Myers, M. K., Aerodynamics via acoustics: Application of acoustic formulas for aerodynamic calculations, AIAA 10th Aeroacoustics Conference, AIAA 86-1877, 1986