Mitteilung

Fachgruppe: Strömungsakustik

Broadband noise simulation of small coaxial rotor configurations

Jianping Yin
German aerospace center DLR, Institut für Aerodynamik und Strömungstechnik Institution,Departtment Helicopter, Lilienthalplatz 7, 38108 Braunschweig,jianping.yin@dlr.de

1. Introduction

In the development of a multirotor propulsion system for Urban Air Mobility vehicles (UAM) or for small-scale drones, noise may become a potential major barrier to market success as the rising concern for environmental issues and increasingly stringent noise regulation. Similar to the rotorcraft, the main sources of the noise from the multirotor system consists of rotor tonal and broadband noise. In contrast to the rotorcraft, broadband noise may become a dominant noise source for rotors with low tip Mach number or disturbed rotor inflow, which is the case in multirotor configurations. The contributions of the broadband noise, especially in the multirotor configurations, has not been studied extensively. To further understand the noise radiation and propagation for multirotor system configurations, the GARTEUR Action Group HC/AG-26 [ref.1] is established. The present studies are part of the activities conducted within this group.

2. DLR methodologies and multirotor model

Broadband noise is a stochastic noise source. A direct computation of broadband noise from turbulent boundary layers (BL) using CFD or CAA still requires a very significant effort, especially for the rotor configurations. DLR broadband noise code (BbaN) [ref.2] was derived according to Brooks, Pope, and Marcolini airfoil self-noise prediction model (BPM model) [ref.3]. The accuracy of predictions depends on a number of factors including the accuracy of the BL module used, how well the aeroacoustic scaling is determined and effects of flow unsteadiness. To overcome some of the limitations, an approximate boundary layer analysis based on the inviscid potential flow solution from DLR's Unsteady Panel Method (UPM) was applied. The tonal noise is obtained utilizing a coupled simulation of the UPM-Code and the DLR Ffowcs-Williams-Hawkins APSIM-Code. This process chain has already been successfully applied to a number of propeller and helicopter investigations [ref.4,5]. Therefore, validations in this work focus on the BbaN with the experiment data. The predictions will be analyzed and compared with the test results. This paper will focus on the results from the numerical and wind tunnel activities conducted by DLR.

The multirotor experimental data for acoustics were obtained in DLR's Acoustic Wind tunnel in Braunschweig (AWB). In this paper, the data acquired with 13 inches diameter (D=330.2 mm) and 7 inches (177.8 mm) pitch beechwood rotors from the German small propeller manufacturer Xoar Electric (Xoar PJN BW 13x7 rotor) is used. The rotor rig was designed to extend the capabilities of the facility to meet the requirements of simultaneous measurements of multiple rotors under hover and forward flight conditions, e.g. Figure 1. Using this setup, several rotor configurations can be investigated; isolated, coaxial, and tandem with vertical and lateral offset. A coupled simulation utilizing the DLR UPM-Code with BL-modelling for flow field computations and the BbaN code for a subsequent computation of the broadband noise emissions was performed.

3. Results and discussion

Figure 2 left shows an example of the comparisons of 1/3 Octave spectrum with experiment for a coaxial rotor configuration in hover at two microphones. Both the numerical simulation (BbaN) and test indicate that tonal noise is the dominant source for the frequencies below 8000Hz while above 8000Hz the broadband noise is dominant. The comparison shows a very good agreement when using the BbaN method. In contrast the results using the original BPM do not capture the shape of the broadband noise indicating that the BL information provided by the BPM model is not suitable for this rotor. In the final paper, the comparisons between the simulation and experimental results will be extended. The details of the method for the broadband noise and the pros and cons will be discussed.

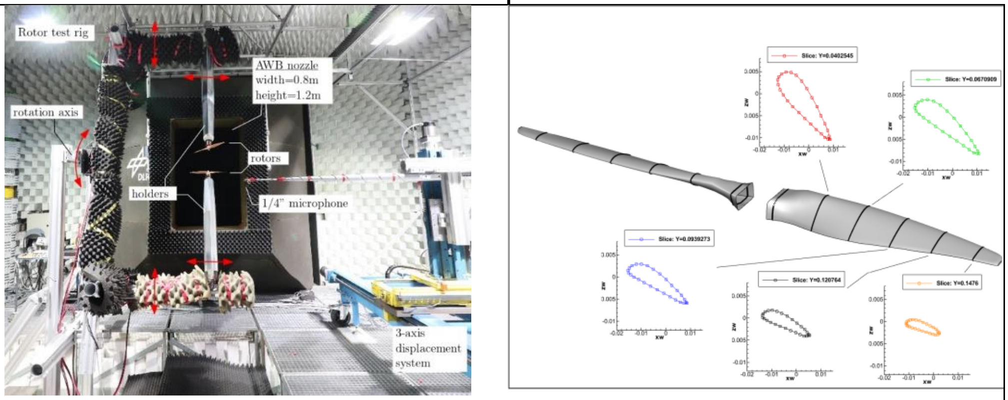

Figure 1. Rotor test rig in AWB (left), 13x7 Rotor geometry

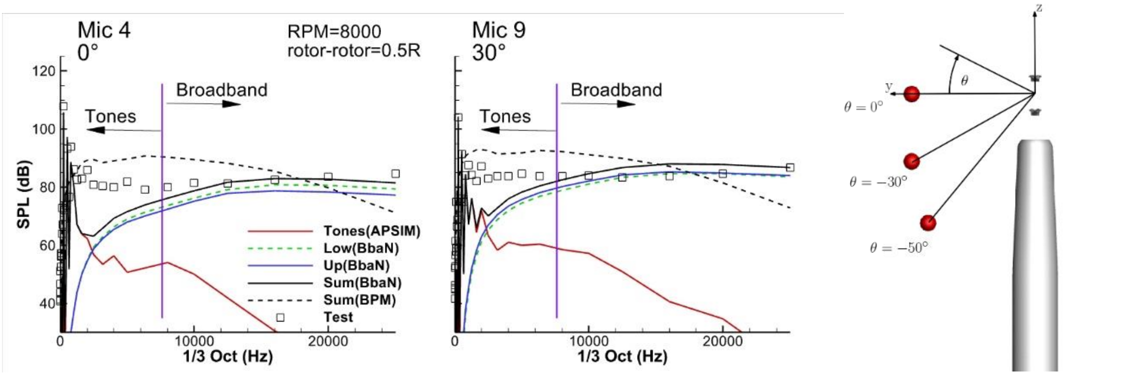

Figure 2. comparisons of 1/3 Oct spectrum with test at two microphones (right)

Literatur:

[1] Yin, J., De Gregorio, F., Petrosino, F., Rossignol, K-S, Schwarz, T., Cotte, B., Brouwer, H., Clero, F., Mortain, F., Reboul, G., Zanotti, A., Vigevano, L., Gibertini, G., Bernardini, G. Schmähl, M., Kaltenbach, HK., Pagliaroli, T., Keßler, M., Barakos, G., Ragni, D., Testa, C.: Noise Radiation and Propagation for Multirotor System Configurations. In: Terms of Reference for the GARTEUR Action Group HC/AG-26, December 2021

[2] Yin, J.: DLR BROAD BAND NOISE CODE (BbaN), in DLR-Projekt URBAN-Rescue, D4.2.2c, 2023

[3] Thomas F. Brooks, D. Stuart Pope, and Michael A. Marcolini, "Airfoil Self-Noise and Prediction", NASA Reference Publication 1218, July 1989.

[4] Rossignol, K.-S., Yin, J., Rottmann, L.: Investigation of Small-Scale Rotor Aeroacoustic in DLR's Acoustic Wind Tunnel Braunschweig, in 28th AIAA/CEAS Aeroacoustics 2022 Conference., Southampton, UK, 2022

[5] Rossignol, K.-S., Yin, J., De Gregorio, F., Visingardi, A., Ceglia, G., Barbarino, M., Petrosino, F.: Aeroacoustics of Small Contra-Rotating Co-Axial Rotors in Hover and Forward Flight, in 30th AIAA/CEAS Aeroacoustics 2024 Conference, Rom, Italy.