Aerodynamic Scaling of Coaxial Rotor Performance

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Experimental measurements that validate the design performance of coaxial rotorcraft is critical to reducing uncertainty and enhancing safety in the final prototype. However, achieving full-scale conditions (i.e. Reynolds and Mach numbers) on small-scale models is technically challenging due to large full-scale rotor diameters. Reynolds and Mach number are the key non-dimensional parameters and are coupled via the velocity scale in the flow, meaning that increasing facility velocity does not directly counteract the model scale reduction. To address this problem, the Miller Fluids lab at Penn State uses the Compressed Air Wind Tunnel (CAWT) to vary air density, and therefore Reynolds number, independent of Mach number. The project presented uses this approach to assess scaling trends in the performance of a coaxial rotor system. For these experiments, the NASA Dragonfly rotor geometry is used as an extensive dataset exists from full-scale testing performed in both air and heavy-gas (R-134a) at the NASA Transonic Dynamics Tunnel [1]. Small-size coaxial rotors are mounted inside the CAWT for a variety of axial and edgewise flight configurations and a fixed rotor spacing. Performance metrics, such as C_T and C_Q, are measured for each rotor individually in addition to the combined coaxial system to determine Reynolds number trends. Comparison is made to existing experimental data taken by NASA on full-scale rotors, as well as single rotor data taken in the CAWT using the same model rotor. Future work will acquire detailed datasets for a wider range of rotor operating conditions by varying parameters, such as rotor spacing and alignment, to build a complete database of Reynolds number trends for coaxial and novel rotor configurations.

[1] Marshall, M., Tang, E., Cornelius, J., Ruiz, F., and Schmitz, S., “Performance of the dragonfly lander’s coaxial rotor in Vortex Ring State,” AIAA SCITECH 2024 Forum, Jan. 2024.

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