The Analysis and Prediction of Jet Flow and Jet Noise about Airframe Surfaces

Matthew J. Smith

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Christopher R. Fuller, Chair
Steven A.E. Miller
William J. Devenport
Craig A. Woolsey

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(ABSTRACT)

Aircraft noise mitigation has been an ongoing challenge for the aeronautics research community. In response to this challenge, aircraft concepts have been developed in which the propulsion system is integrated with the airframe to shield the noise from the observer. These concepts exhibit situations where the jet exhaust interacts with an airframe surface. Jet flows interacting with nearby surfaces exhibit a complex behavior in which acoustic and aerodynamic characteristics are altered. The physical understanding and accurate modeling of these characteristics are essential to designing future low-noise aircraft. In this thesis, an alternative approach is created for predicting jet mixing noise that utilizes an acoustic analogy and the solution of the steady Reynolds-Averaged Navier-Stokes (RANS) equations using a two equation turbulence model. A tailored Green's function is used in conjunction with the acoustic analogy to account for the propagation effects of mixing noise due to a nearby airframe surface. The tailored Green's function is found numerically using a newly developed ray tracing method. The variation of the aerodynamics, acoustic source, and far-field acoustic intensity are examined as a large flat plate is moved relative to the nozzle exit. Steady RANS solutions are used to study the aerodynamic changes in the field-variables and turbulence statistics. To quantify the propulsion airframe aeroacoustic (PAA) installation effects on the aerodynamic source, a non-dimensional number is formed that can be used as a basic guide to determine if the aerodynamic source is affected by the airframe and if additional noise produced by the airframe surface is present. The aerodynamic and noise prediction models are validated by comparing results with Particle Image Velocimetry (PIV) and far-field acoustic data respectively. The developed jet noise scattering methodology is then used to demonstrate the shielding effects of the Hybrid Wing Body (HWB) aircraft. The validation assessment shows that the acoustic analogy and tailored Green's function provided by the ray tracing method are capable of capturing jet shielding characteristics for multiple configurations and jet exit conditions.

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Current Contact Information

Current Email Address: msmith07@vt.edu

Street Address (line 1): 2285 Estuary Court

Street Address (line 2):

City: Virginia Beach | State/Province: VA | Daytime Phone: 757-407-2309

Country: United States | Postal Code: 23451 | Evening Phone: 757-407-2309

Permanent Contact Information

Permanent Email Address: smith.matt307@gmail.com

Street Address (line 1): 516 Shakespeare Drive

Street Address (line 2):

City: Virginia Beach | State/Province: VA | Future Phone: 757-407-2309

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