Project 076 Improved Open Rotor Noise Prediction Capabilities

Georgia Institute of Technology

Project Lead Investigator

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University Participants

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- FAA Award Number: 13-C-AJFE-GIT-078
- Period of Performance: August 11, 2020 to August 10, 2021
- Task(s):
  - Task 1: Literature Review
  - Task 2: Parametric CAD Model Creation
  - Task 3: CAA Case Setup and Validation

Project Funding Level

The project funding is $300,000 per year from the FAA. Cost share match amount is $300,000 per year. The sources of match are cash and in-kind cost-share from an industry partner, General Electric (GE).

Investigation Team

Dr. Dimitri Mavris, Professor, Georgia Tech (Project Management)
Dr. Jimmy Tai, Senior Research Engineer, Georgia Tech (Project Management)
Mr. Srujal Patel, Research Engineer II, Georgia Tech (Project Management, CAD, Computational Aeroacoustics)
Dr. Miguel Walter, Research Engineer II, Georgia Tech (Computational Aeroacoustics, Stochastic Methods)
Christopher Roper, Graduate Student, Georgia Tech (Computer Aided Design, Computational Fluid Dynamics)
Brenton Willier, Graduate Student, Georgia Tech (Computational Fluid Dynamics, Aeroacoustics)
Marcos Dos Santos, Graduate Student, Georgia Tech (Computational Fluid Dynamics, Rotor Performance))
Mariam Emara, Graduate Student, Georgia Tech (Tool-chain integration, Stochastic Methods)
Maxime Varoqui, Graduate Student, Georgia Tech (Aeroacoustics, Stochastic Methods)

Project Overview

The Contra-Rotating Open Rotor (CROR) system has promising environmental benefits due to its ultra-high bypass ratio and high propulsive efficiency. The reduced fuel burn and emissions of the CROR compared to an equivalent thrust turbofan make it a viable economic and environmentally friendly propulsion alternative to traditional ducted systems. However, in the absence of a noise-conditioning duct, aerodynamic interactions within the CROR system, as well as between the system and surrounding installation components like the engine pylon, may result in noise penalties. If such a system configuration is not optimized, the added effect of flow asymmetry to the aerodynamic interactions could potentially result in severe noise penalties, making the CROR system infeasible for use in the aircraft industry. The proposed work will perform a sensitivity study on the design parameters of a CROR-pylon configuration. This study will leverage knowledge from past efforts with this type of configuration in order to narrow down the space of design parameters. High-fidelity computational aeroacoustics analyses will be carried out in order to analyze the effect of each of the chosen parameters on noise. This research is intended to provide both the FAA and industry with key insights necessary for the design optimization of the CROR system in the future.

Task 1 – Literature Review

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Objective

The Georgia Tech research team will conduct a literature survey to summarize the state of the art in reducing open rotor source noise and will document the current best practices and processes used by various industry entities and researchers.

Research Approach

The ongoing literature review is geared towards investigating the following questions:

- Q1. What are current experimental and computational approaches that researchers use to predict the noise of open rotor configuration?
- Q2. What parameters have been studied for noise sensitivity and what are the study findings?
- Q3. Are there any active flow control related technologies currently being implemented for open rotor noise reduction? If yes, what are the findings of such studies?
- Q4. What is the computational cost of performing a high-fidelity computational aeroacoustics study?
- Q5. What are the key performance and noise characteristics of the baseline geometry provided by GE?.
- Q6. Which low-fidelity noise assessment tools are available to perform the preliminary level noise analysis to narrow the design space to select parameters for high-fidelity studies?

The current literature review is focused on Q1, Q2 and Q3. In particular, for Q2, the literature review effort is divided into three groups of parameters:

i) Open rotor blade design parameters
ii) Pylon effects related design parameters
iii) Airframe integration related design parameters

Milestone

We are currently compiling all the findings and are periodically sharing those with FAA during our bi-weekly telecons.

Major Accomplishments

None

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement
For this task, all five students are grouped into three design parameter categories as described above and are compiling and sharing their findings during the bi-weekly telecons.

Plans for Next Period
We will continue investigating the answers for all questions in the next quarter. In particular, once the geometry is finalized by FAA, we should be able to answer Q5.

Task 2 – Parametric CAD Model Creation
Georgia Institute of Technology

Objective
The Georgia Tech research team will develop a fully parametric CAD model of the open rotor and pylon configuration so that it can be used for a computational aeroacoustics sensitivity study in the future.

Research Approach
In this task, a fully parametric model of the baseline geometry of the CROR and pylon configuration will be generated. A CAD tool will be used for the model creation. During this step, emphasis will be placed on ensuring that the resulting geometry is an accurate representation of the physical design and is also suitable for CFD mesh generation. A scripting language such as Python may be used to automate the model update based on a design point. This is typically a time-consuming step because the mapping must be robust enough such that design variable instances do not lead to a geometry with undesirable imperfections, such as wrinkles or open surfaces, which might render them unsuited for CFD analysis.

While we are waiting on the final decision by FAA for the baseline geometry, we have already begun getting familiar with the CAD model creation process. Two software tools are under evaluation for the implementation work: CATIA V5 and Engineering Sketch Pad (ESP). CATIA V5 provides an industrial standard GUI-based platform to generate high-quality CAD geometries. As a second option, ESP, an open-source script-based and MDAO-friendly CAD tool is being evaluated as well; ESP has a more platform-independent framework, which is especially useful for cluster use. Some test geometries are being produced to identify the strengths and shortcomings of both CAD tools.

Also, in parallel, Python scripts are being generated to automate the CAD data extraction process so that once the baseline geometry is finalized, we can extract the section information from the existing STEP/IGES files.

Milestones
This is currently work-in-progress and updates will be shared with FAA as milestones are reached in the following year.

Major Accomplishments
None

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
For this task, two students are assigned: Chris Roper (CAD) and Brenton Willier (Python-based data extraction).

Plans for Next Period
We will continue evaluating the CAD software and performing robust testing and shall have the scripts ready for the implementation work whenever we receive the baseline geometry from FAA/GE.

Task 3 – Computational Aeroacoustics (CAA) Case Setup and Validation
Georgia Institute of Technology

Objective
The Georgia Tech research team will set up a computational aeroacoustics case with the baseline parametric CAD model developed in the previous task and then will perform a validation study.

Research Approach
This task covers all steps involved in setting up the aerodynamics as well as the aeroacoustics simulations. These steps include automatic mesh generation, selection of appropriate boundary conditions, study of mesh resolutions as well as finding solver parameters for the unsteady CFD simulations. Moreover, this task will also compare the numerical simulation results with available experimental data for validation. The main aim of this task is to provide evidence that the numerical simulation setup is robust and provides consistently accurate solutions. Such assurance is necessary before proceeding further with the sensitivity study runs in the future.

Milestones
None

Major Accomplishments
None

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
None

Plans for Next Period
This task will be performed in last six months of the performance period. We anticipate completion of this task on time before the end of the performance period.