Project 075 Improved Engine Fan Broadband Noise Prediction Capabilities

Boston University & Raytheon Technologies Research Center

Project Lead Investigator

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University Participants

Boston University (BU)

- P.I.: Sheryl Grace – Associate Professor, Mechanical Engineering
- FAA Award Number: 13-C-AJFE-BU Amendment 022
- Period of Performance: 09/01/2020 – 8/31/2021
- Task(s):
    1. Fan wake surrogate model creation
    2. Improved low-order model

Project Funding Level

First year's funding:
FAA: $300,000 with $115,000 allocated to BU and $185,000 to Raytheon Technologies Research Center (RTRC). Matching funds total $300,000 with $115,000 provided by BU (data sets, graduate student stipend, MS in Statistical Practice (MSSP) faculty/student time) and $185,000 provided by RTRC (personnel time).

Investigation Team

Sheryl Grace, BU: PD/PI. Tasks 1 and 2.
Jeff Mendoza, RTRC: Co PD/PI. Tasks 1 and 2.
Craig Aaron Reimann, RTRC: Staff Scientist. Tasks 1 and 2.
Julian Winkler, RTRC: Staff Scientist. Tasks 1 and 2.

Project Overview

The noise signature of contemporary turbofan engines is dominated by fan noise, both tonal and broadband. Accepted methods for predicting the tone noise have existed for many years, and engine designers have developed methods for controlling or treating this tonal noise. Broadband noise, however, remains an outstanding problem. In order to enable design decisions that will achieve the goal of further reductions in engine noise, accurate prediction methods for broadband noise will accordingly be required. Interaction noise from the fan stage is a dominant broadband mechanism in a modern high bypass engine and is created by the interaction of the turbulence in the fan wakes with the fan exit guide vanes (FEGVs). This project will leverage prior development of low-order models for the prediction of fan broadband interaction noise. Gaps in the low-order approach will be addressed based on knowledge gained from computation and experimentation. In particular, a method for determining the inflow into the stator via a machine learning (ML) algorithm will be developed. The low-order method will also be validated against full-scale rig data and appropriate development undertaken based on the findings.

Task 1– Fan Wake Surrogate Model Creation

Boston University and RTRC

Objective

The goal is to build a surrogate model using ML that would work with performance level unsteady Reynolds-averaged Navier-Stokes (URANS) to specify the turbulent length scales and turbulence spectrum at locations along the helical fan wake path.

Research Approach

Subtask 1.1: Development of autoencoder

When attempting to learn something about a flow field, there are often many inputs but relatively few outputs. This means that there is usually correlation among the input variables, which can be captured in a low-dimensional manifold using an autoencoder (AE). Many ML algorithms start by training an AE that provides dimension reduction of the input parameter space. In short, an AE takes input data and determines a low-dimensional representation of that data via an encoder. Students in the BU Masters in Statistics Program will assist the BU and RTRC researchers with the development of the autoencoder.

Subtask 1.2: Development of decoder

Once the AE is trained to find a good low-dimensional representation, it must be combined with a decoder to obtain the desired output. The second half, or decoder, of the ML algorithm must also be trained to provide the desired output.

Subtask 1.3: Identification and creation of training data

Subtask 1.3.a: Existing training data: BU and RTRC will work to collect relevant existing fan wake data sets.

Subtask 1.3b: Creation of additional training data: RTRC will take the lead on producing new data sets.

Subtask 1.4: Application of surrogate model to relevant fan geometries

Cases that are used to produce training data can also be utilized during the validation stage, though further datasets will need to be identified for full validation. During later years of the project, the surrogate model, in particular, will be assessed against data obtained experimentally for modified fan rig trailing edge wake flows.

Milestone

The initial milestone is to identify and access geometries and operating conditions that are relevant to study. The curation of data sets has begun. Both BU and RTRC are accumulating existing data sets and making plans to create new data sets.

Major Accomplishments

- BU set up the internal portion of the grant and has begun to set up the subcontract to RTRC.
- BU MSSP is putting forward the AE development as a project to their students. A student group should be identified by December.
- RTRC has begun discussions with Pratt & Whitney to obtain access to past data sets.
- Source Diagnostic Test (SDT) fan geometry and flow path information is being obtained by BU and shared with RTRC so further computational runs can commence.
- File transfer methods have been set up between RTRC and BU so that data can be easily shared.

Publications

None

Outreach Efforts

None

Awards

None

Student Involvement
One undergraduate student has just begun to work with rotor wake data sets at BU. A new graduate student is currently being recruited to work on the project.

Plans for Next Period
The milestones that have been set out for the first year of this project are:
- Identify and access geometries and operating conditions relevant to study.
- Prepare initial ML training datasets.
- Develop ML autoencoder. Begin feature extraction.
- Continued preparation of ML training datasets, initial training of ML decoder.
- First validation test of surrogate model.

Task 2 – Improvement of Low-order Model
Boston University and RTRC

Objective
The existing low-order methods are regularly applied to the SDT cases and as such have been well-validated against this test, which represents one scaled fan and multiple FEGVs. The low-order method must now be validated against full-scale test data. The low-order method might also require reformulation to account for other real-flow effects.

Research Approach
BU will lead this task and will be provided geometry and comparison data by RTRC.

Subtask 2.1: Ability to predict full-scale results
The low-order method will be applied to a full-scale geometry with available validation data. Due to the difference in frequency range of interest for the full-scale case as compared to the scaled fans, it is surmised that the low-order method will require grid adjustments and integral extent adjustments. Such improvements to the low-order method will be completed as part of this task.

Milestones
None

Major Accomplishments
None

Publications
None

Outreach Efforts
None

Awards
None

Student Involvement
None

Plans for Next Period
The milestones that have been set out for the first year of this project include validating the low-order model on a new geometry and testing rig scale versus full-scale applicability.