



Data-Theory Comparisons for the Advanced Ducted Propulsor Tone Noise Using the V072 Code

Jeffrey Severino

NASA Glenn Pathways Intern, Acoustics Branch

Jeffrey.Severino@nasa.gov

Mentors: Edmane Envira and Clifford Brown

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Outline



- Motivation
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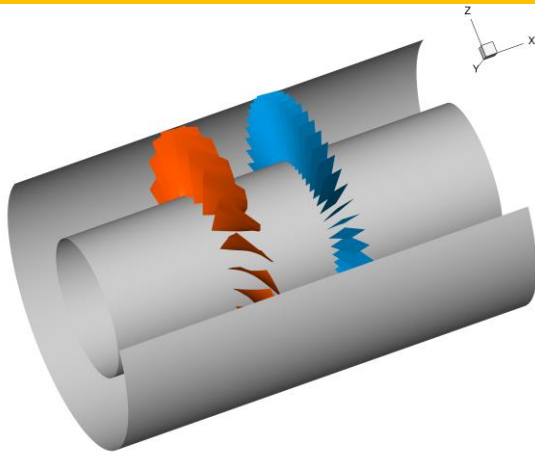
Motivation

- Fan tone noise prediction models range in fidelity from simple to complex.
- Can low-fidelity models be improved by judicious choice of parameters?



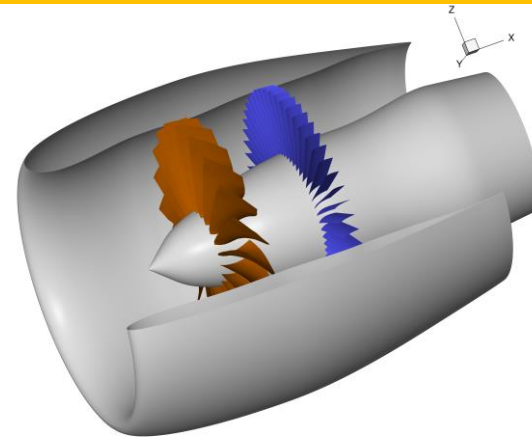
Low-Fidelity Models

Simplified Geometry and Flowfield



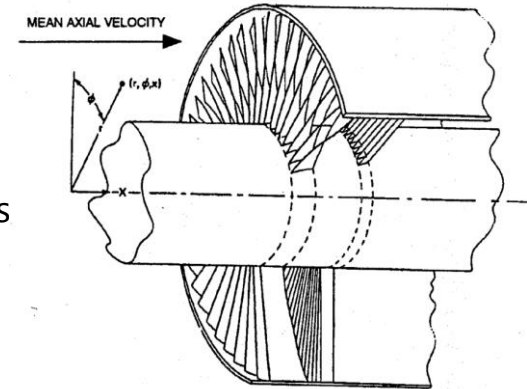
High-Fidelity Models

Realistic Geometry and Flowfield



Introduction

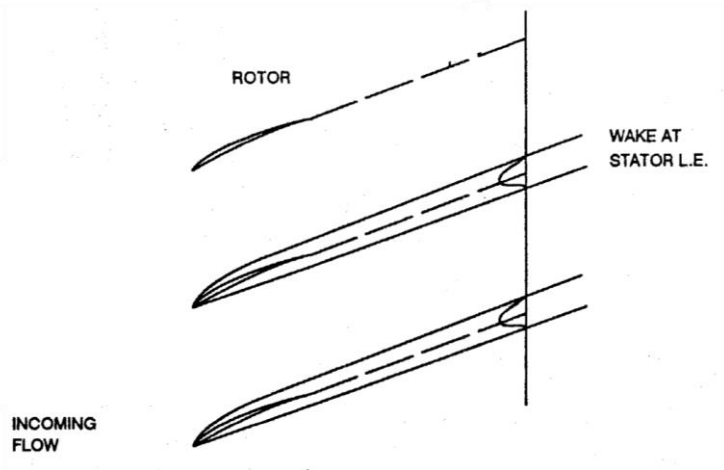
- V072 is a collection of FORTRAN 77 routines initially developed for NASA under a contract by Bolt Beranek and Newman Technologies in early 1980s for computing fan tone noise levels. The code was later updated and improved under a NASA contract by P&W in the 1990s.
- In keeping with its low-fidelity nature, in the theory underlying V072 code, the fan stage geometry and associated flow field are simplified in order to make the model mathematically tractable via analytical methods
- The fan duct is modeled as a constant area annulus, the fan blades and stator vanes are modeled as twisted zero thickness flat plates, and flow field is modelled as a uniform plug flow.
- The aim of the current study is assessing the sensitivity of the V072 code predictions to the geometric parameters in the code. In this presentation the focus is on the stator stagger angle.



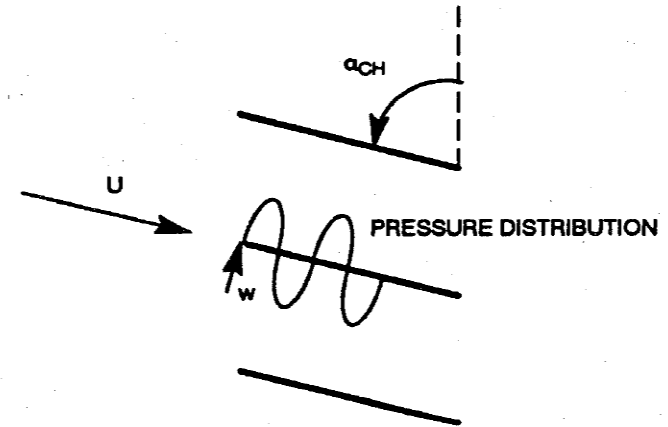
Sketch of V072's Rotor/Stator Geometry

Introduction

Pictorial Description of the Aerodynamic Model in V072



Flowfield Viewed in Rotor Frame



Flowfield Viewed in Stator Frame

Test Case

- Several fans are under consideration for this work.
- The results here are for the NASA/P&W ADP fan.
- A number of fan operating conditions were considered.

ADP Fan Stage Parameter	
Rotor Diameter, in (m)	22 (0.56)
Corrected Tip Speed, ft/s (m/s)	840 (256)
Stage Pressure Ratio	1.29
Bypass Ratio	13.3
Mass Flow, lbm/s (kg/s)	85.7 (38.9)
Rotor Blade Count	18
Bypass Outlet Guide Vane Count	45
Core Inlet Guide Vane Count	63

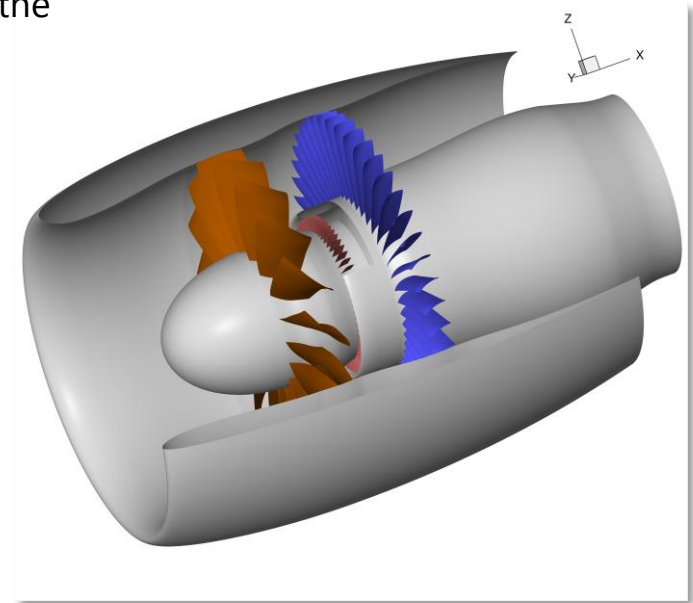


Condition	Fan RPM	% Design Speed
Approach	5423	62.0
-	6700	76.6
Cutback	7525	86.0
-	8345	95.3
Take-Off	8750	100.0

Test Case

➤ The V072 input deck, supplied as a name list, is principally comprised of a number of geometric and flow parameters, most of which, are supplied at multiple radial locations for both the bypass and core ducts. These include:

- Fan RPM and ambient thermodynamic parameters
- Rotor blade and stator vane chords
- Rotor-Stator spacing
- Blade and vane sweep and lean
- Blade and vane stagger angles
- Rotor loss parameter
- Blade and vane flow angles
- ...



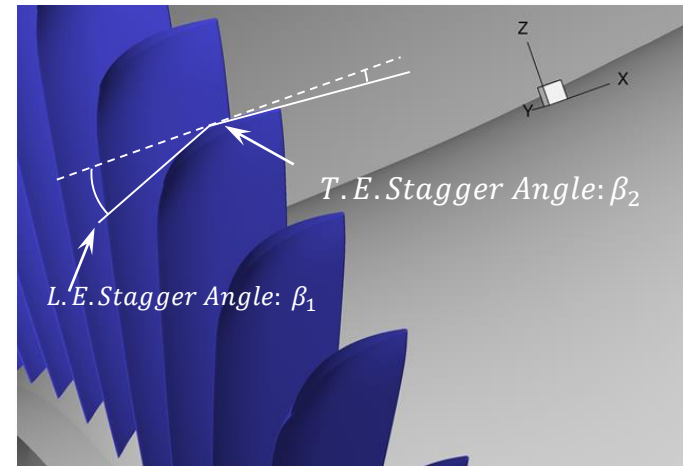
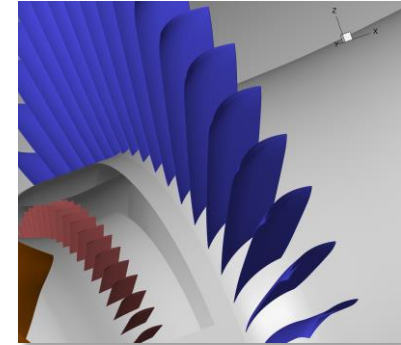
Cut-Away of ADP

Focus of This Study

- The results presented in the next few slides focus on the impact of the stator stagger angle on the predicted exhaust tone noise levels.
- Impact on the inlet noise levels is not considered since the V072 code does not have provisions to model rotor transmission loss.
- In the V072 code, the stator stagger angle is taken to be the “weighted average” of angles from the leading and trailing edges of the stator vane, namely,

- $$\text{Stagger Angle} = \alpha_s = \arctan\left(\frac{3\tan(\beta_1) + \tan(\beta_2)}{4}\right)$$

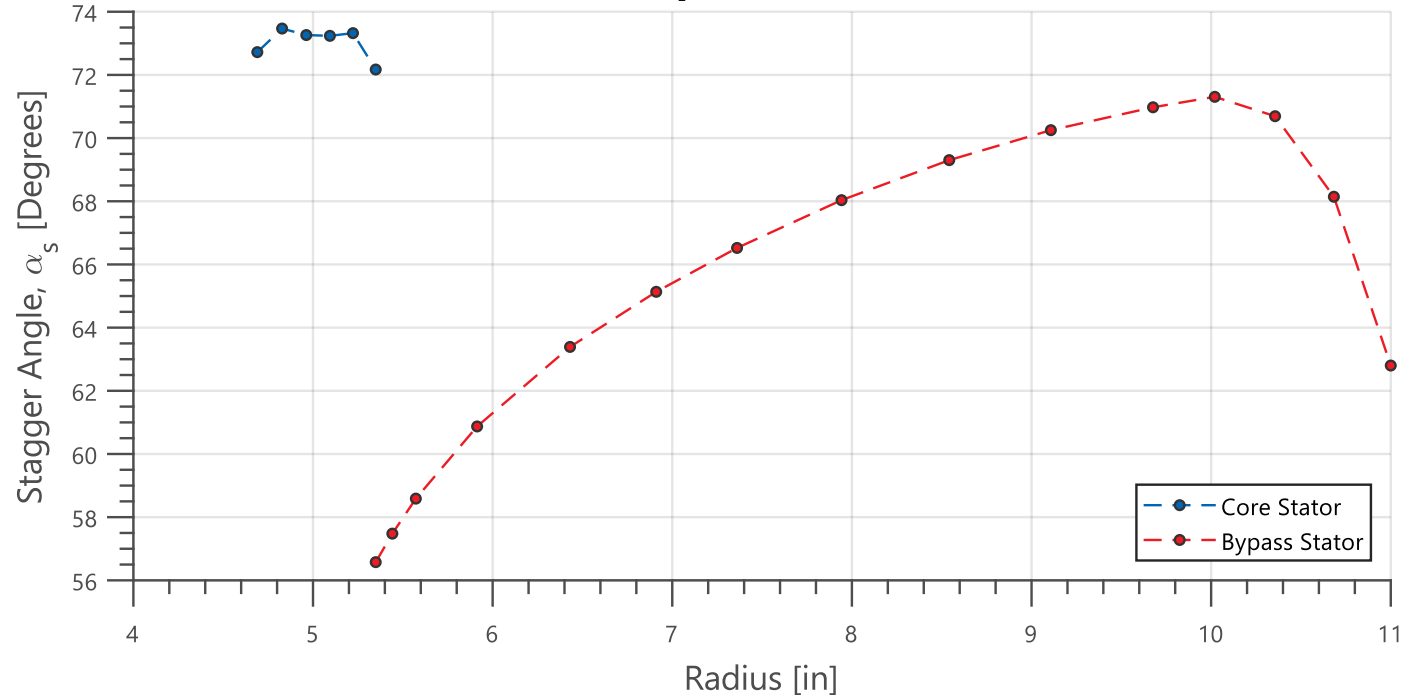
- Is this choice a good one for the downstream noise, i.e., exhaust noise?



Focus of This Study

A Few Choices for Defining the Stator Stagger Angle

V072 Input for ALPHCH



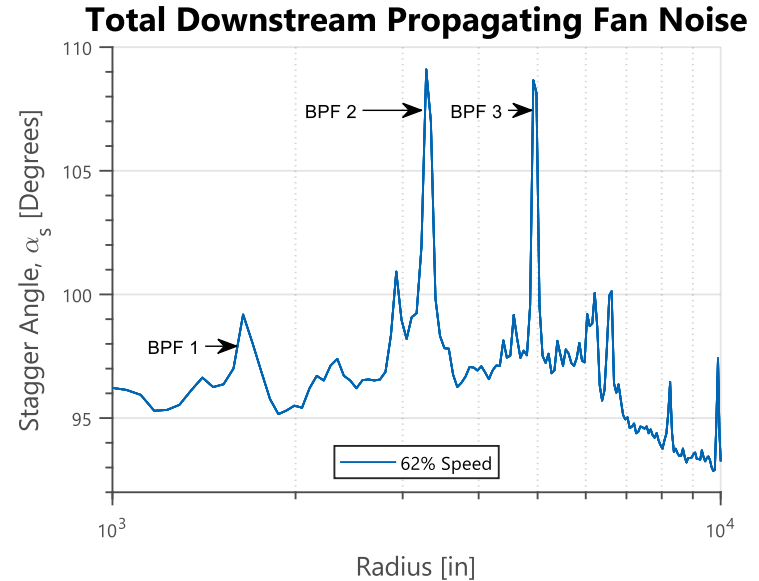
Note: Geometric angles in the V072 code are defined with respect to the tangential direction, not axial.

Preliminary Results: Experimental Data



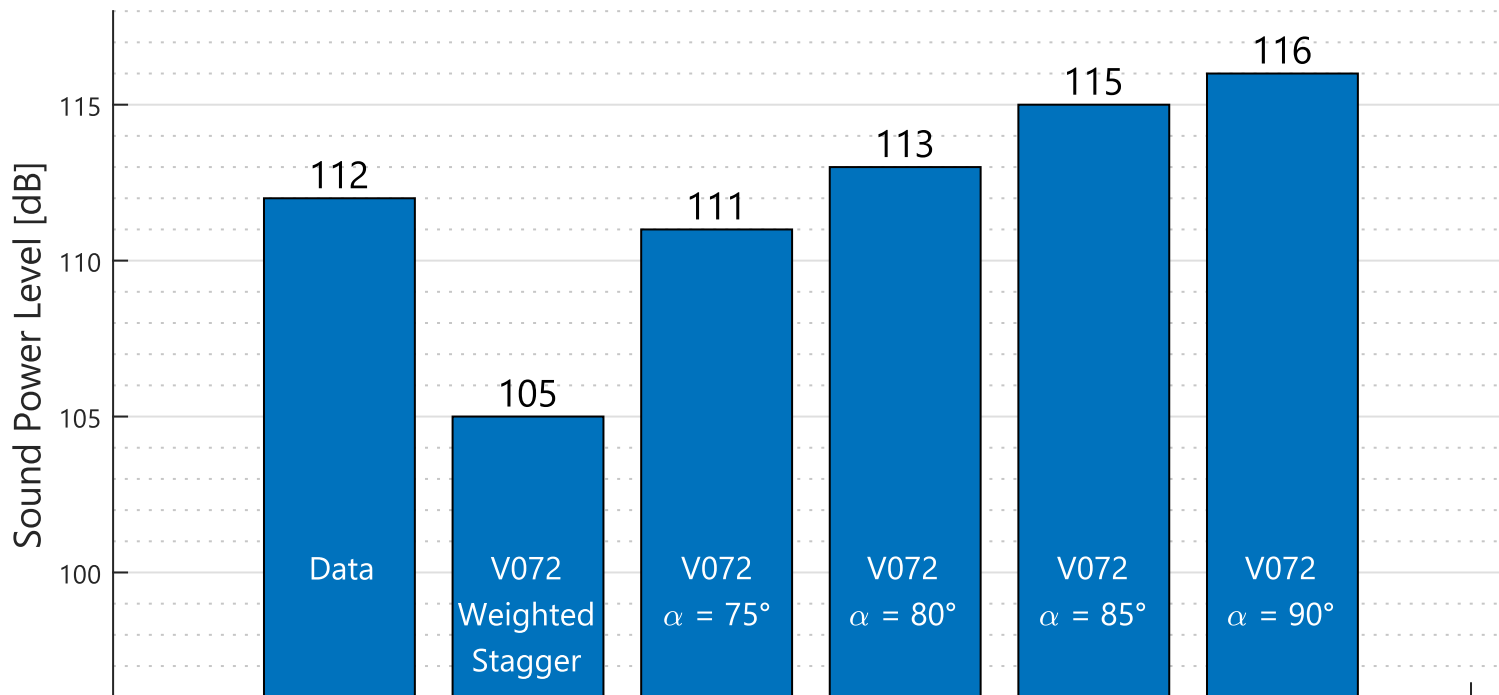
- Downstream acoustic power level was chosen as the metric of comparison in this study.
- The dominant harmonics of the blade passing frequency (n BPF) were selected for this study. The blade passing frequency for this fan is technically cut-off.
- The acoustic power for each selected tone was obtained by summing the power in the three frequency bins centered on the target tone:

$$\text{Weighted Peak (Data)} = 10 \log_{10} \left(10^{\frac{L_{\text{left}}}{10}} + 10^{\frac{L_{\text{center}}}{10}} + 10^{\frac{L_{\text{right}}}{10}} \right)$$



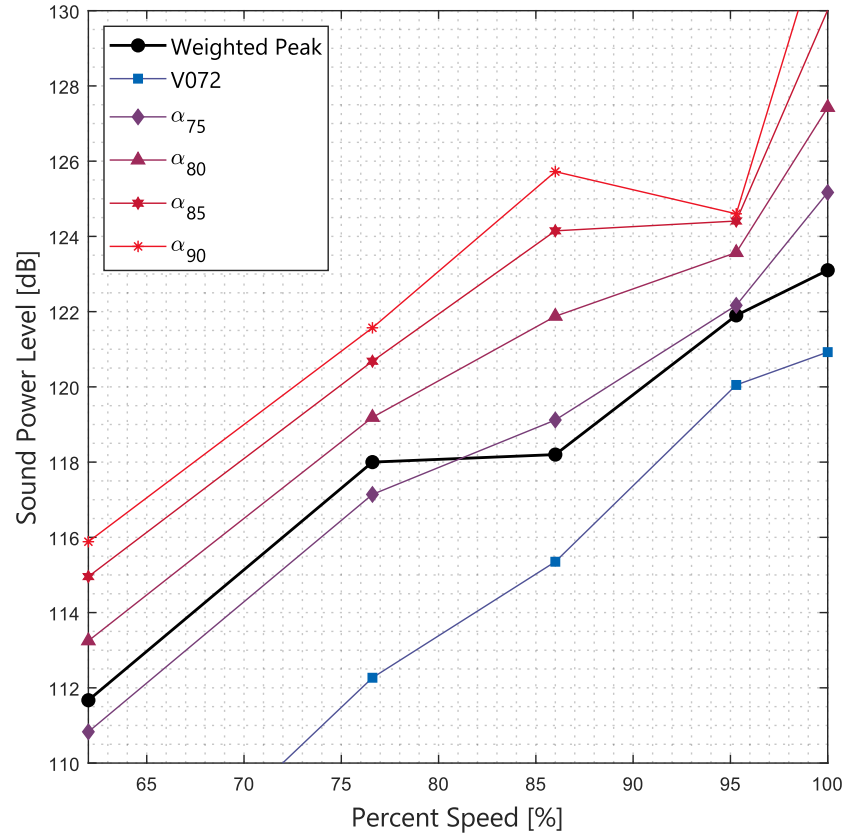
Spectrum of Acoustic Power Obtained
from Wind Tunnel Measurements

Preliminary Results: Parametric Study



Data-Theory Comparisons at Approach Tip Speed

Preliminary Results: Parametric Study



Data-Theory Comparisons
at Multiple Tip Speed



Conclusions

- The downstream sound power levels are sensitive to the stator stagger angle.
- Based on these preliminary results it appears that using a weighted stagger angle, which is a compromise between the L.E. and T.E. staggers, under-estimates the down stream power.
- Stagger angles that are closer to the trailing edge angle improve the data-theory agreement for the down stream power across the range of tip speeds.
- This effect will be tested for other candidate fans across the pressure ratio range.
- The influence of the stagger angle on the broadband noise levels will also be investigated.

