Preliminary Design of a Distributed Facesheet Acoustic Liner for Broadband Acoustic Attenuation

Martha C. Brown, Douglas M. Nark,

and Michael G. Jones

2023 AIAA AVIATION Forum
12-16 June 2023

Introduction

Goal

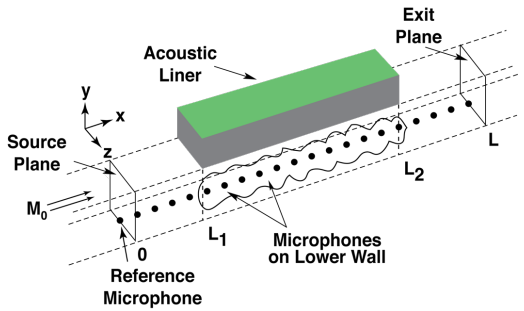
Explore the acoustic performance of a distributed facesheet liner for broadband attenuation.

Approach

Design a three-cell cluster of chambers for broadband attenuation over range of 1000 Hz to 2000 Hz.
Facesheets optimized for Mach 0 and 0.3 flow conditions, at SPL=120 dB.
Samples tested in NASA Langley Grazing Flow Impedance Tube (GFIT) and measured results compared with predictions.

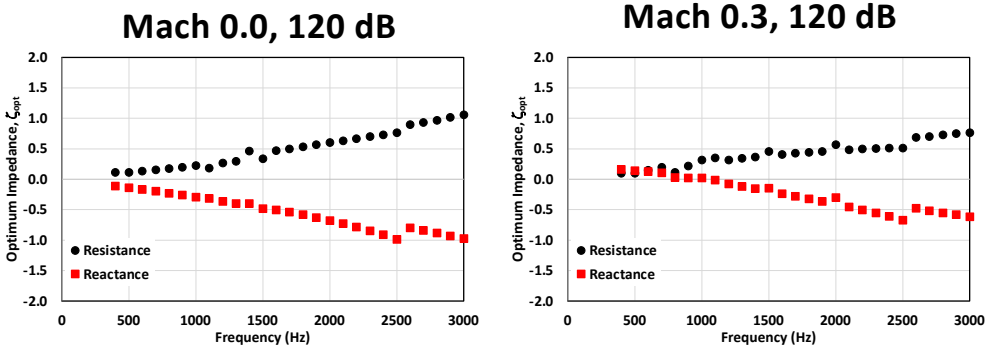
Target Impedance

Computational Domain of Grazing Flow Impedance Tube



Convected Helmholtz Equation + Optimizer

Optimized Impedances for GFIT Configuration



References | Figures 1 and 2

Liner Design Methodology

Define the physical constraints, flow conditions, target impedances.

Physical constraints: is it buildable? => FIX facesheet thickness, optimize on porosity and hole diameter
3-chamber variation
Target flow conditions: Mach 0 and 0.3 (separately)
Target Impedances: Based on GFIT optimized impedances for target flow conditions. Optimized on REACTANCE.

Use the facesheet parameters and flow conditions as INPUTS into Semianalytical Impedance Model to output corresponding impedance.

INPUT impedance spectra into CHE propagation code to get attenuation plots

Define 10 dB of attenuation over length of liner as a reasonable metric for a good absorber.

Select case with lowest frequency and widest bandwidth to build.

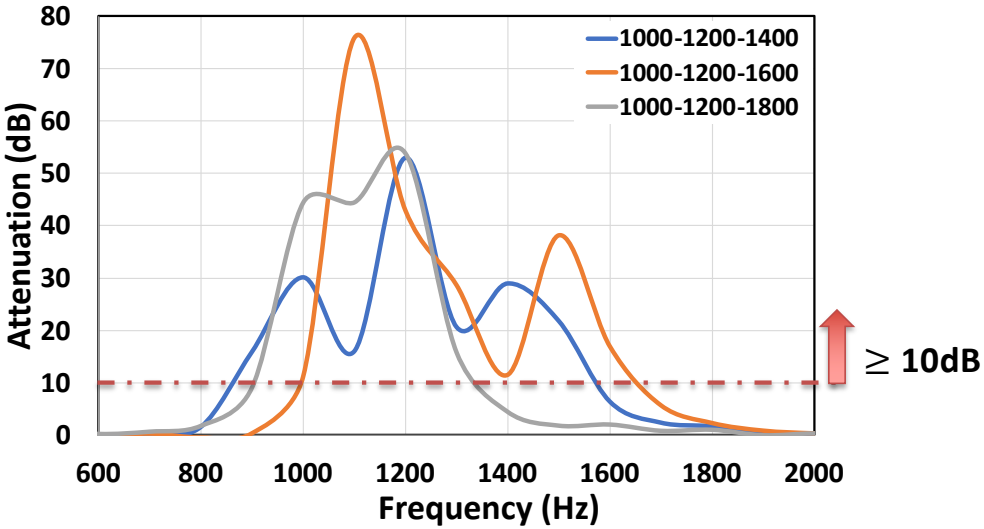
Widest bandwidth => broadband-like acoustic performance

Predicted Attenuation Spectra

Objective

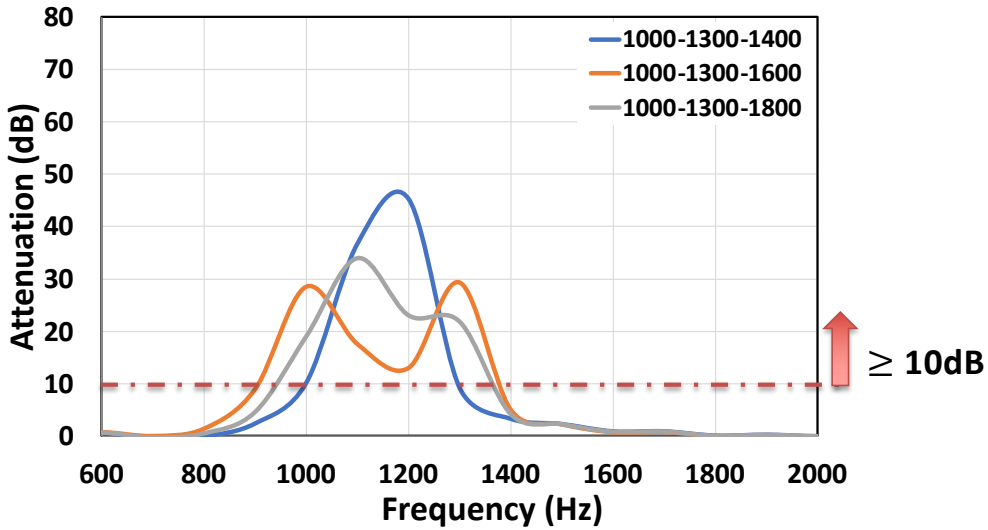
Select the best three-frequency combination to build and test.

Optimized for Mach 0, 120 dB



Selected Combination for Mach 0
1000-1200-1600 Hz

Optimized for Mach 0.3, 120 dB

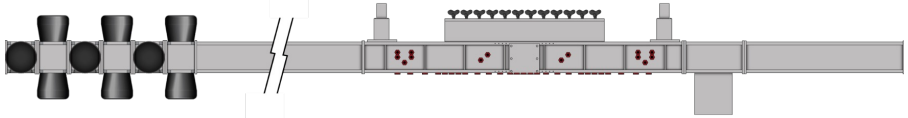


Selected Combination for Mach 0.3
1000-1300-1600 Hz

Reference | Figure 4

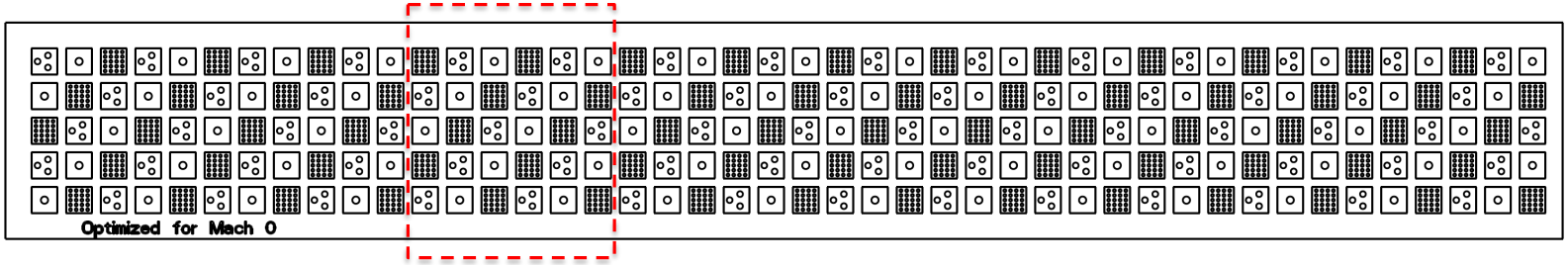
Experimental: Testing in GFIT

Grazing Flow Impedance Tube (GFIT)

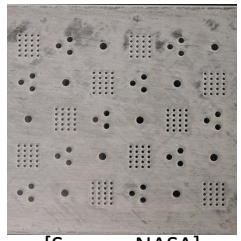


Flow conditions: Mach 0, 0.3, 0.5; SPL= 120 and 140 dB

Optimized for Mach 0, 120 dB

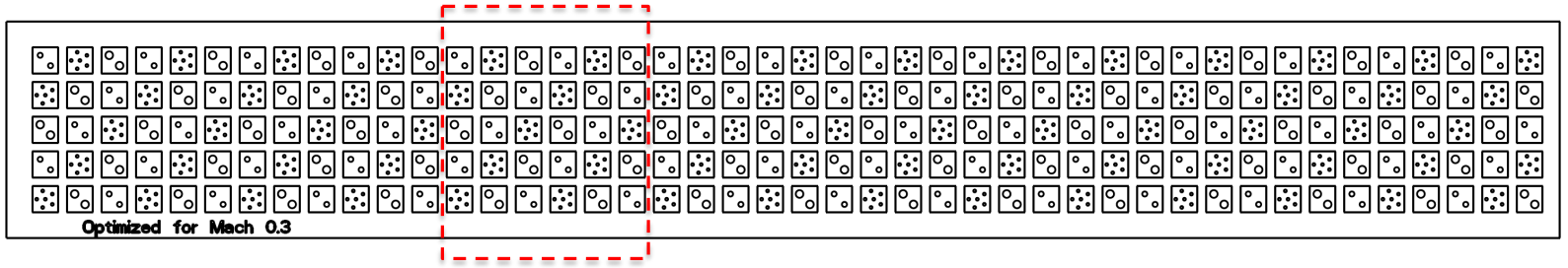


Close-up View Mach 0

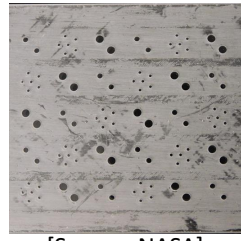


[Source: NASA]

Optimized for Mach 0.3, 120 dB



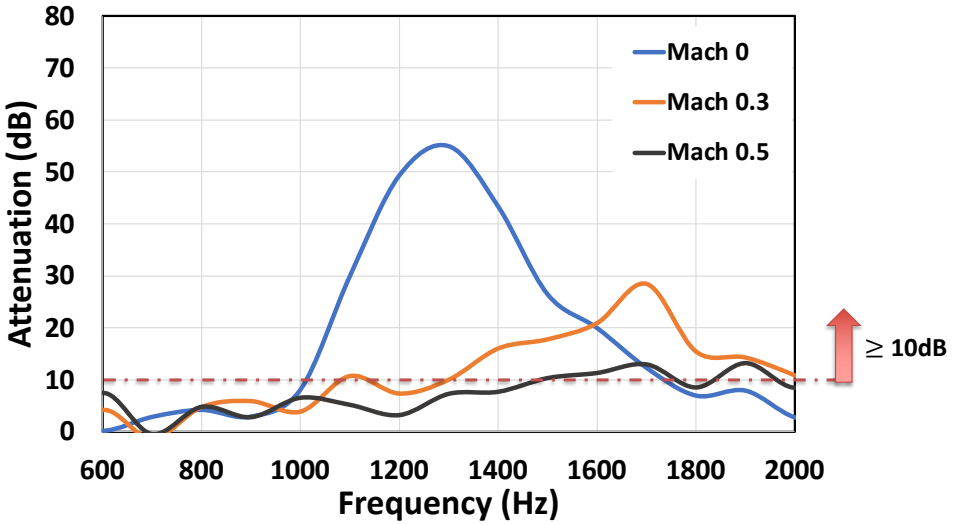
Close-up View Mach 0.3



[Source: NASA]

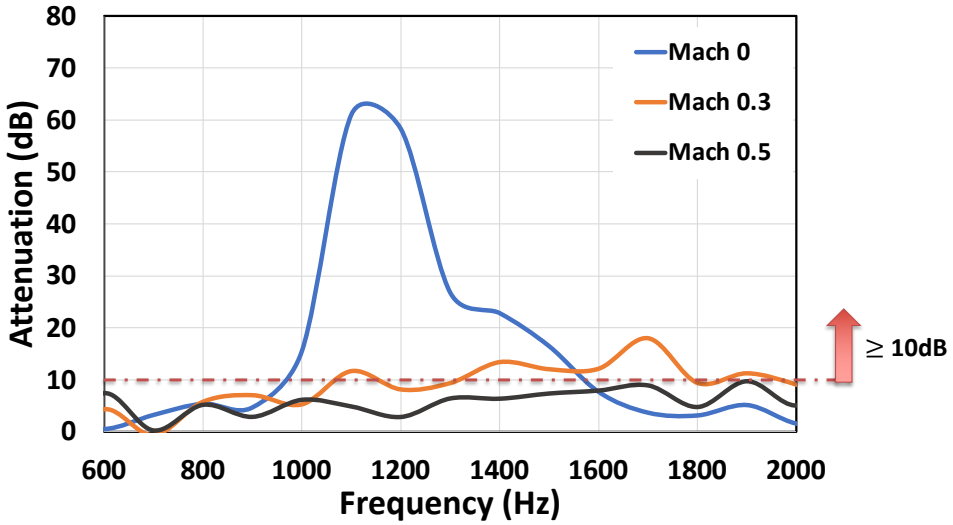
Measured Results: Attenuation Spectra

Optimized for Mach 0, 120 dB



Mach 0
700 Hz frequency range

Optimized for Mach 0.3, 120 dB



Mach 0.3 flow condition
400 Hz frequency range

Reference | Figure 4

Conclusions

- Designed three-chamber facesheets optimized for Mach 0 and 0.3 flow conditions.

- Distributed facesheet liner samples tested in GFIT.
  - Facesheet optimized at Mach 0 => 700 Hz frequency range
  - Facesheet optimized at Mach 0.3 => 400 Hz frequency range

- Predicted and measured attenuation ranges compare favorably.

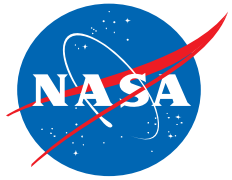
- Demonstrated broadband acoustic performance with a distributed facesheet and uniform core.

Future Work

Use distributed facesheet novel liner concept to test in Curved Duct Test Rig (CDTR) where the acoustic source consists of controlled higher-order modes.

Acknowledgments

Advanced Air Transport Technology Project (AATT) of the
NASA Advanced Air Vehicles Program for funding this work



20 MINUTE PRESENTATION

Preliminary Design of a Distributed Facesheet Acoustic Liner for Broadband Acoustic Attenuation

Martha C. Brown, Douglas M. Nark,

and Michael G. Jones

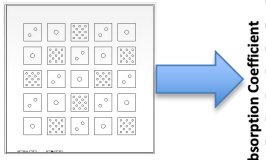
2023 AIAA AVIATION Forum
12-16 June 2023

Background

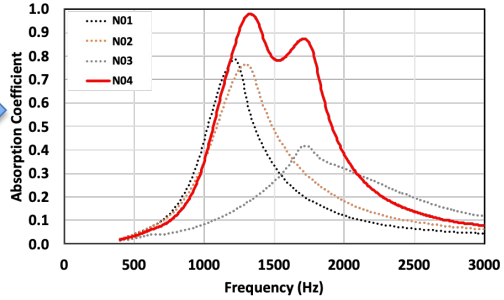
2020 Investigation

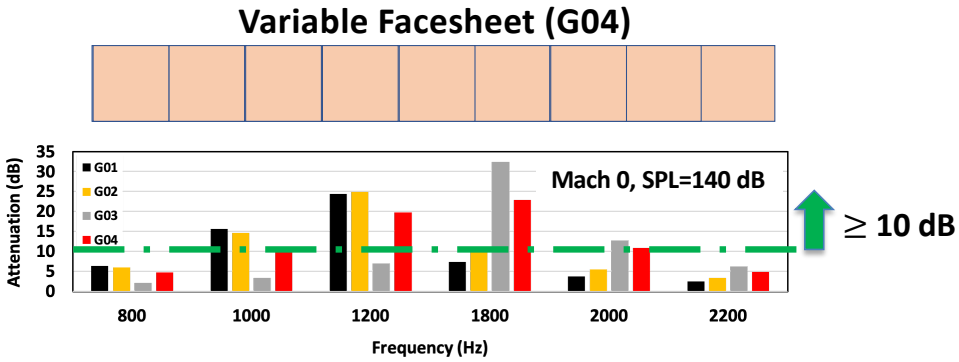
Explore broadband liner by varying the facesheet porosity and hole diameter for each individual core chamber.

FIXED facesheet thickness and core depth.



N04





2021 Investigation

Explore acoustic performance of variable facesheet liner with flow.

Results

Demonstrated a variable facesheet liner can be modeled as a “uniform” liner that yields a “smeared” impedance

Source: *Evaluation of Variable Facesheet Liner Configurations for Broadband Noise Reduction*, https://doi.org/10.2514/6.2020-2616

Source: *Evaluation of a Variable Facesheet Liner Configuration in Grazing Incidence for Broadband Noise Reduction,* https://doi.org/10.2514/6.2021-2243

Introduction

Goal

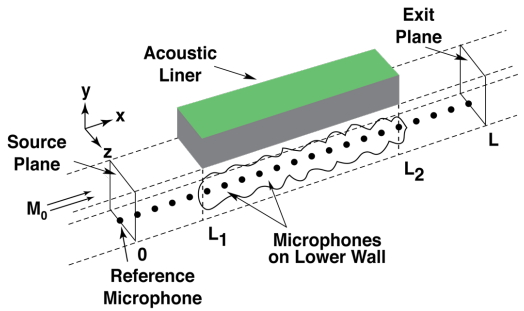
Explore the acoustic performance of a distributed facesheet liner for broadband attenuation.

Approach

Design a three-cell cluster of chambers for broadband attenuation over range of 1000 Hz to 2000 Hz.
Facesheets optimized for Mach 0 and 0.3 flow conditions, at SPL=120 dB.
Samples tested in NASA Langley Grazing Flow Impedance Tube (GFIT) and measured results compared with predictions.

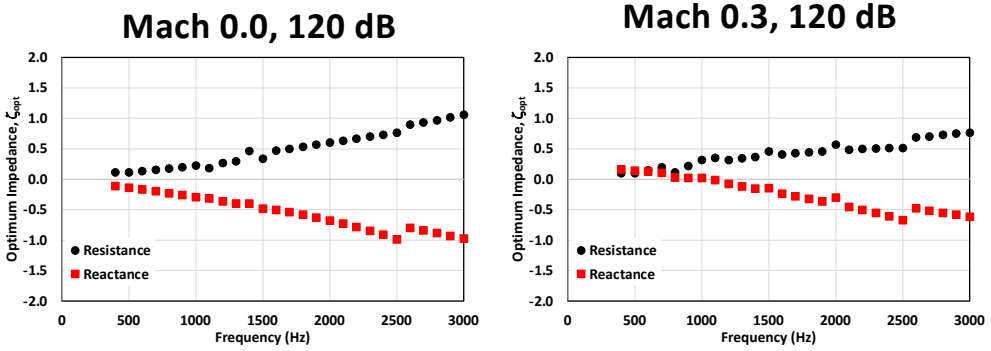
Target Impedance

Computational Domain of Grazing Flow Impedance Tube



Convected Helmholtz Equation + Optimizer

Optimized Impedances for GFIT Configuration



References | Figures 1 and 2

Liner Design Methodology

Define the physical constraints, flow conditions, target impedances.

Physical constraints: is it buildable? => FIX facesheet thickness, optimize on porosity and hole diameter
3-chamber variation
Target flow conditions: Mach 0 and 0.3 (separately)
Target Impedances: Based on GFIT optimized impedances for target flow conditions. Optimized on REACTANCE.

Use the facesheet parameters and flow conditions as INPUTS into Semianalytical Impedance Model to output corresponding impedance.

INPUT impedance spectra into CHE propagation code to get attenuation plots

Define 10 dB of attenuation over length of liner as a reasonable metric for a good absorber.

Select case with lowest frequency and widest bandwidth to build.

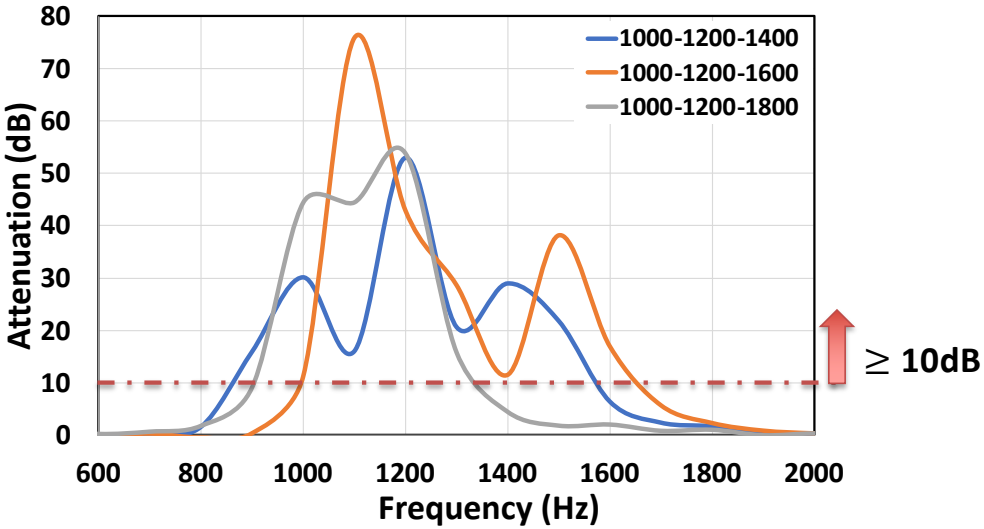
Widest bandwidth => broadband-like acoustic performance

Predicted Attenuation Spectra

Objective

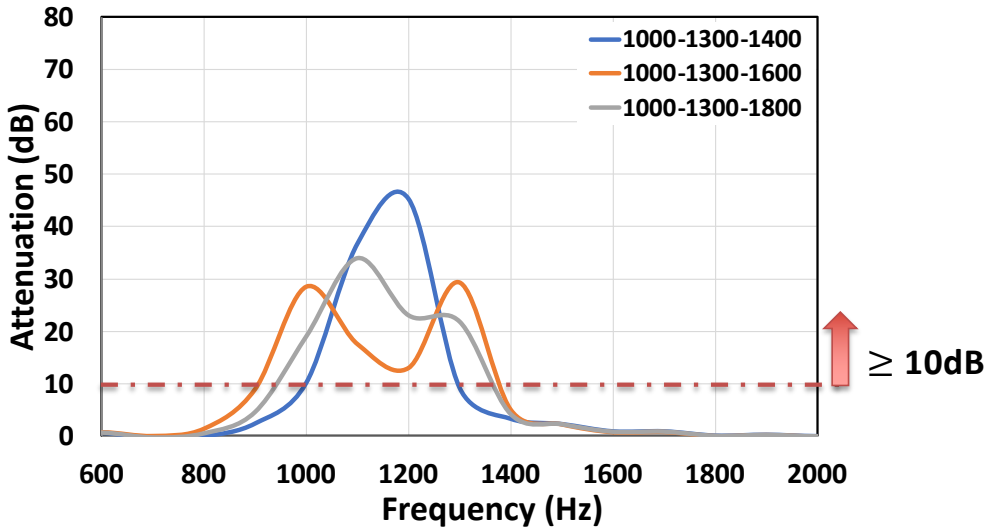
Select the best three-frequency combination to build and test.

Optimized for Mach 0, 120 dB



Selected Combination for Mach 0
1000-1200-1600 Hz

Optimized for Mach 0.3, 120 dB

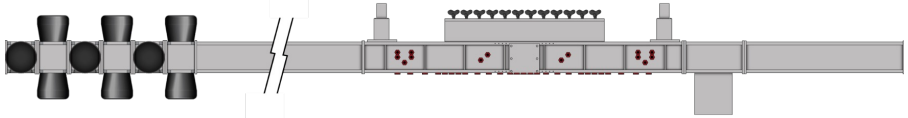


Selected Combination for Mach 0.3
1000-1300-1600 Hz

Reference | Figure 4

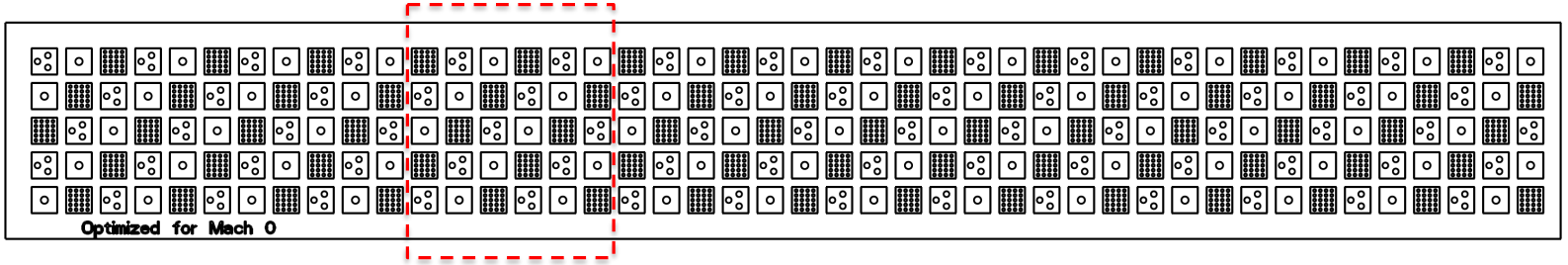
Experimental: Testing in GFIT

Grazing Flow Impedance Tube (GFIT)

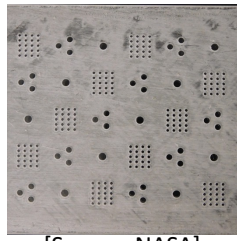


Flow conditions: Mach 0, 0.3, 0.5; SPL= 120 and 140 dB

Optimized for Mach 0, 120 dB

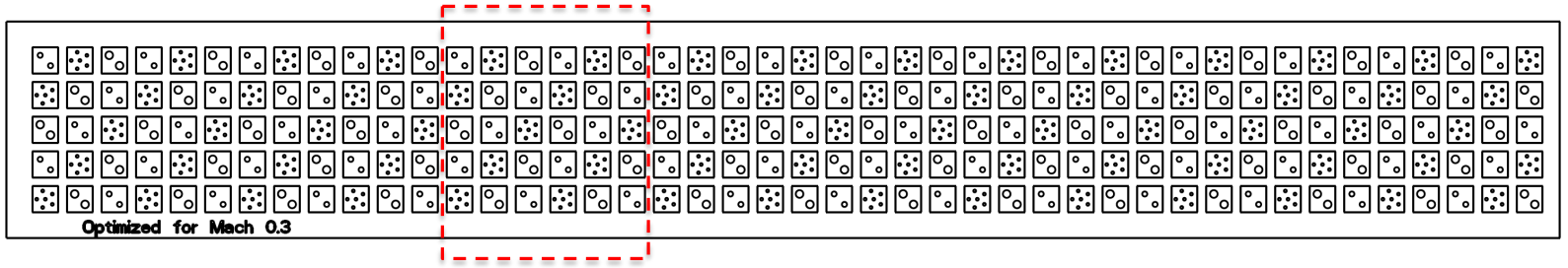


Close-up View Mach 0

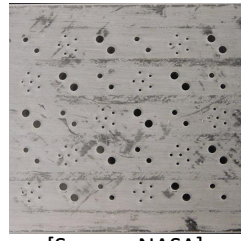


[Source: NASA]

Optimized for Mach 0.3, 120 dB



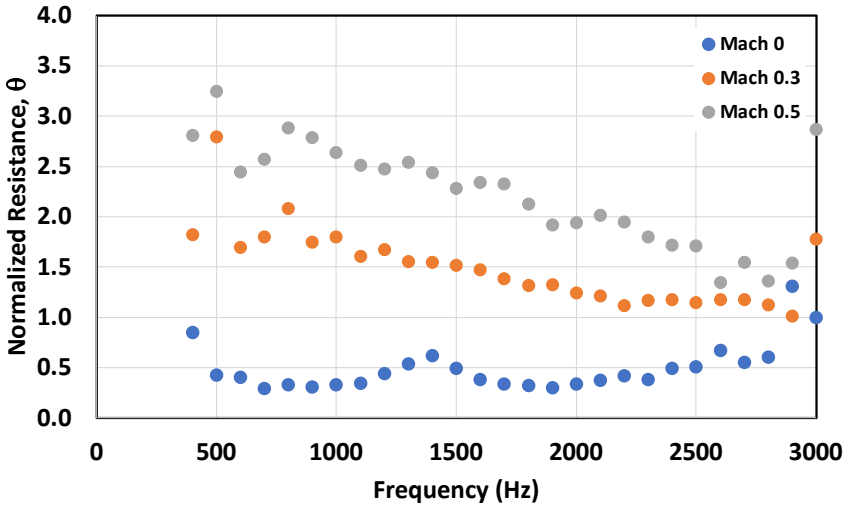
Close-up View Mach 0.3



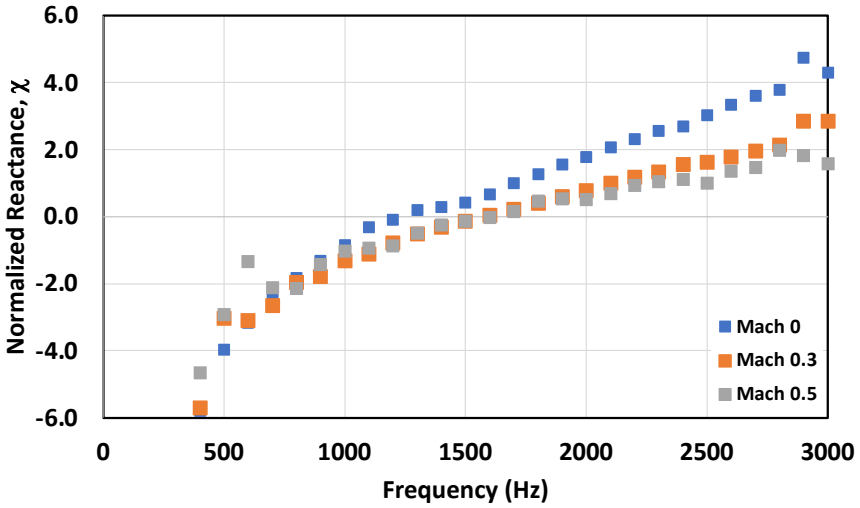
[Source: NASA]

Measured Results: Impedance Spectra

Optimized for Mach 0, 120 dB



Increase in resistance as flow speed is increased

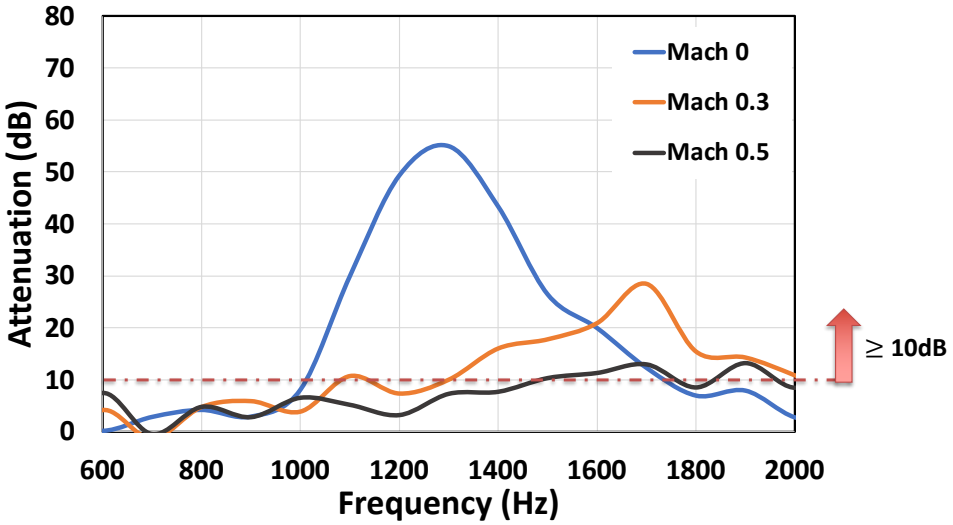


Reduction in slope for increasing Mach number

Reference | Figure 9

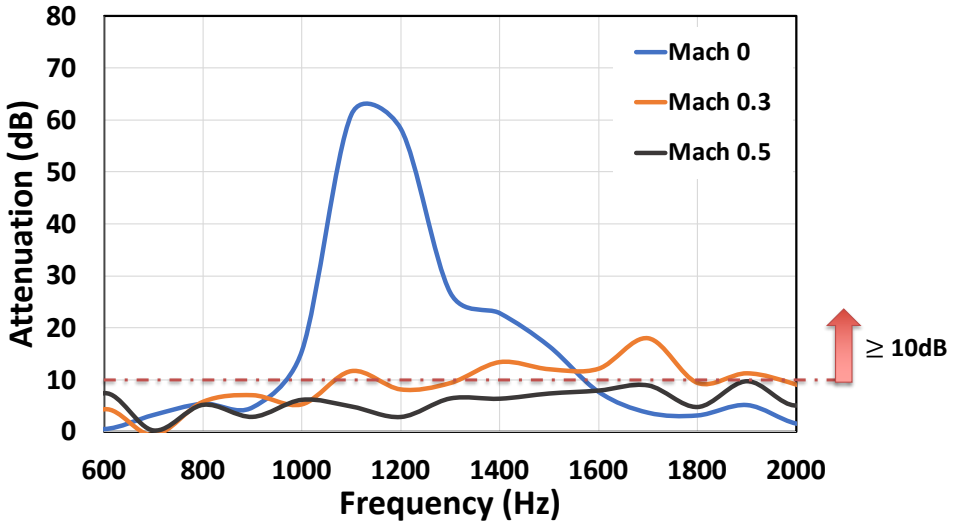
Measured Results: Attenuation Spectra

Optimized for Mach 0, 120 dB



Mach 0
700 Hz frequency range

Optimized for Mach 0.3, 120 dB



Mach 0.3 flow condition
400 Hz frequency range

Reference | Figure 13

Conclusions

- Designed three-chamber facesheets optimized for Mach 0 and 0.3 flow conditions.

- Distributed facesheet liner samples tested in GFIT.
  - Facesheet optimized at Mach 0 => 700 Hz frequency range
  - Facesheet optimized at Mach 0.3 => 400 Hz frequency range

- Predicted and measured attenuation ranges compare favorably.

- Demonstrated broadband acoustic performance with a distributed facesheet and uniform core.

Future Work

Use distributed facesheet novel liner concept to test in Curved Duct Test Rig (CDTR) where the acoustic source consists of controlled higher-order modes.

Acknowledgments

Max Reid, Christopher (Mark) Cagle and Robert Andrews

Advanced Air Transport Technology Project (AATT) of the
NASA Advanced Air Vehicles Program for funding this work