Experimental Investigation of Porous Materials for Trailing-Edge Noise Reduction

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SFB 880 Hochauftrieb künftiger Verkehrsflugzeuge

Knowledge for Tomorrow

Motivation

- Long-term collaborative research initiative *CRC 880: Fundamentals of High Lift for Future Civil Aircraft*

Hochauftrieb künftiger Verkehrsflugzeuge SFB 880

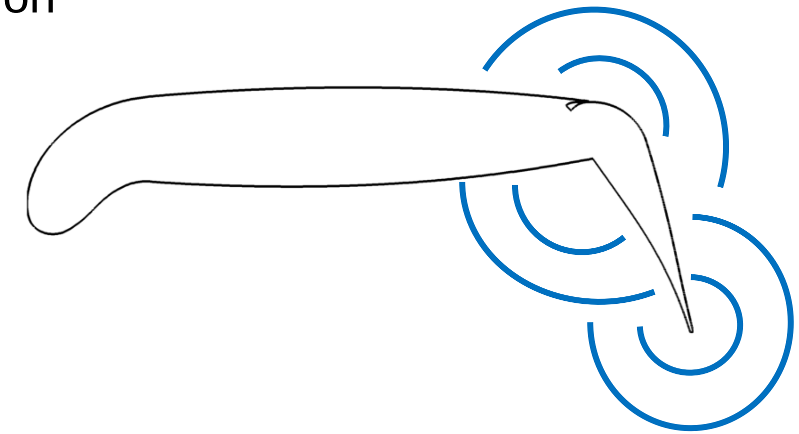
DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

Technische Universität Braunschweig

Focus : quiet short take-off and landing (STOL) for civil aircraft operations in close proximity to the population

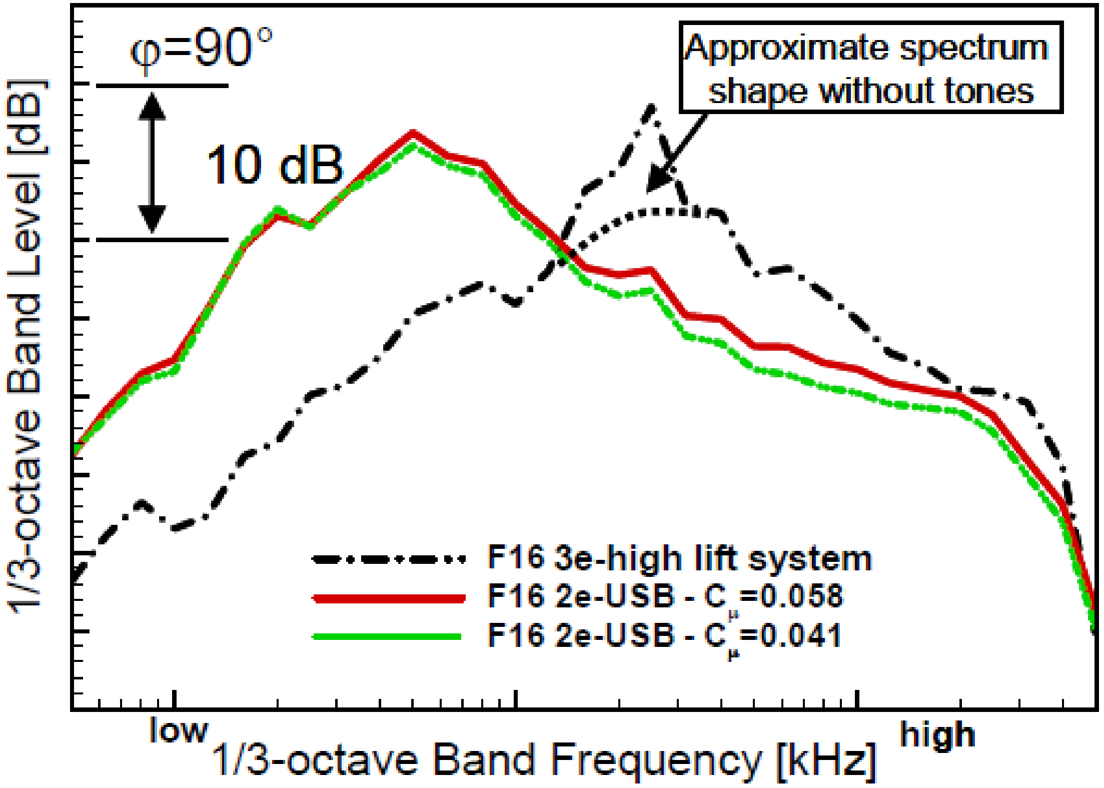
Technology Challenge : Extreme lift augmentation vs. low noise immision

Concept : active high lift system,
non-slotted flap with flow control (Coanda effect), droop nose



Research goals

Airframe noise from active high-lift systems



M. Pollenske, AIAA 2010-3881

(1) Physical understanding of source mechanisms

(2) High-lift noise reduction by advanced porous materials

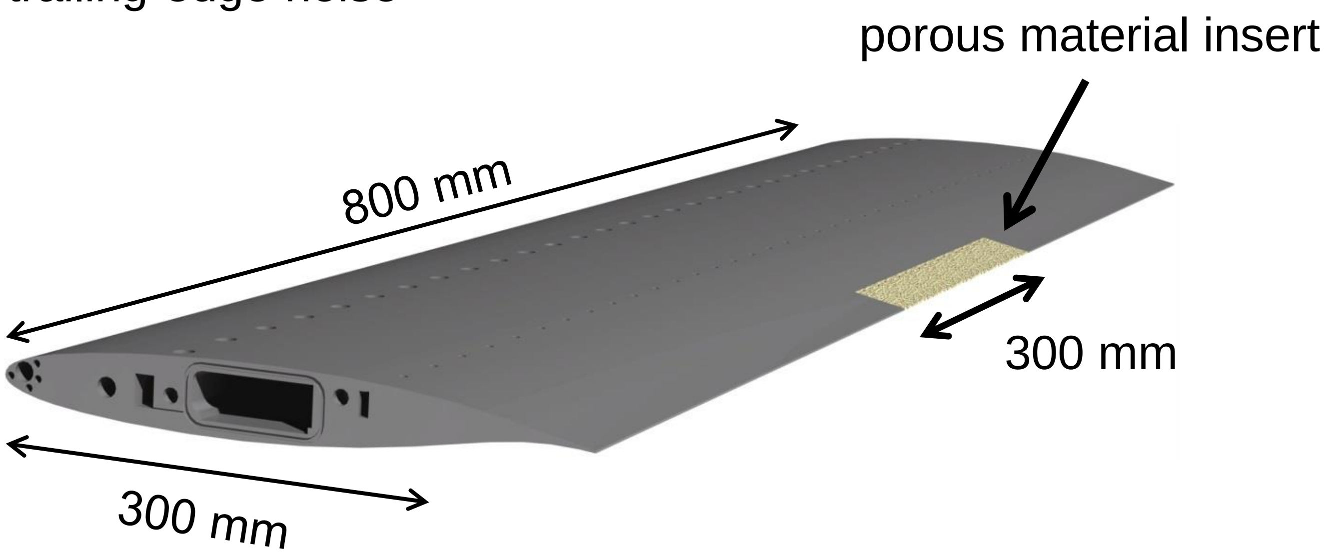
(3) Development of aeroacoustically tailored materials

Numerical Aeroacoustics ⟺ Experimental Aeroacoustics

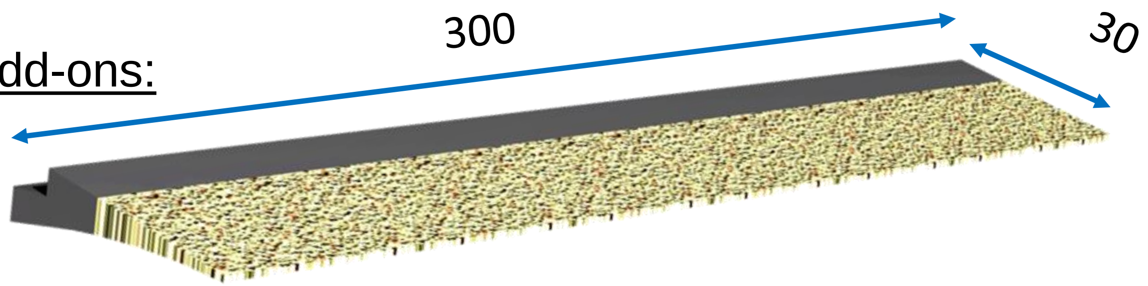
Material Science

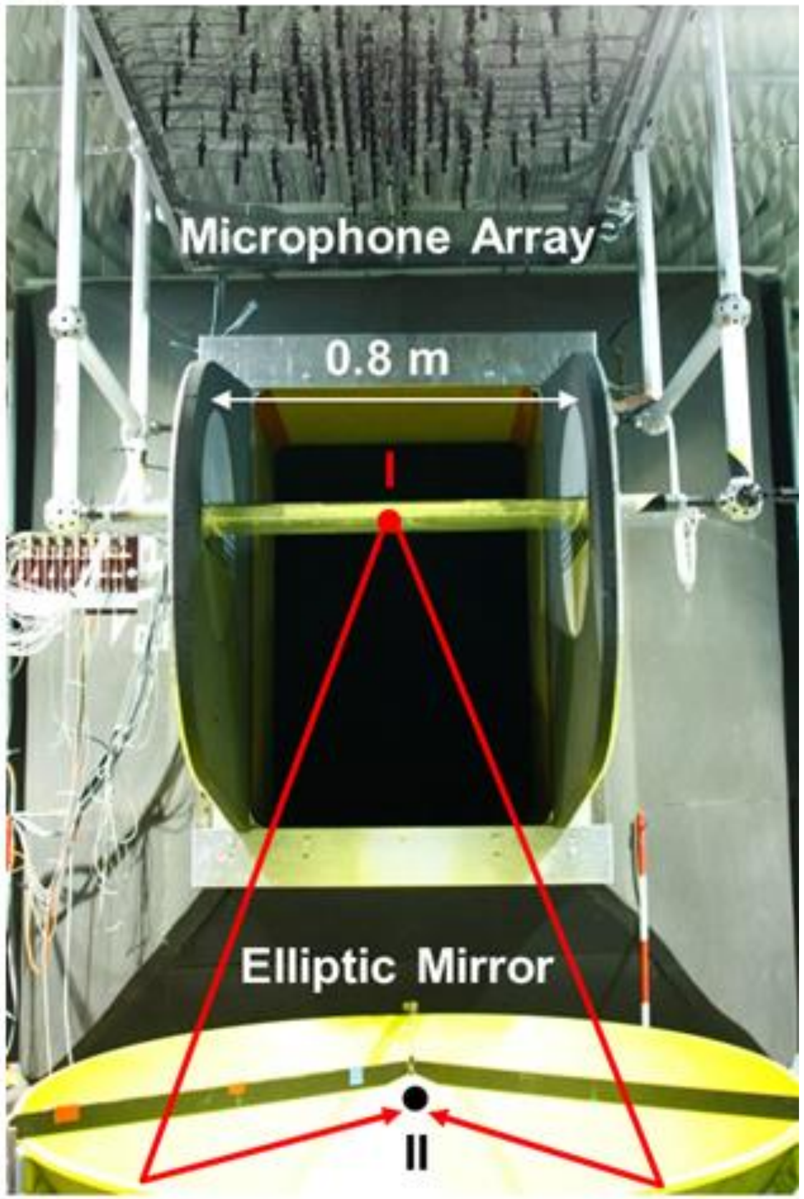
Generic setup - DLR F16 2D-airfoil

- parametric investigations effect of porous materials on trailing-edge noise



Block porous TE add-ons:





Acoustic Wind Tunnel Braunschweig (AWB)

Material characterization

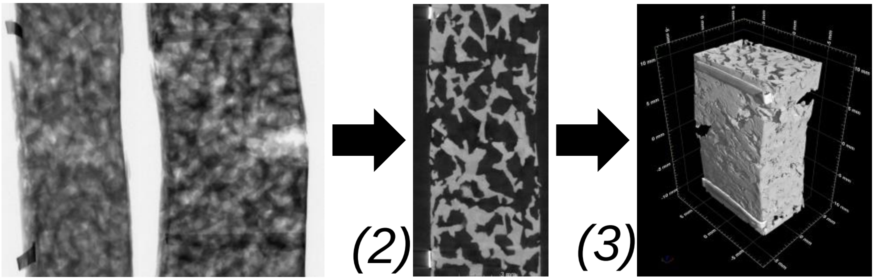
Computertomography (CT) for porosity, pore morphology (and damage behavior)

(1) Measurement: Image stacks of radiographic images 0-360°

(2) Reconstruction of sample, 2-D planes (grey scale)

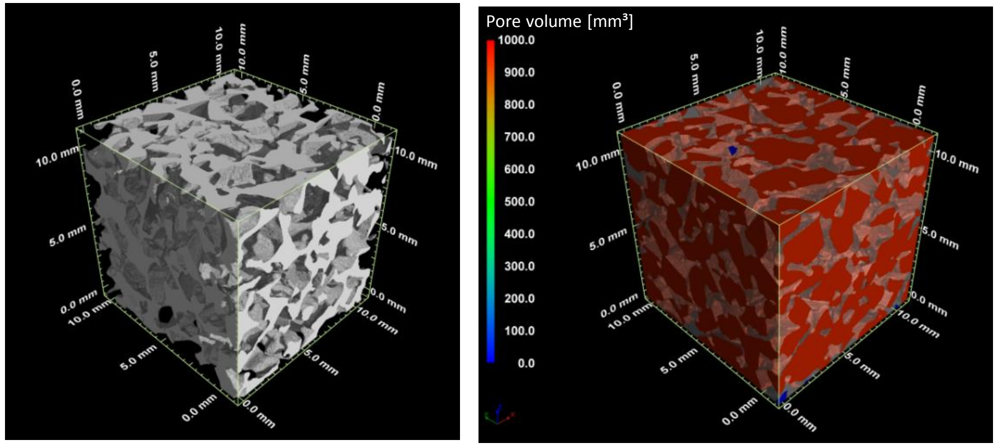
(3) 3-D volume with detected surface

(1) (2) (3)

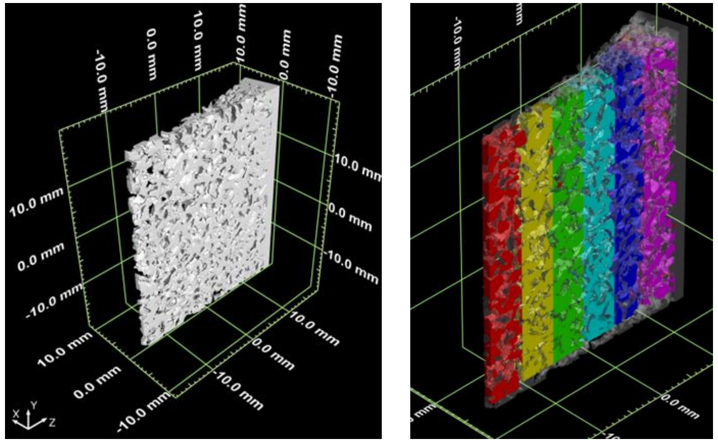


PA200-250: Sample for tensile testing

- Measurement of structures and porosity with defect detection for Regions of Interest (ROI)
- 2-D cross sections of volume for line segmentation technique (leading to segment length)



CT Reconstruction of PA 200-250
(left: material ; right: porosity color coded)



CT Reconstruction of TE of PA 200-250
(left: material ; right: ROI1-6 for porosity analysis)

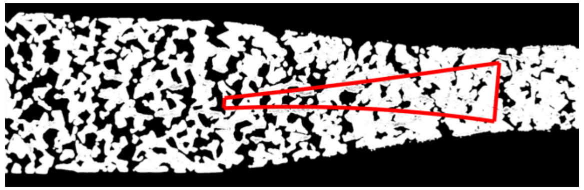
(Source: J. Tychsen, N. Lippitz, J. Rösler, Metals, 8, 598 (2018))

Material characterization

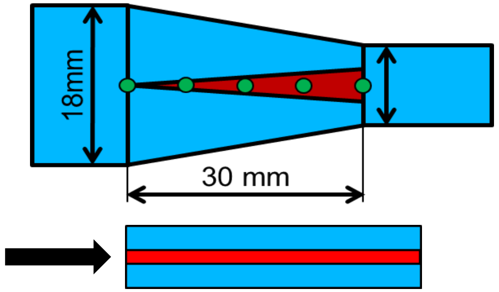
Flow resistivity (and acoustic absorption) measurements:

- Problems:
  - samples with ø = 100 mm ideally needed
  - trailing edges cannot be characterized
  - thin areas of TEs do not have representative amount of volume (pores may directly connect upper and lower side)

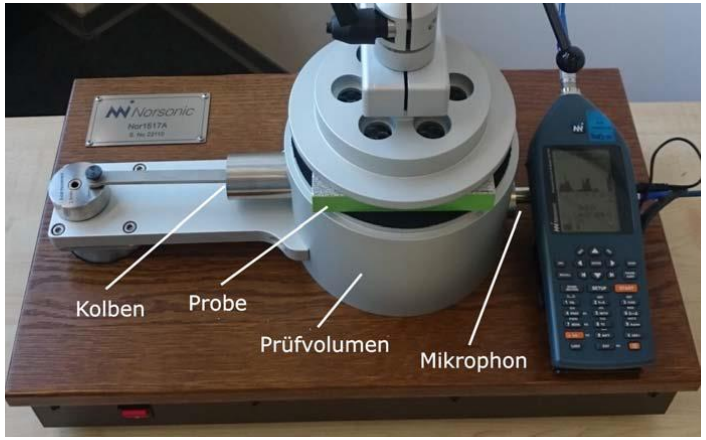
➢comparative samples needed (made of constant rolled material)



Cross-section of graded PA200-250, shape of TE highlighted

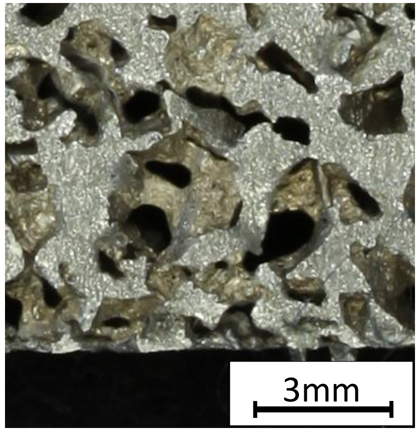


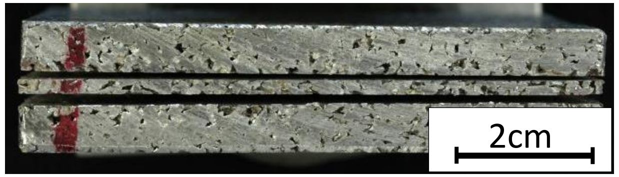
Schematic diagram showing graded material with five positions that are to be measured



Setup for measuring flow resistance with the air-flow process (Process B) according to DIN EN 29 053

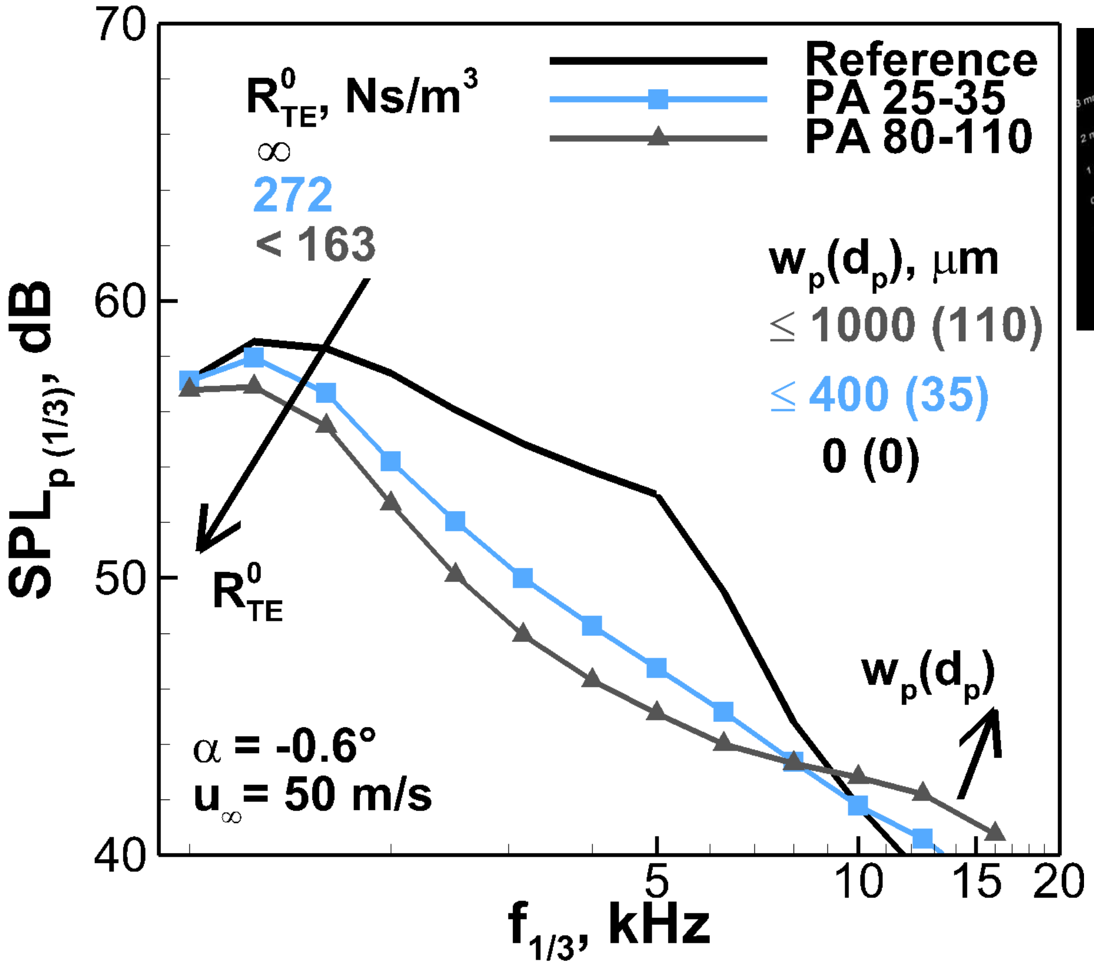
(Source: adapted from N. Lippitz, NFL Forschungsbericht 2017-18, TU BS– NFL)

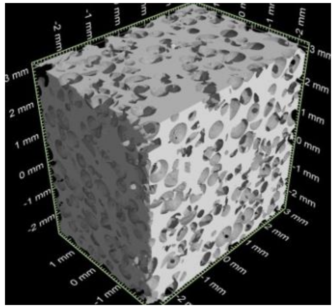




2 mm – sample separated by electrical discharge machining
left: surface (pores directly connecting upper and lower side)
right: original sample (thickness=16 mm) with eroded disc (2 mm)

Results – parameter variations (pore size, flow resistivity)





(1) Pressure release across TE necessary

(2) Largest low-f. (< 10 kHz) noise reduction, $R^0_{TE} < 100\ Ns/m^3$

(3) No High-f. excess noise (f < 20 kHz) when $w_p \leq 160\ \mu m$


Specification of Porous Materials for Low-Noise Trailing-Edge Applications

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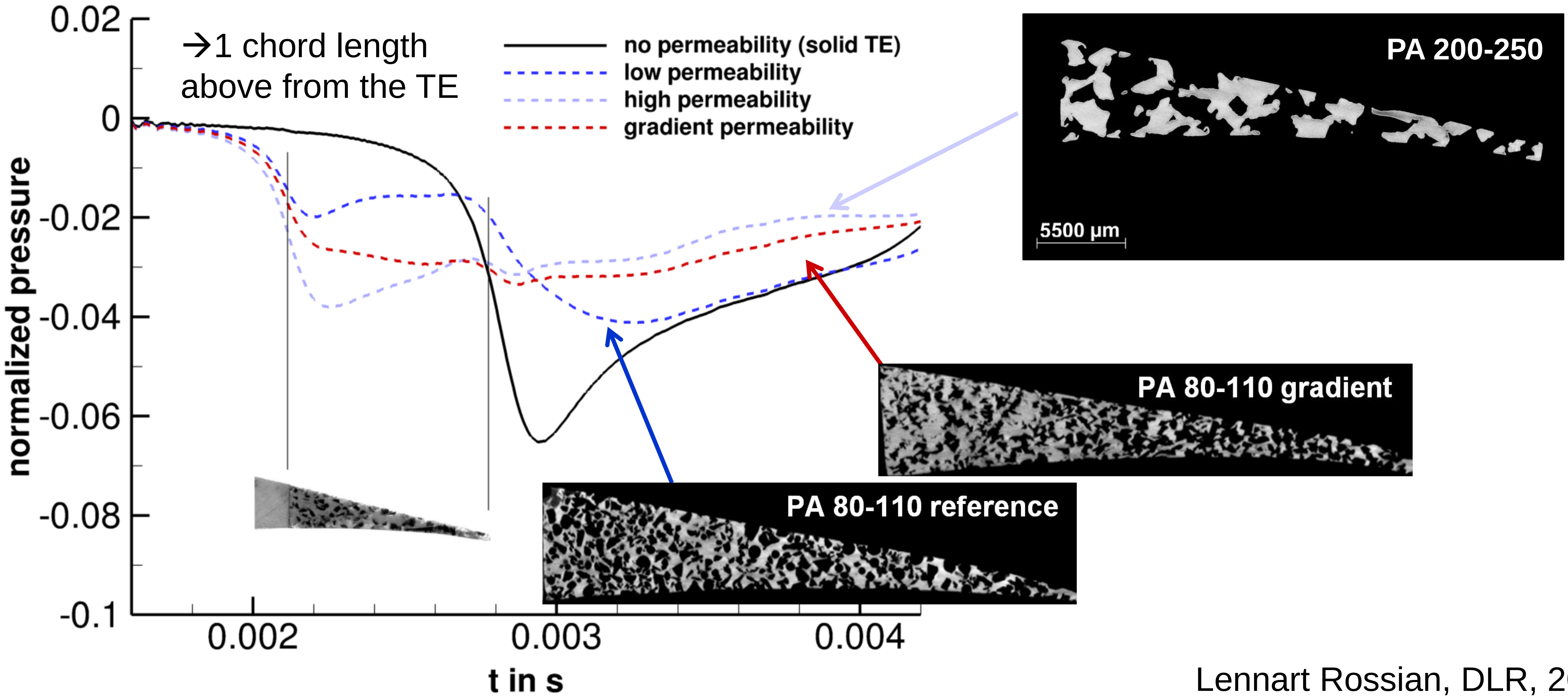
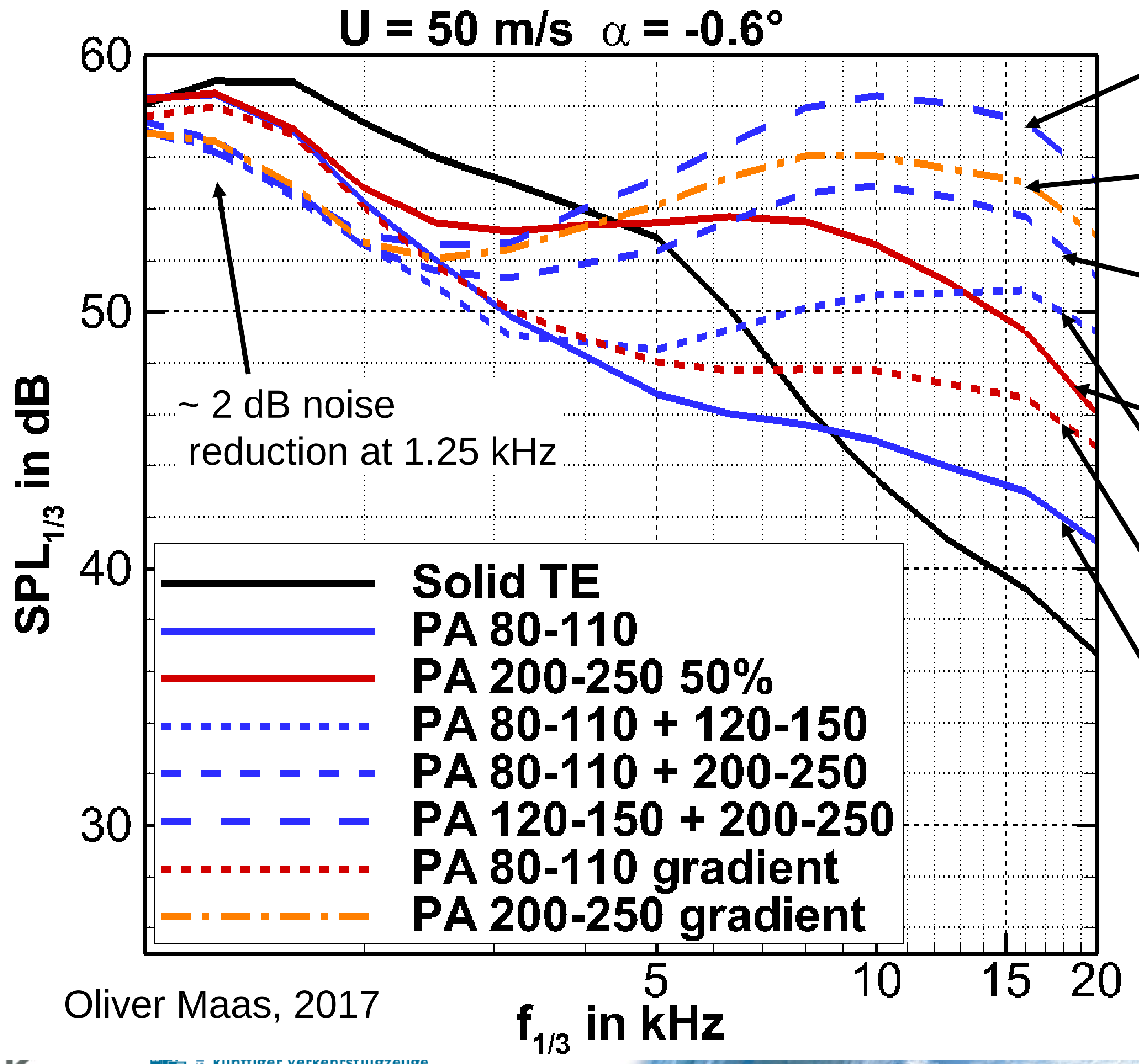
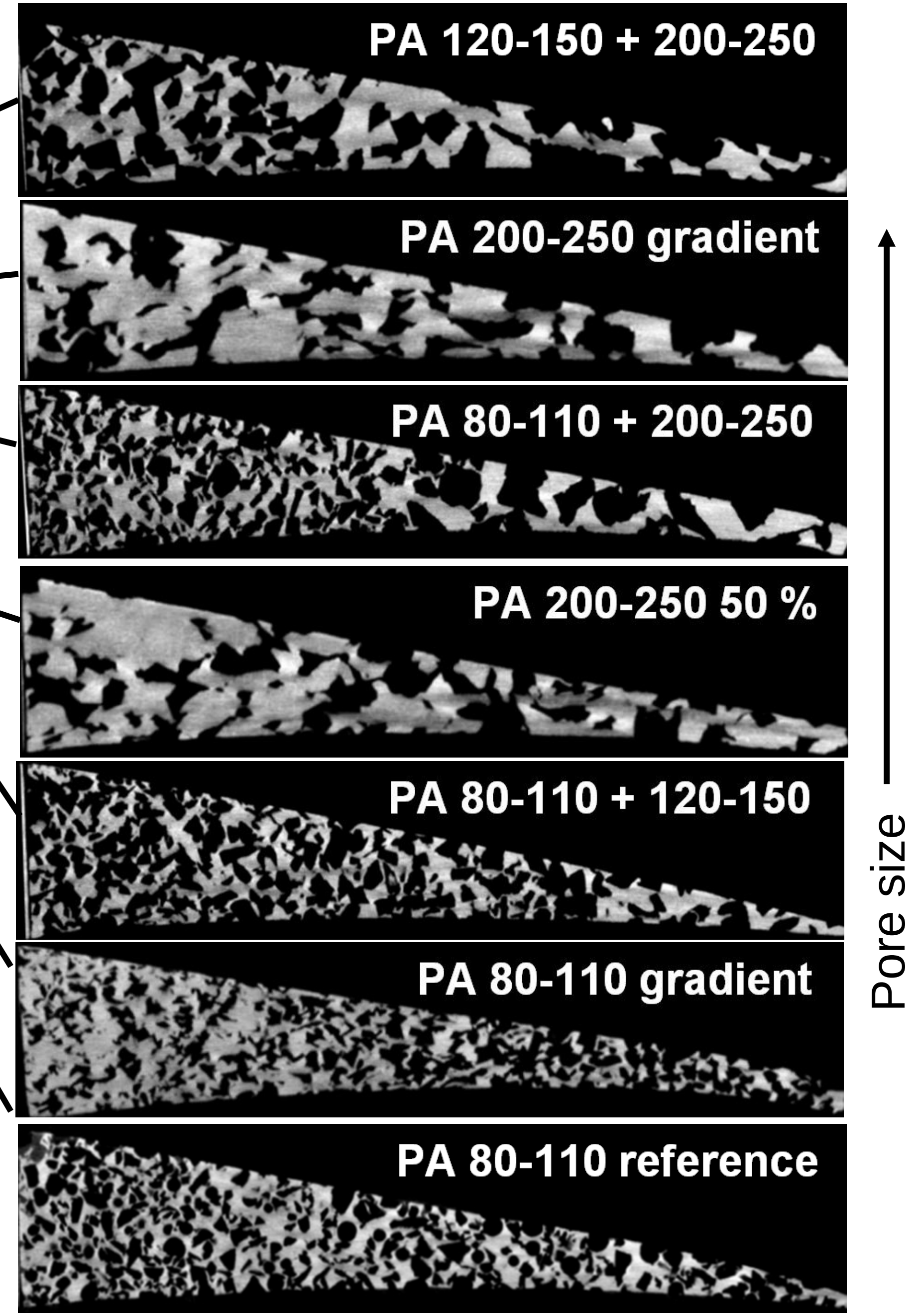
AIAA 2014-3041

Tailored porous inserts for optimized noise mitigation performance



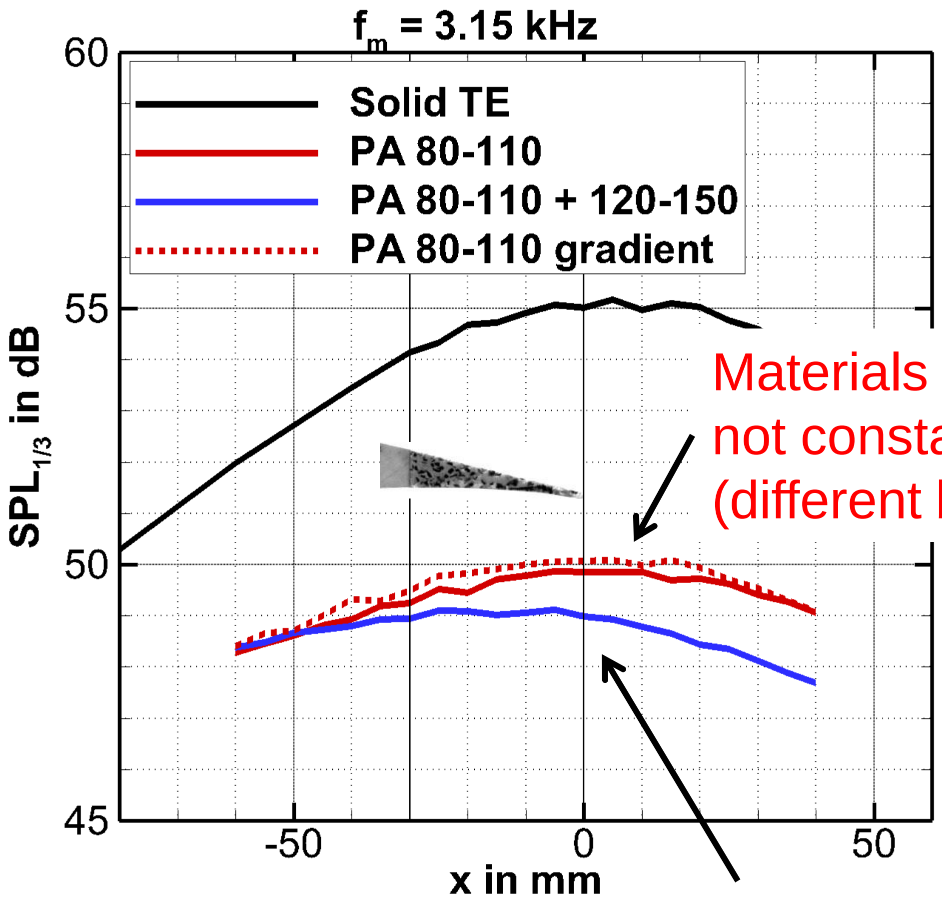
Lennart Rossian, DLR, 2017



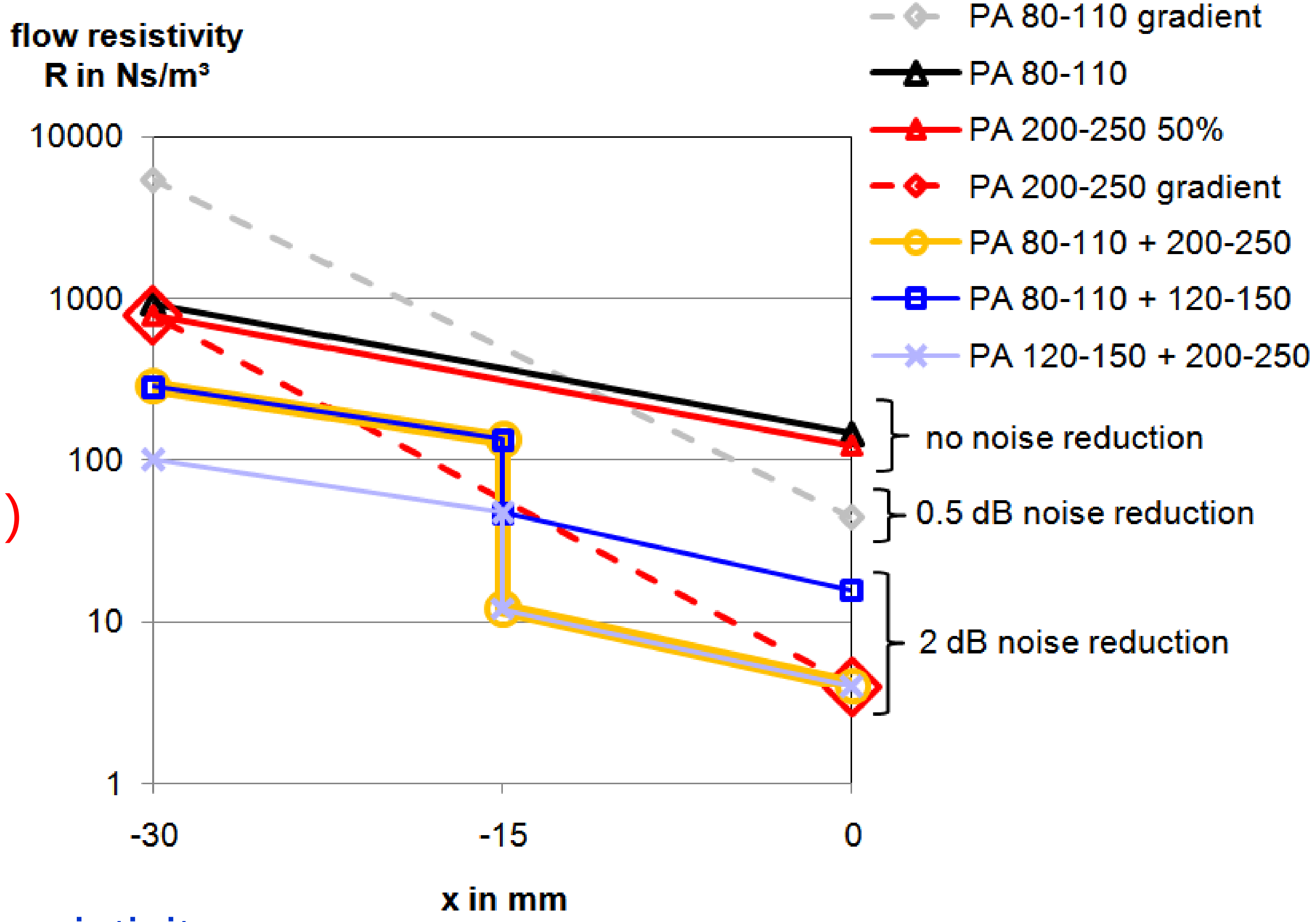


Oliver Maas, 2017

Low frequency noise (1.25-3.15 kHz)



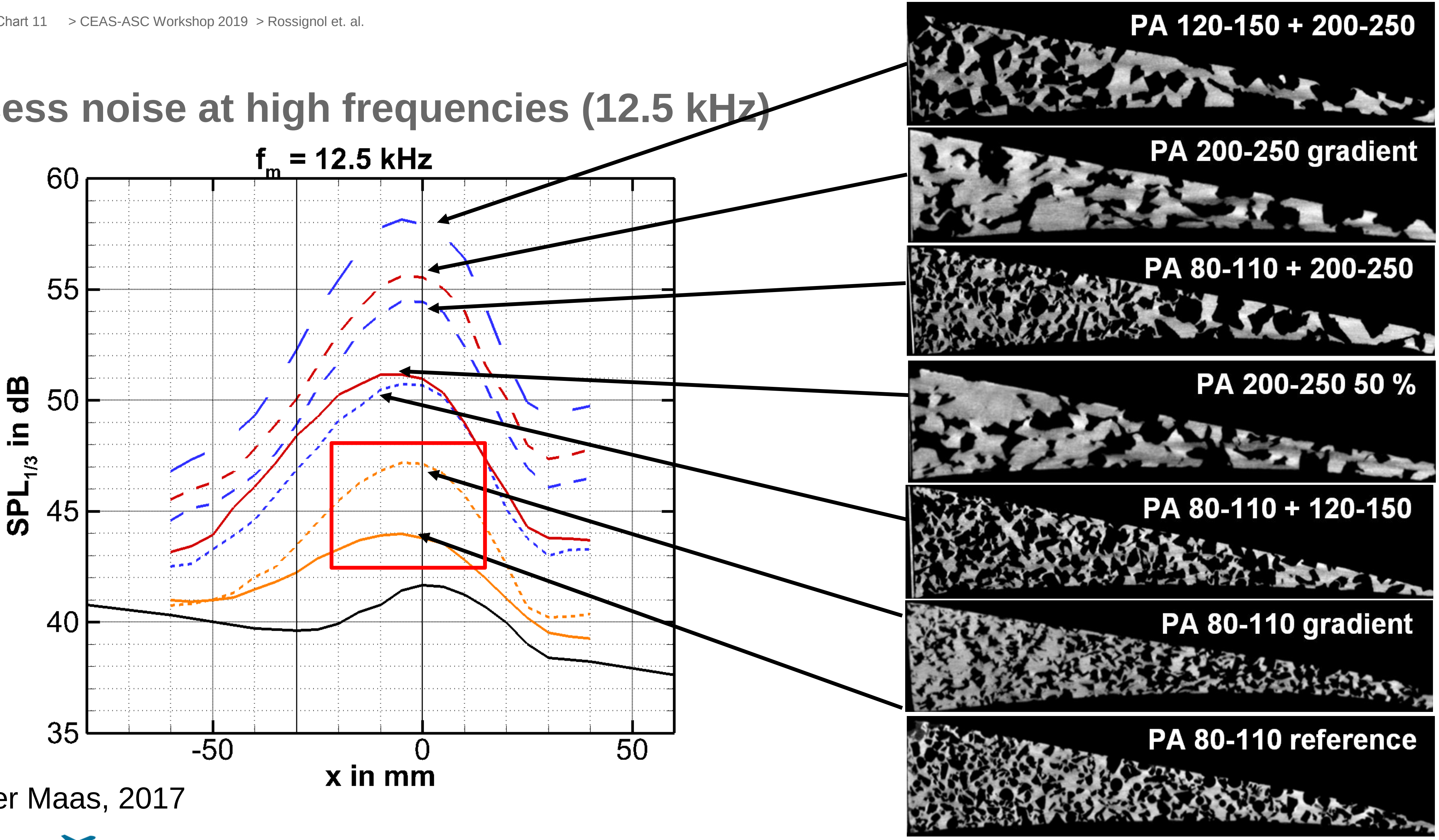
Materials props not constant (different batch!)



Effect of flow resistivity or stepwise resistivity adjustment?

Oliver Maas, 2017

Excess noise at high frequencies (12.5 kHz)

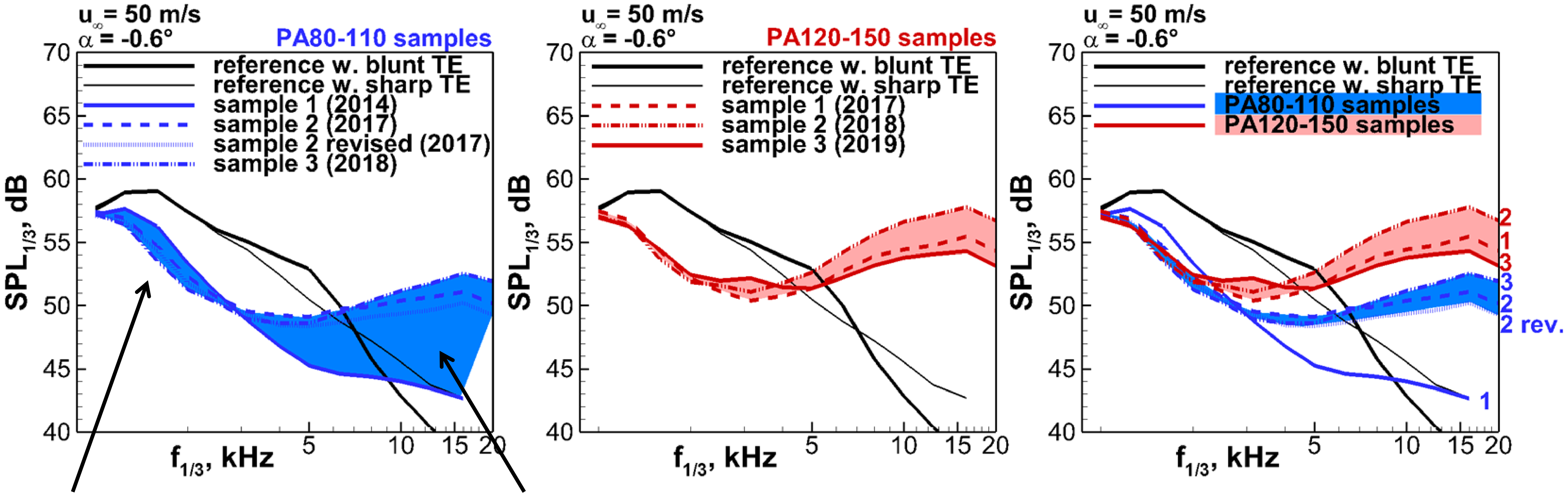


Oliver Maas, 2017

Variability of samples properties related to the manufacturing process

	Porosity	Pore size	Flow resistivity	
	-	µm	10^3 Ns/m^4	Ns/m³
Reference, solid	0	0	-	-
PA 80-110	0.46	305	**145.5**	931 - 146
PA 200-250 50%	0.29	480	**122.8**	786 - 123
PA 80-110 gradient	0.27 - 0.57	222 - 416	**839.6 - 44.2**	5373 - 44
PA 200-250 gradient	0.29 - 0.57	480 - 1052	**122.8 - 4.0**	786 - 4
PA 80-110 + 120-150	0.57 / 0.55	416 - 630	**44.2 - 15.6**	283 - 16
PA 80-110 + 200-250	0.57 / 0.57	416 - 1125	**44.2 - 4.0**	283 - 4
PA 120-150 + 200-250	0.55 / 0.57	630 - 1125	**15.6 - 4.0**	100 - 4
		w_p		R_{TE}^0

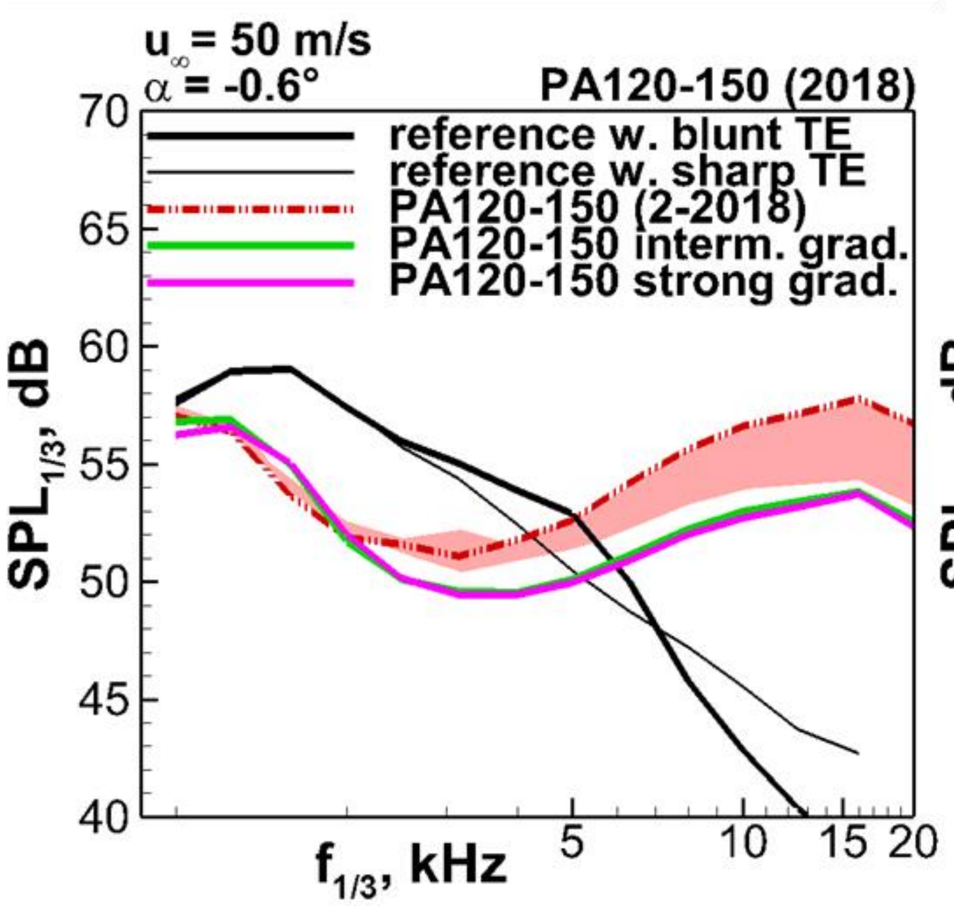
Material samples properties variability

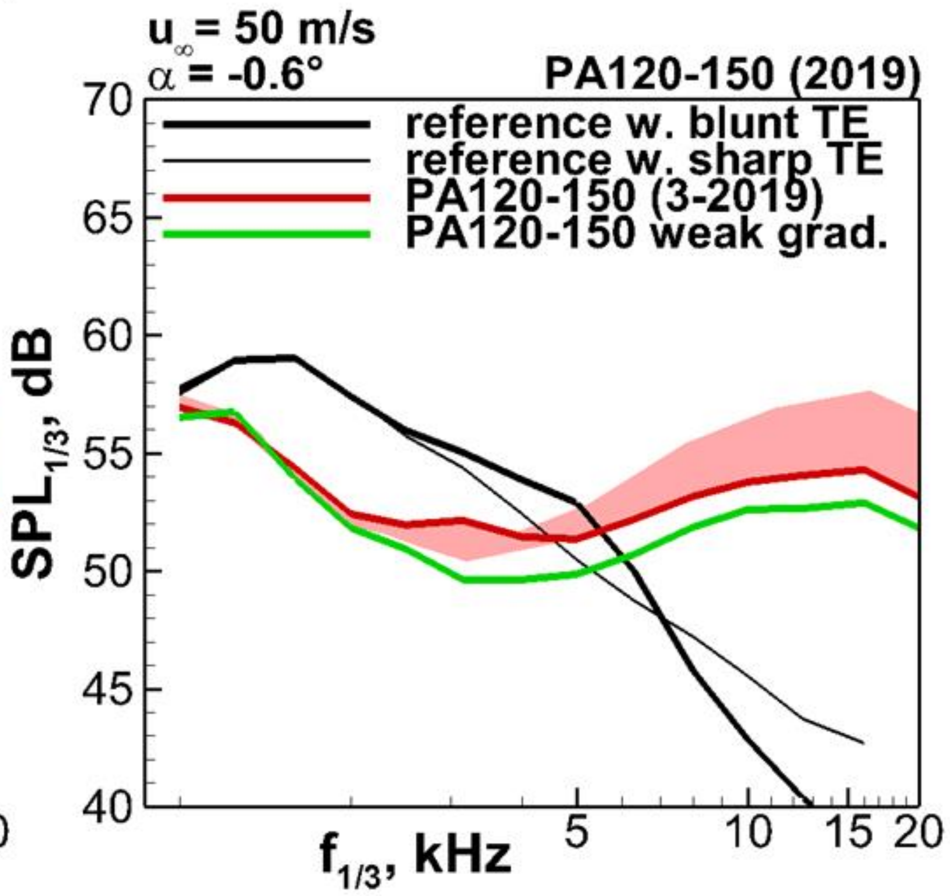


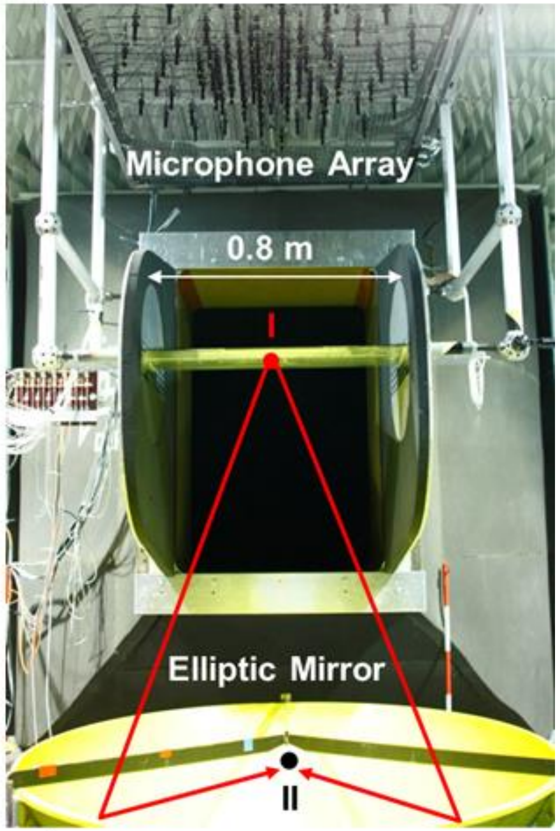
Variations in flow resistivity

Variations in pore size

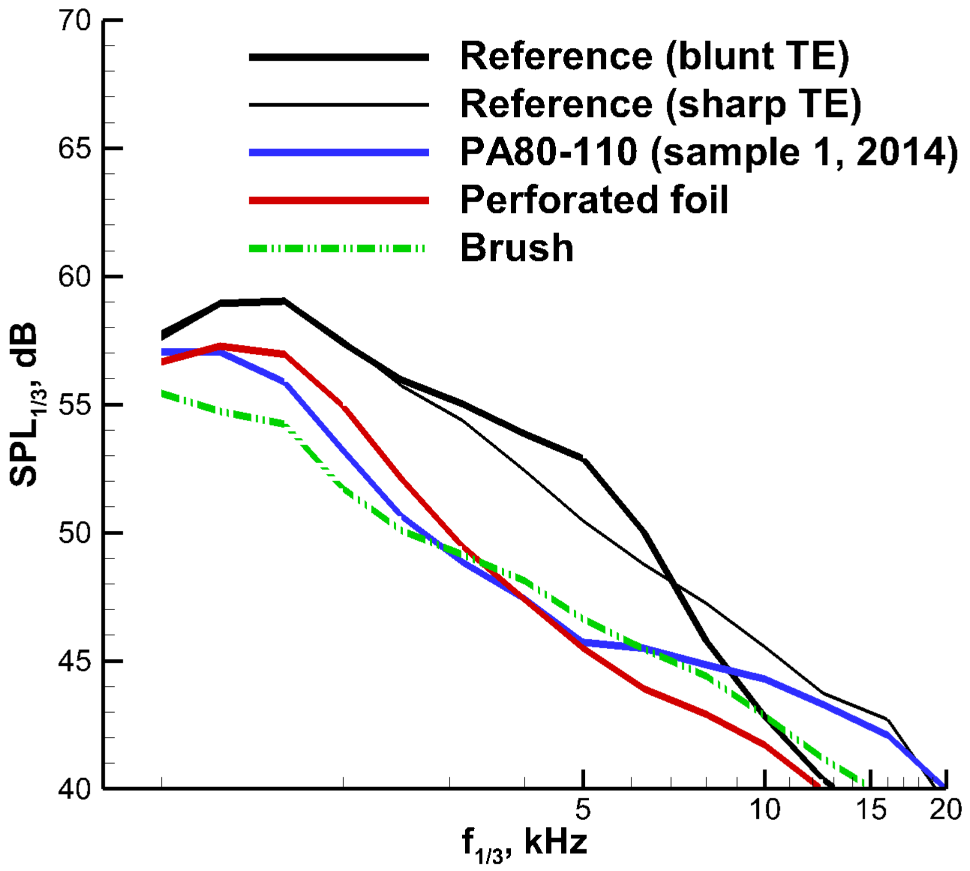
Material samples properties variability – effect of permeability gradient



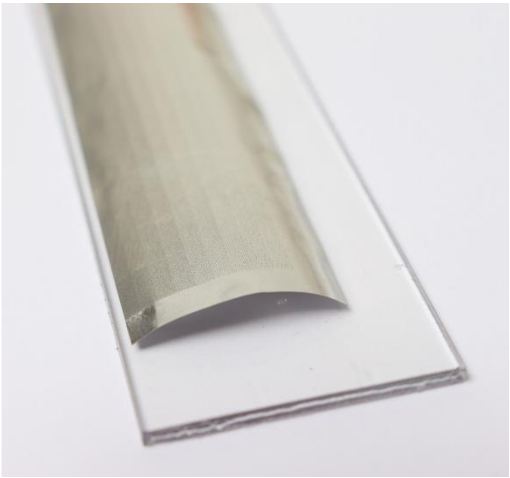


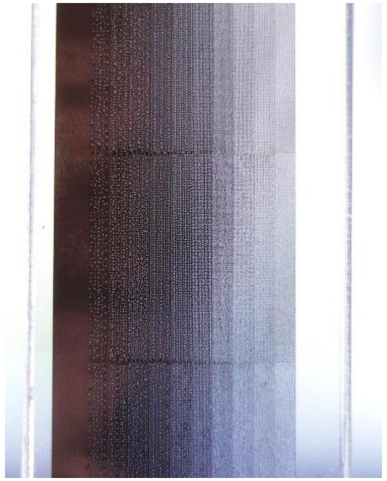


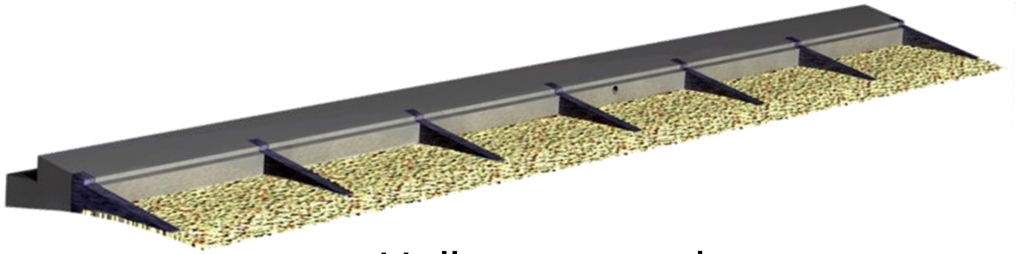
Mitigation of high-frequency excess noise



Hole diam.: 45 µm – 90 µm

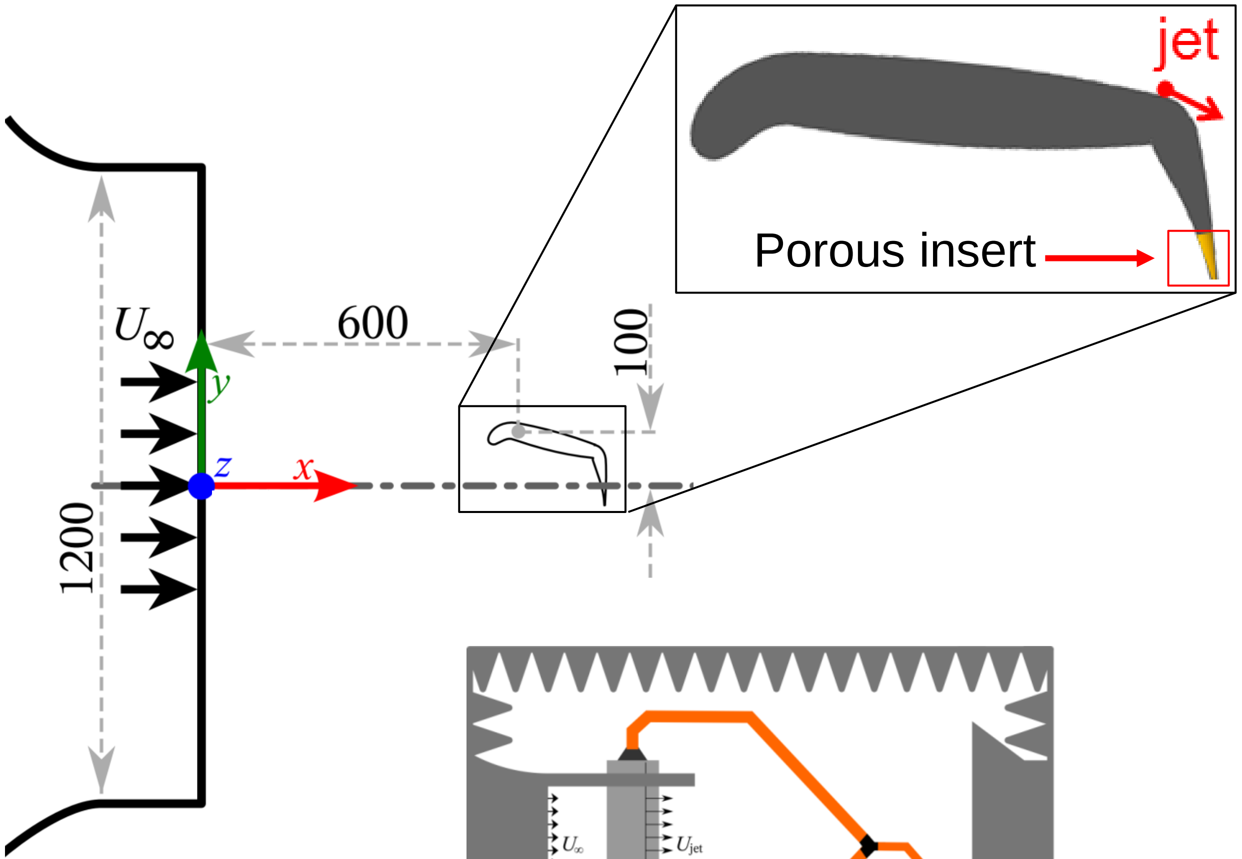


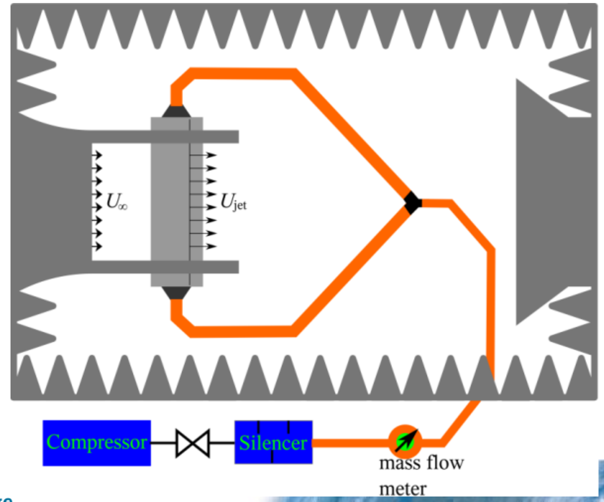




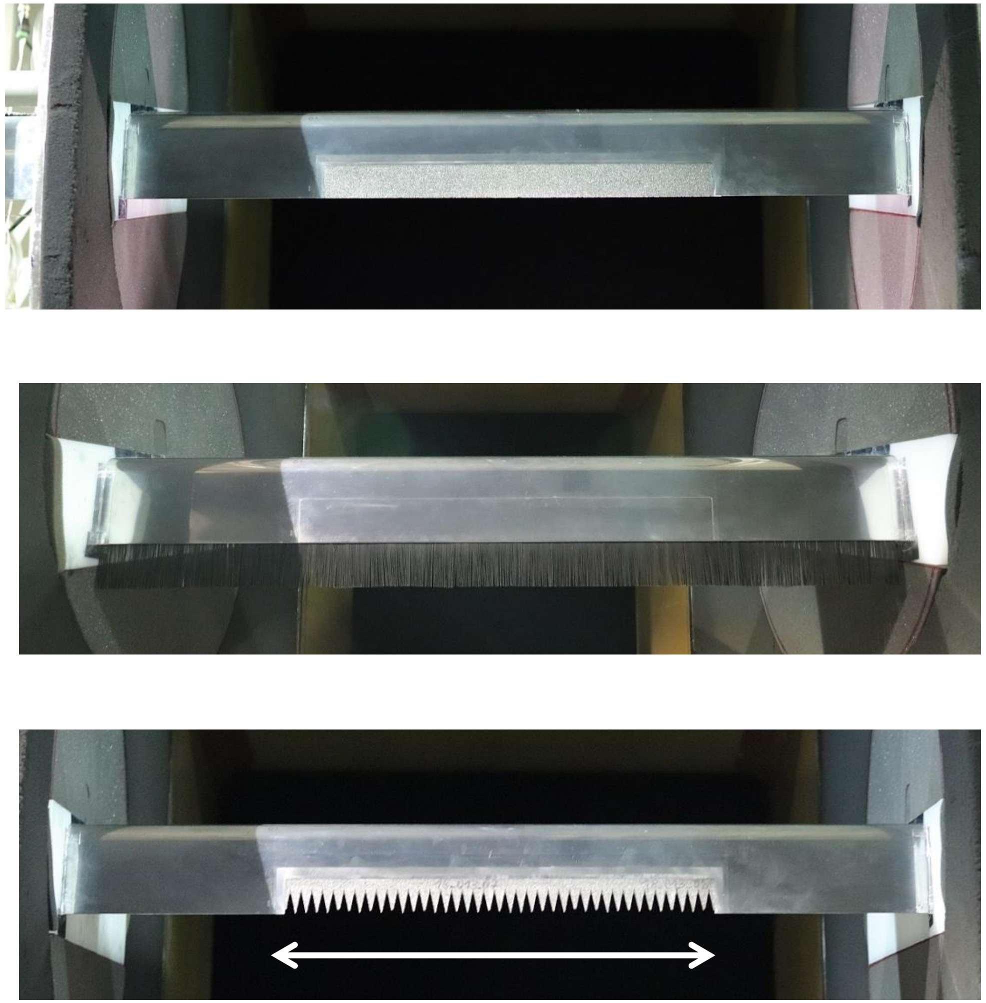
Hollow supporting structure

High-lift system with active flow control

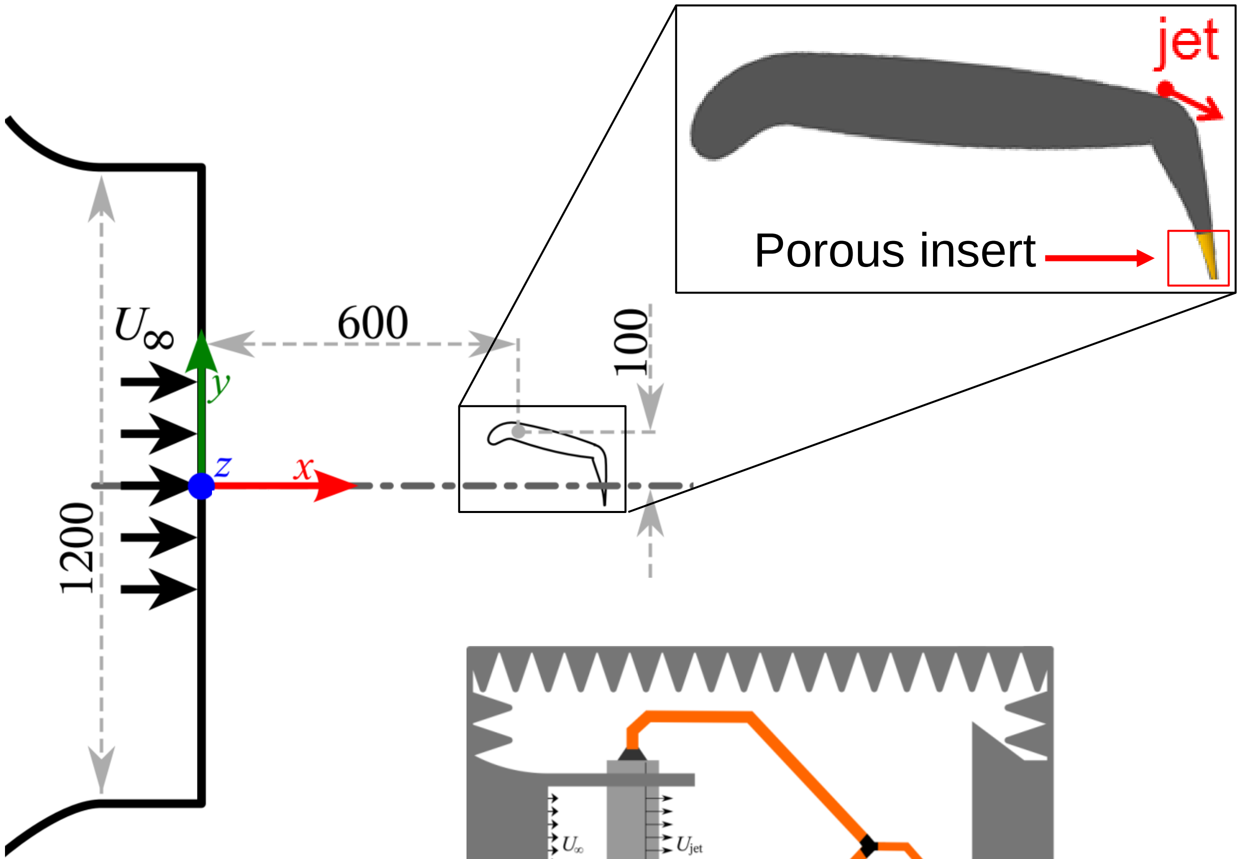


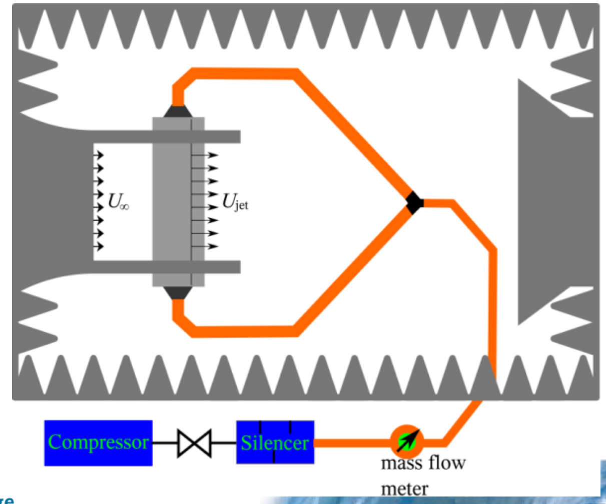


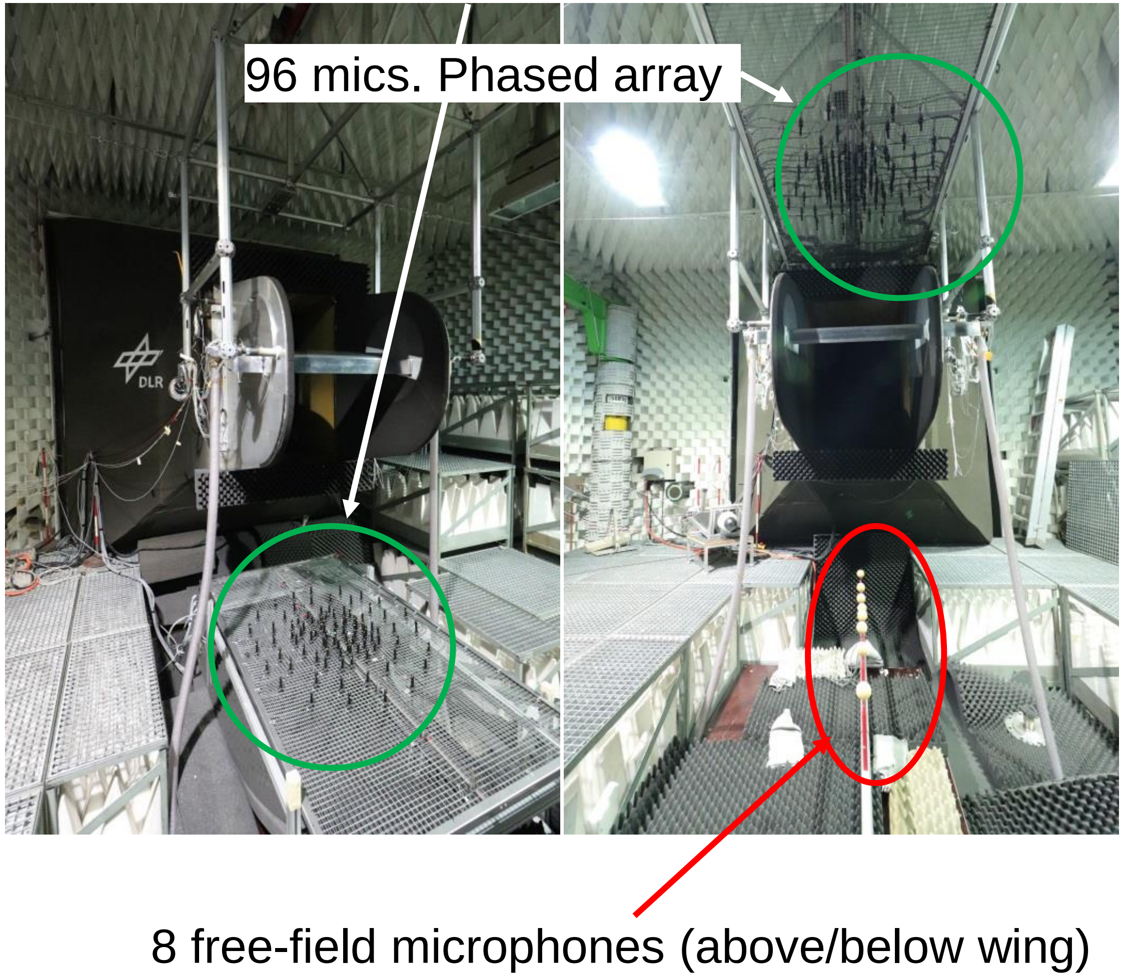
Porous TE inserts



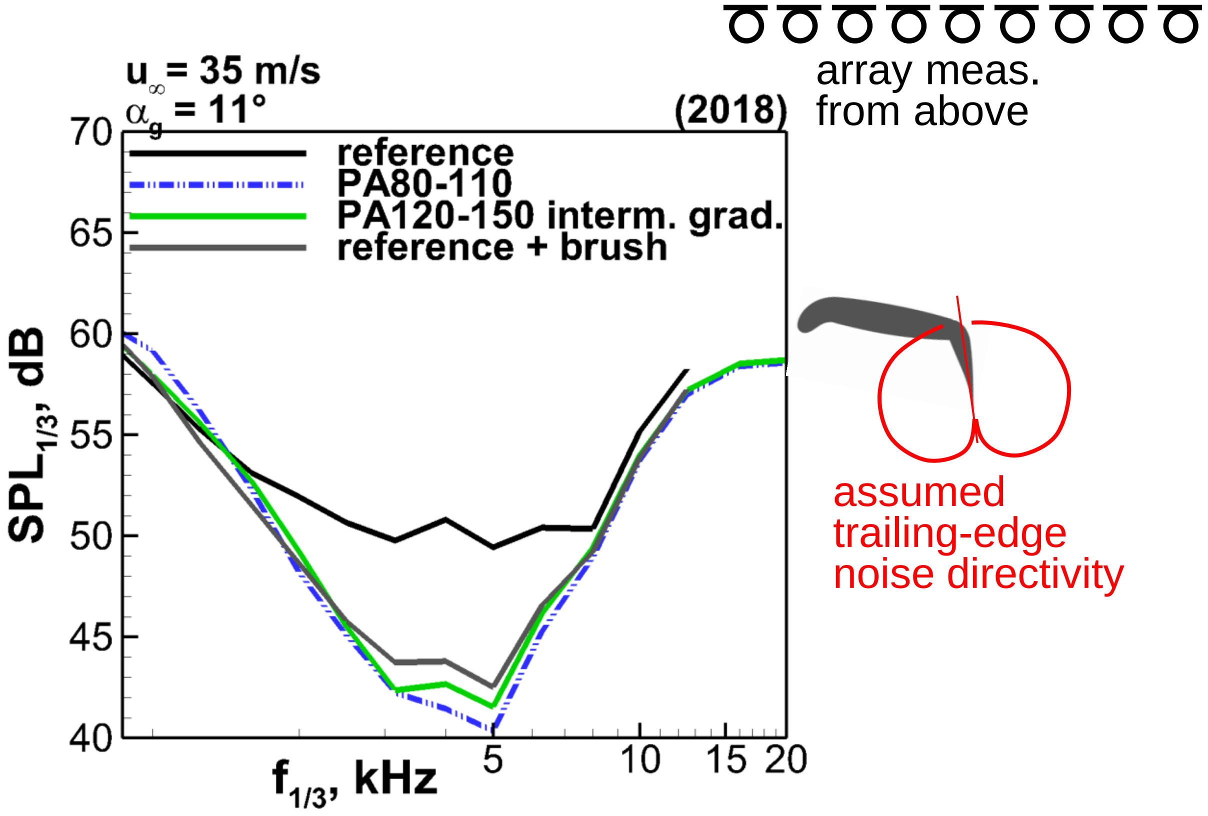
High-lift system with active flow control



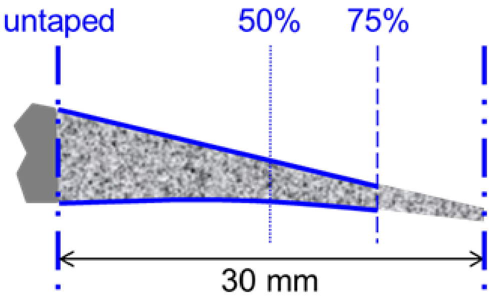


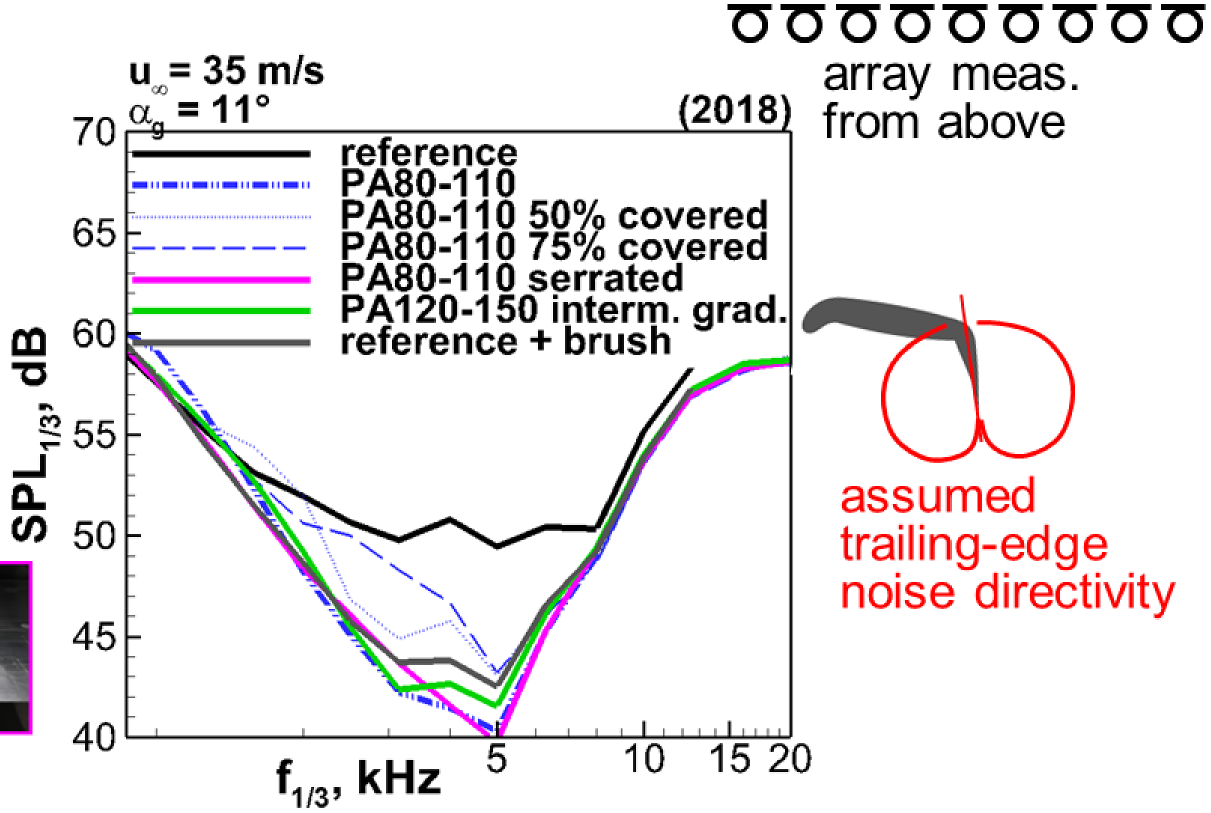


High-lift system with active flow control

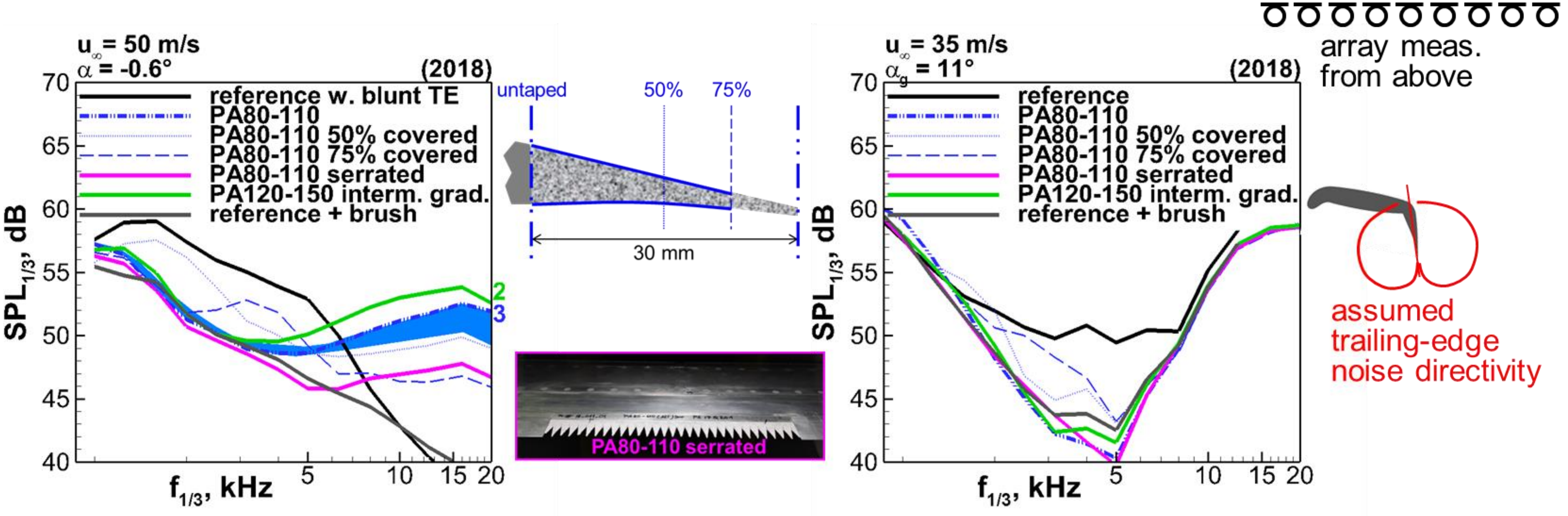


High-lift system with active flow control





High-lift system with active flow control



Conclusions

Material characterization:

- samples with ø = 100mm ideally needed
- trailing edges (as in the experiment) cannot be characterized
- thin areas of TEs do not have representative amount of volume (pores may directly connect upper and lower side)

Acoustics

- Pressure release across TE necessary
- Largest low-f. (<10kHz) noise reduction, $\boldsymbol{R^0_{TE} < 100\, Ns/m^3}$
- No High-f. excess noise (f < 20 kHz) when $\boldsymbol{w_p \leq 160\, \mu m}$
- Conflicting criterias!
- Combination of hydraulicaly smooth porous plates and porous metals
- **Consistency of manufacturing process is critical to ensure consistency materials properties**

Conclusions

Acoustic continued …

- Quantification of the effect of graded porous properties difficult in the experiment
- Results of the generic test at a 2D airfoil successfuly transposed to active flow control high-lift system (TE noise reduction on the order of ~10 dB)
- Porous insert integration details might be important in defining largest noise reduction
- Noise reduction at low frequencies (< 2kHz): **25%** of porous length sufficient for equivalent results