Reduction of flow generated noise of airfoils by means of acoustically soft coating

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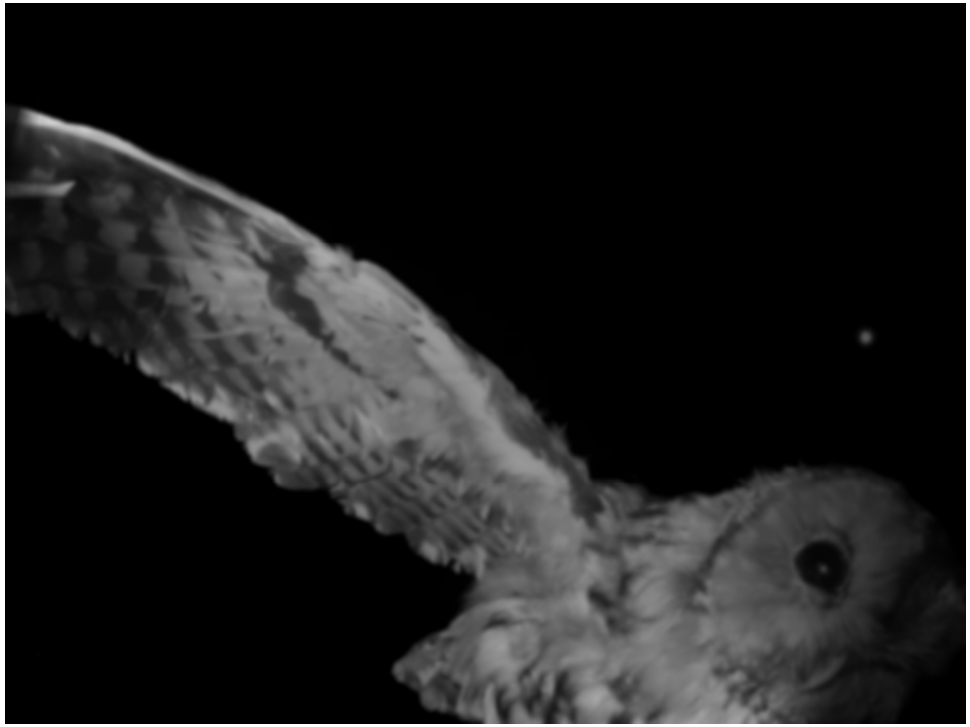
Outline

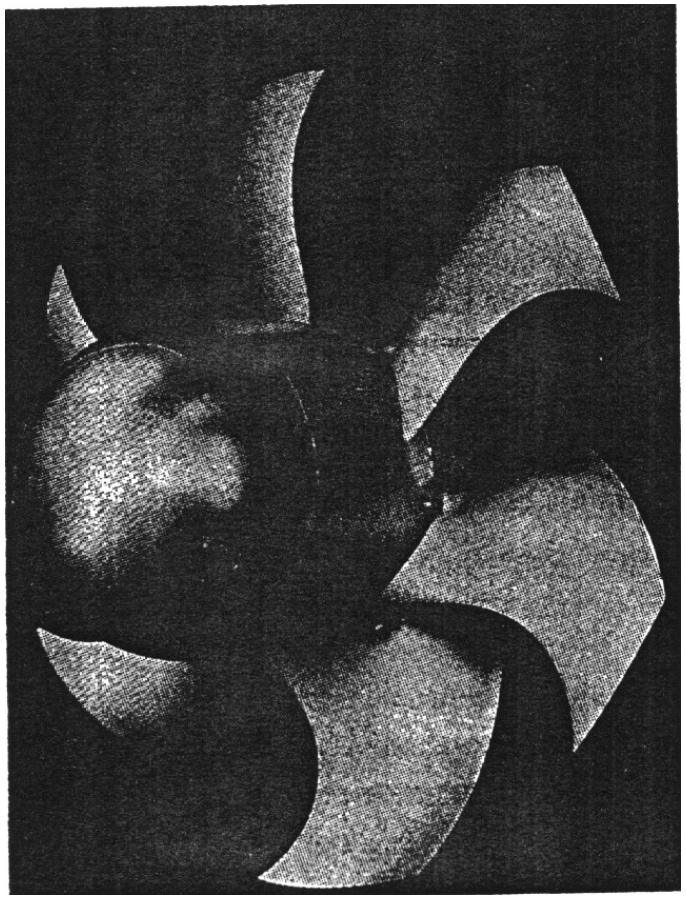
- Noise reduction of axial flow fans: an introduction
- Application of acoustically soft coating
- Airfoil of case study
- Acoustic investigation
- Wind tunnel investigation
- Summary



1. Noise reduction of axial fans: an introduction

CONSTRUCTION, GEOMETRY:

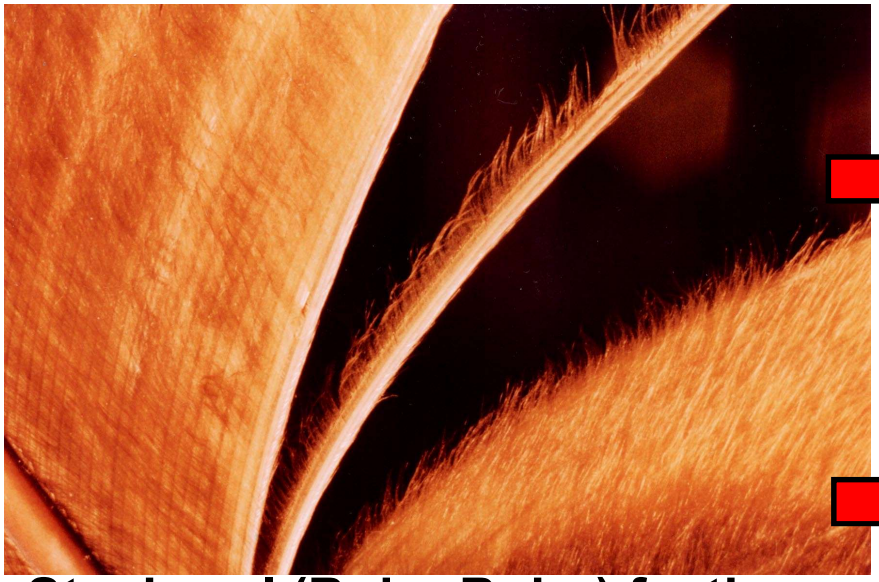
- **High efficiency**
- **High specific performance (low speed)**
- **Tip clearance reduction**
- **Sweep, skew**



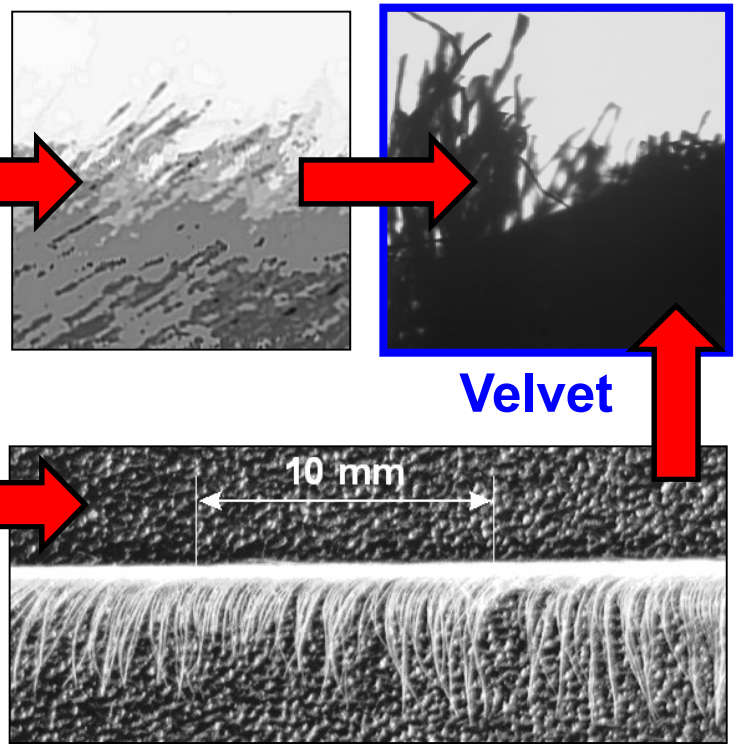
BLADE SURFACE TREATMENT

?

Night hunting birds: silent wing operation



Stock owl (Bubo Bubo) feathers near the wing leading edge

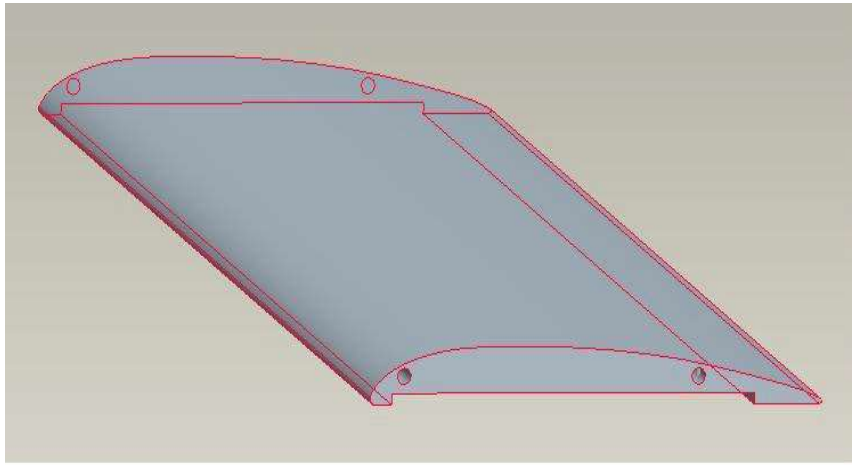


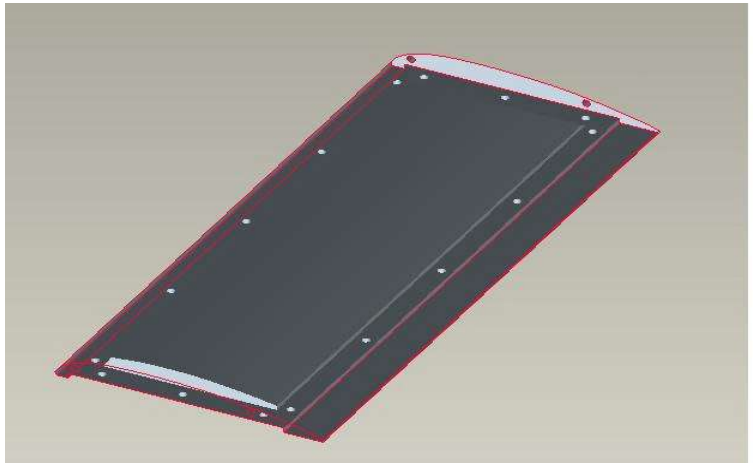
Garment trade velvet: modelling the fuzzy wing surface: filament length, number / unit area

2. Fan blades ⇔ Rectilinear isolated airfoil

RAF 6E profile

- Geometry (chord, span), lift ⇔ owl
- Re = 145 500
- Incidence: 0 deg, 5 deg (max. lift-to-drag), 15 deg (max. lift)



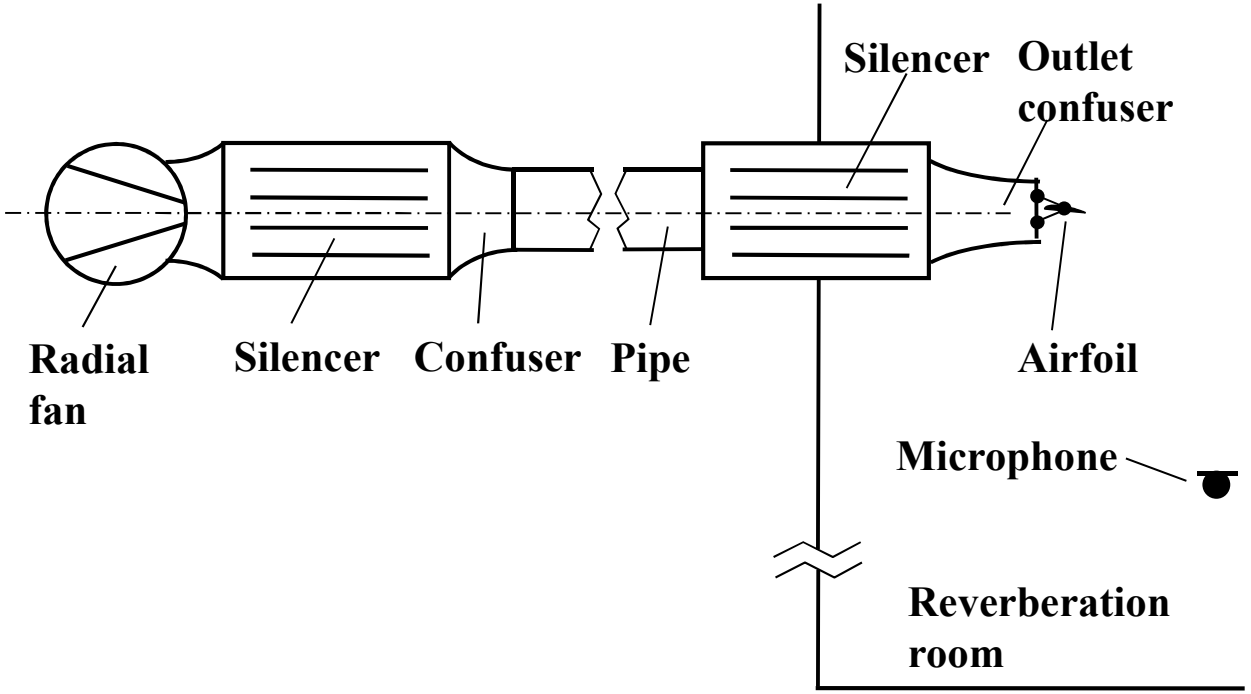


- Static pressure taps at midspan

Velvet coating:
entire surface

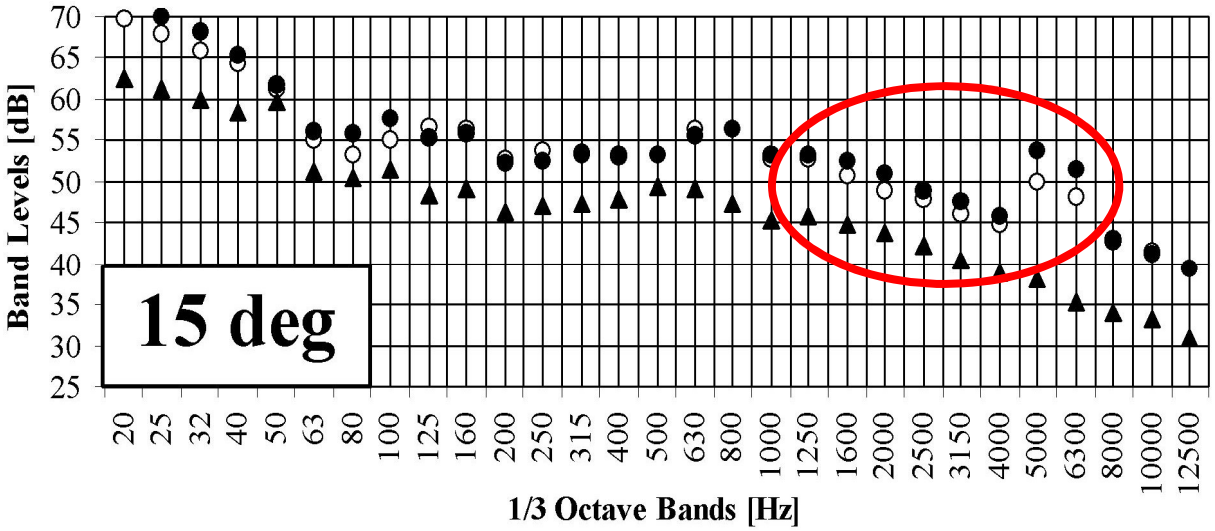
3. Acoustic studies

Low-speed fan ⇒ silencer ⇒ confuser ⇒ duct ⇒ silencer ⇒ confuser ⇒ silent free jet ⇒ airfoil ⇒ reverberation room

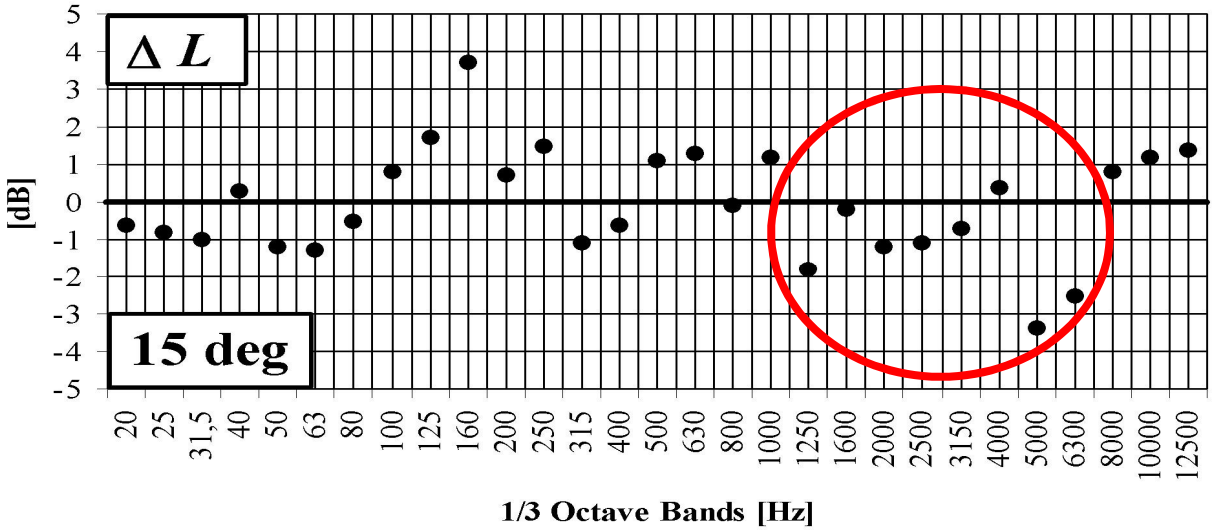


Test case	L_A [dB(A)]
Airfoil uncoated, 0 deg inc.	64.4
Airfoil coated, 0 deg inc.	63.0
Airfoil uncoated, 5 deg inc.	63.0
Airfoil coated, 5 deg inc.	62.7
Airfoil uncoated, 15 deg inc.	74.7
Airfoil coated, 15 deg inc.	73.8

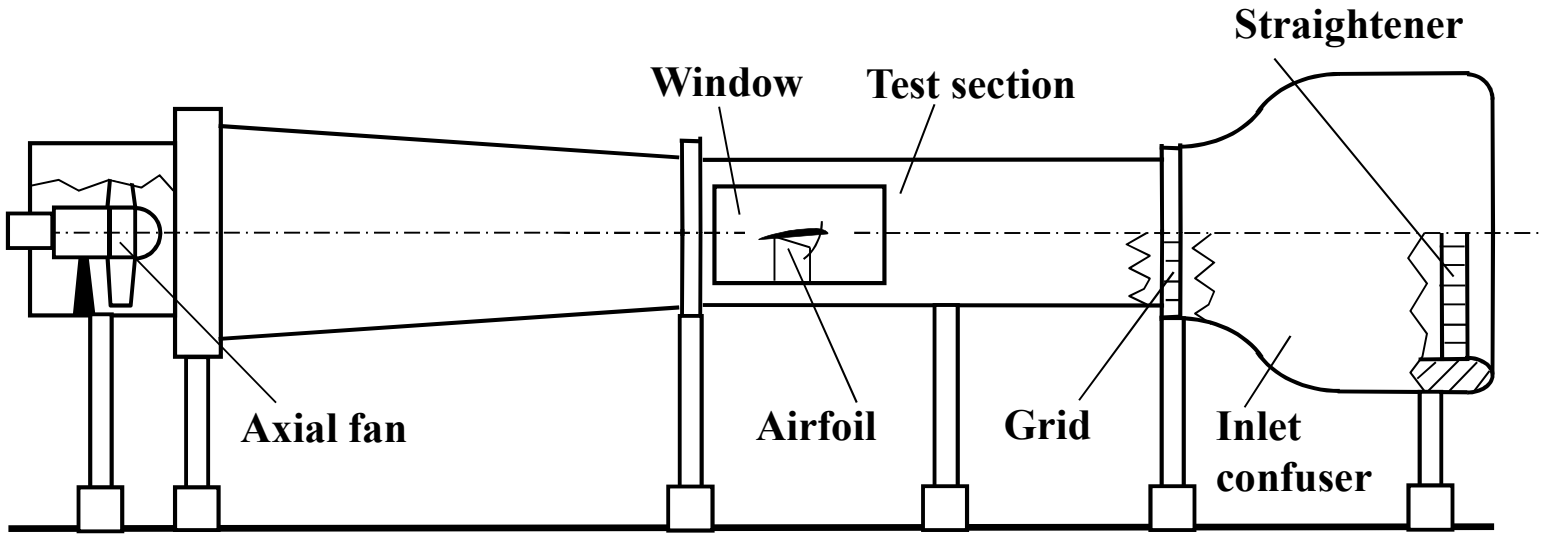
- An example: 15 deg



● uncoated ○ coated ▲ jet w/o airfoil

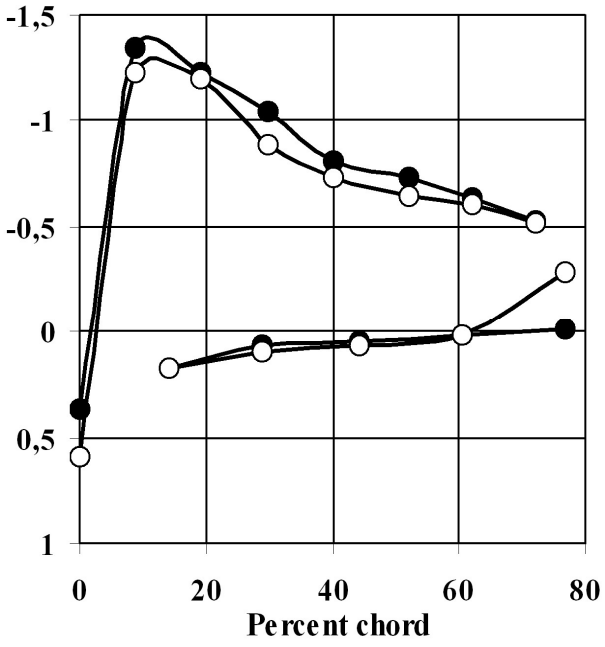


4. Wind tunnel studies

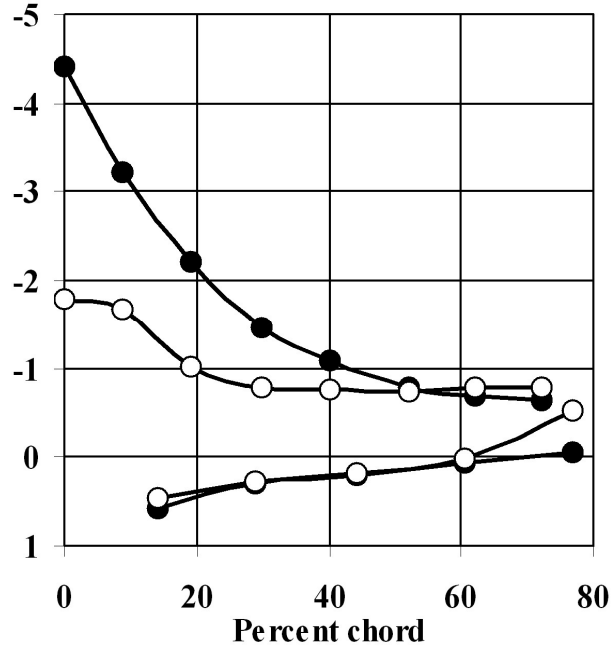


•**Surface static pressure distribution**

$$c_p = \frac{p - p_{\text{in}}}{(\rho/2)v_{\text{in}}^2}$$



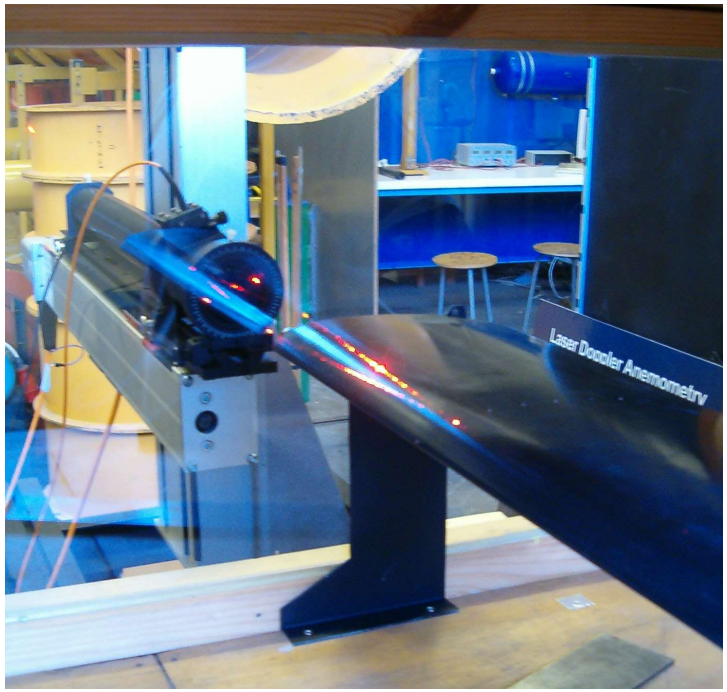
5 deg incidence

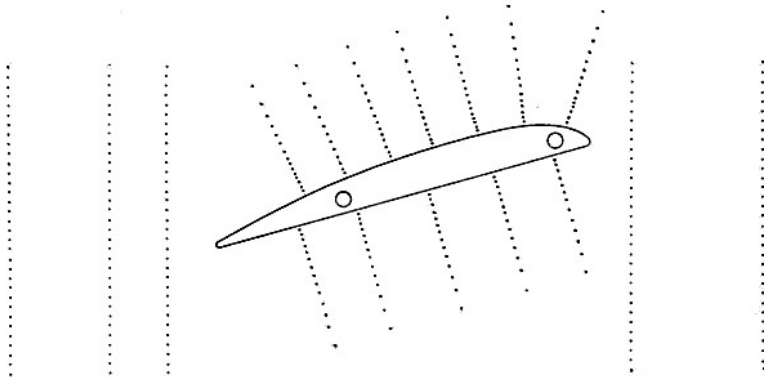


15 deg incidence

● **uncoated** ○ **coated**

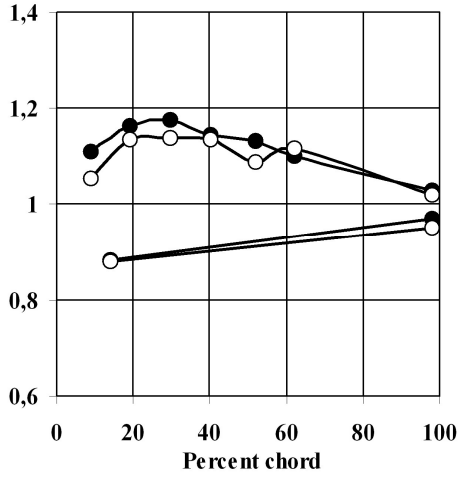
Laser Doppler anemometer measurements



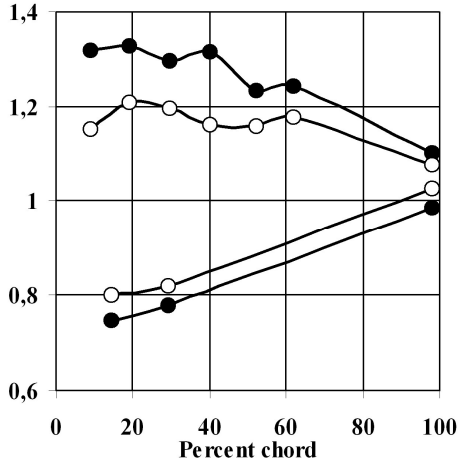


•v_b/v_{in}

5 deg inc.

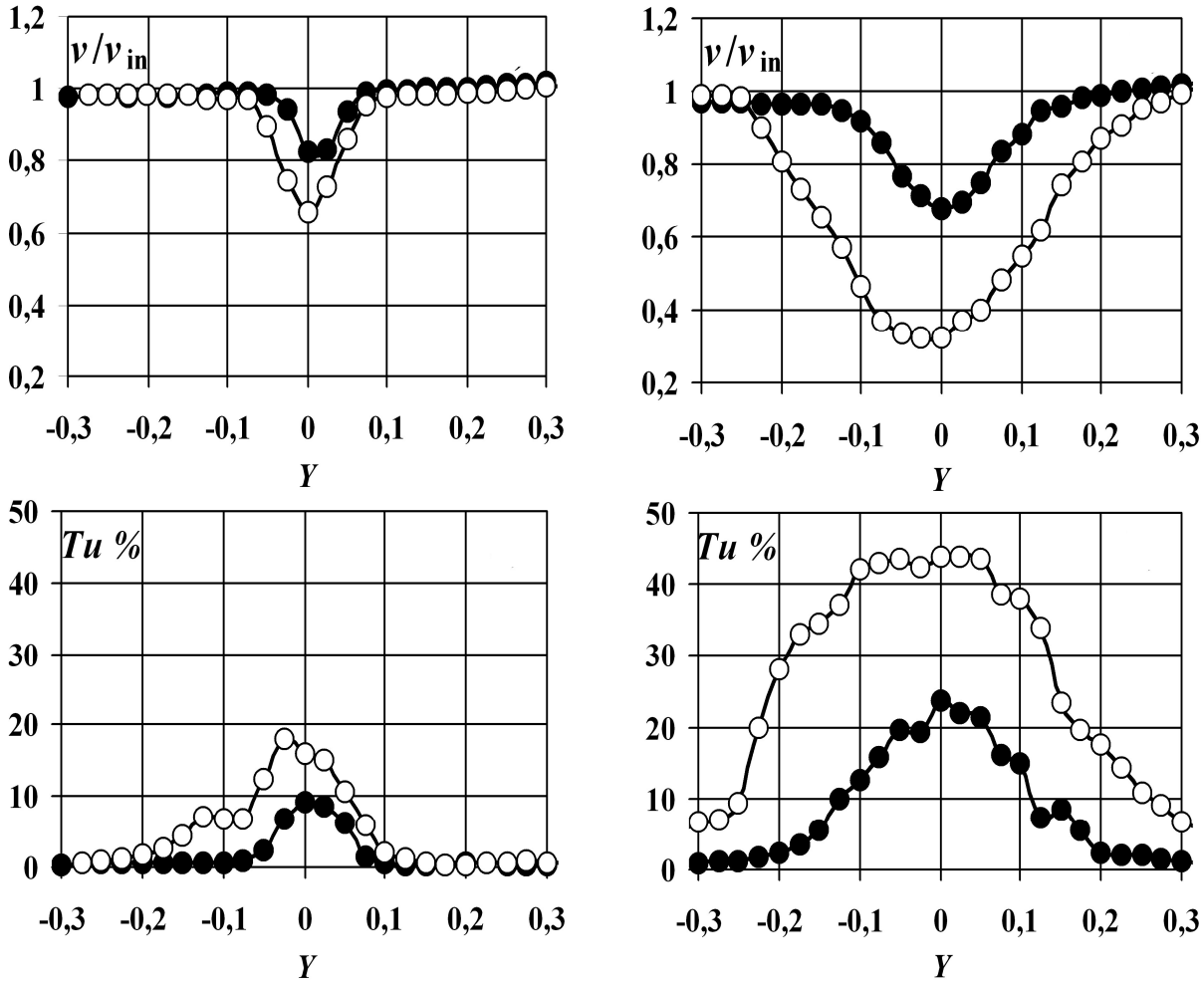


15 deg inc.



● uncoated ○ coated

•Wake data



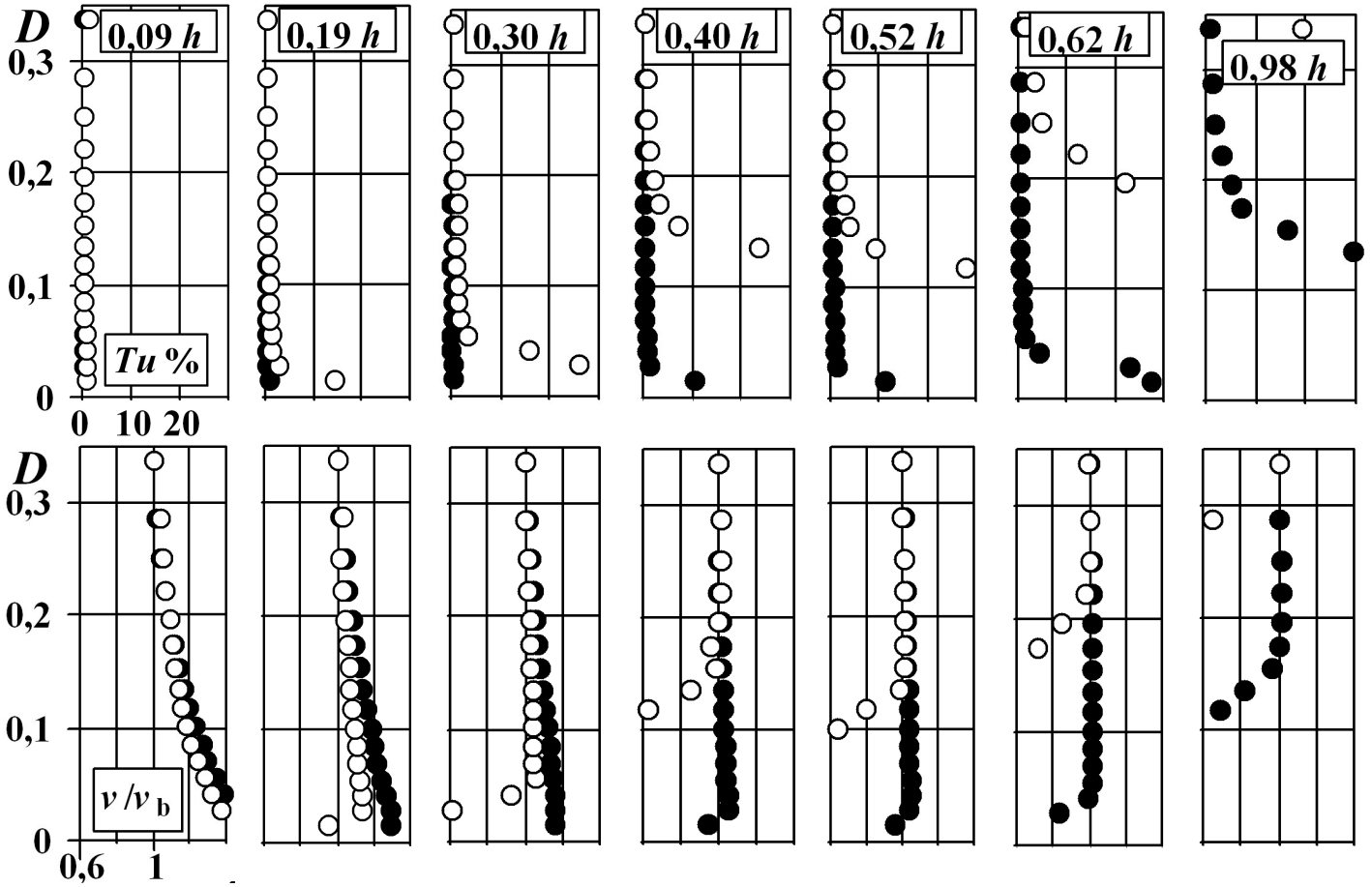
5 deg incidence

15 deg incidence

● uncoated ○ coated

•An example: development of suction side boundary layer:

15 deg incidence



•**Lift and drag coefficient**

Test case	c_L	c_D
5 deg incidence, uncoated	0.75	0.03
5 deg incidence, coated	0.65	0.08
15 deg incidence, uncoated	1.45	0.12
15 deg incidence, coated	0.85	0.61

5. Summary

1/ Acoustically soft coating:

- Reduction of noise: ≈ 1000 to 5000 Hz – human audibility
- Reduction of lift, increase of drag ⇔ boundary layers, wake

2/ Possible causes for noise reduction:

- Reduction of inlet turbulence effects ?
- Reduction of boundary layer noise ⇔ increased turbulence ?
- Reduction of wake noise ⇔ wake characteristics ?

3/ Further steps:

- Detailed turbulence studies
- Tests on partial coating: benefits in acoustics and aerodynamics