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

J. Vad –

G. Koscsó – M. Gutermuth – Zs. Kasza – T. Tábi

Department of Fluid Mechanics

Budapest University of Technology and Economics

T. Csörgő

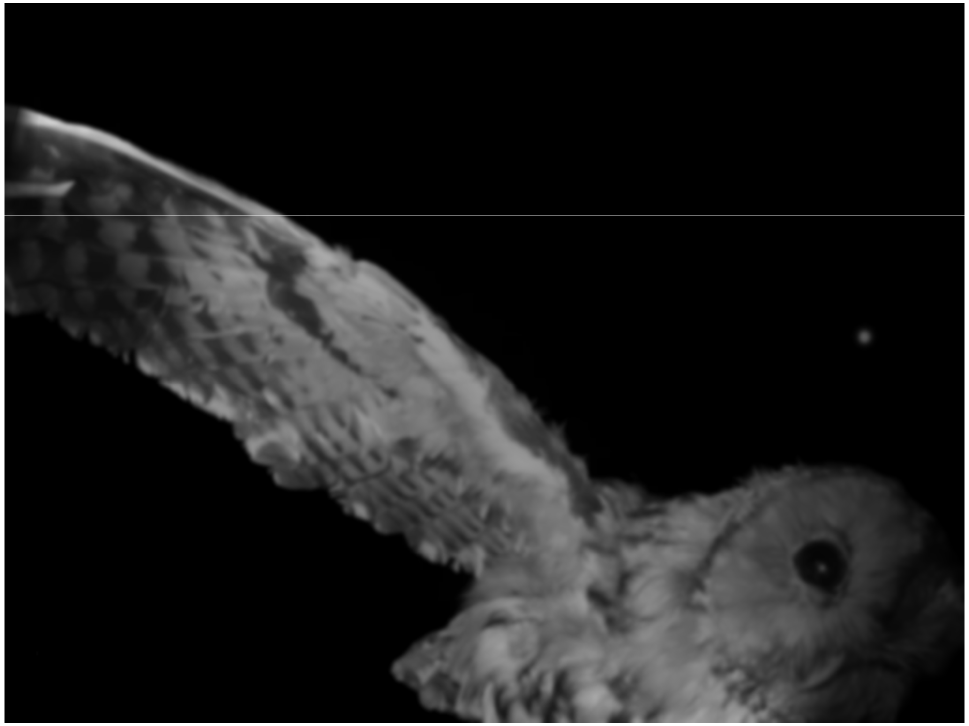
Department of General Zoology

Eötvös Loránd University of Science

The First International Symposium on
Advanced Technology of Vibration and Sound
Hiroshima, Japan, 2005

Outline

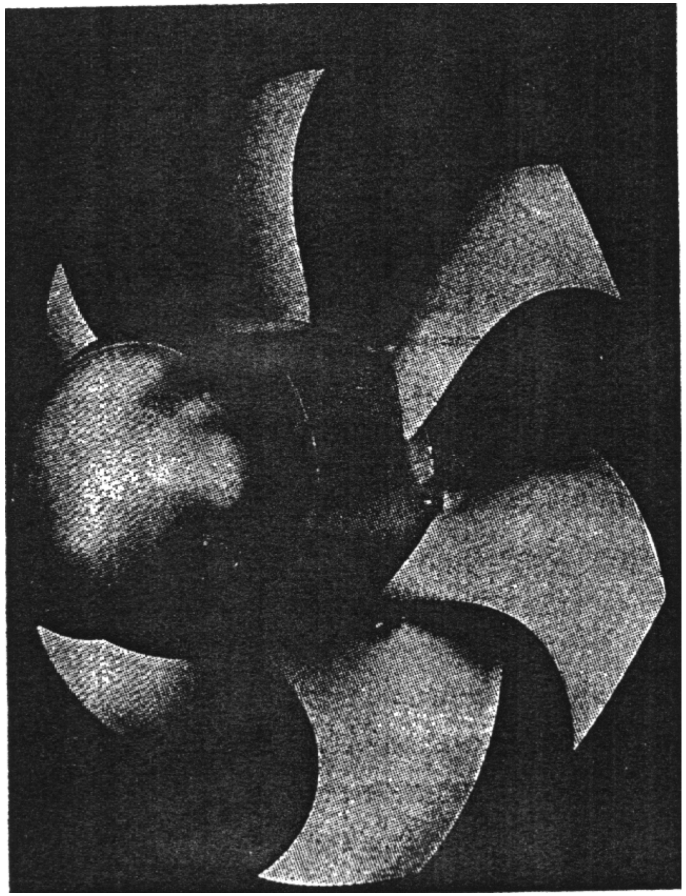
- Noise reduction of axial flow fans: an introduction
- Application of acoustically soft coating
- Airfoil of case study
- Acoustic investigation
- Wind tunnel investigation
- Summary



1. Noise reduction of axial fans: an introduction

CONSTRUCTION, GEOMETRY:

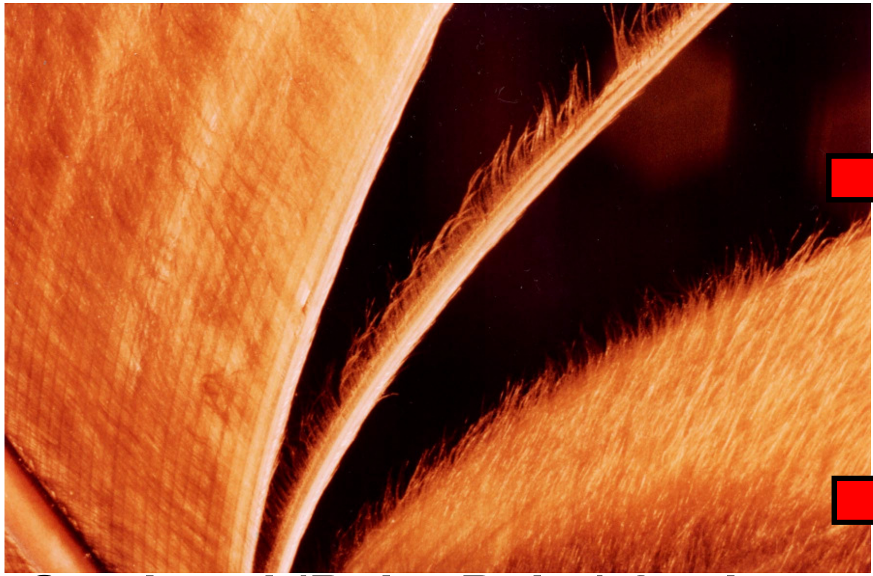
- **High efficiency**
- **High specific performance (low speed)**
- **Tip clearance reduction**
- **Sweep, skew**



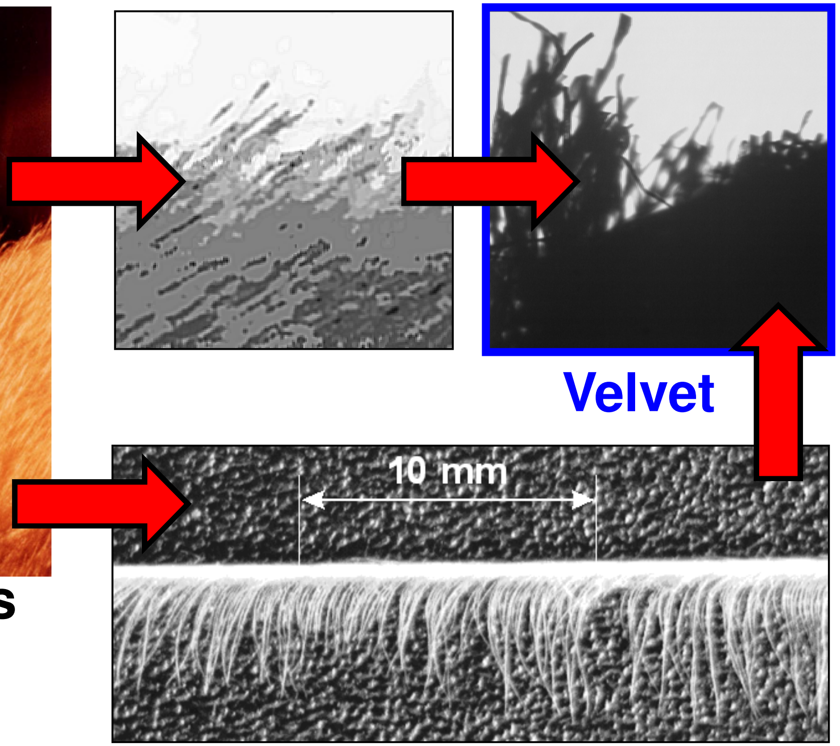
BLADE SURFACE TREATMENT

?

Night hunting birds: silent wing operation

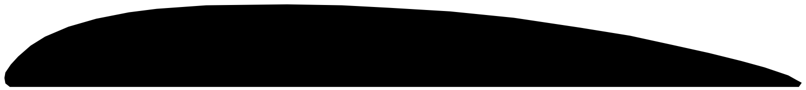


Stock owl (Bubo Bubo) feathers
near the wing leading edge



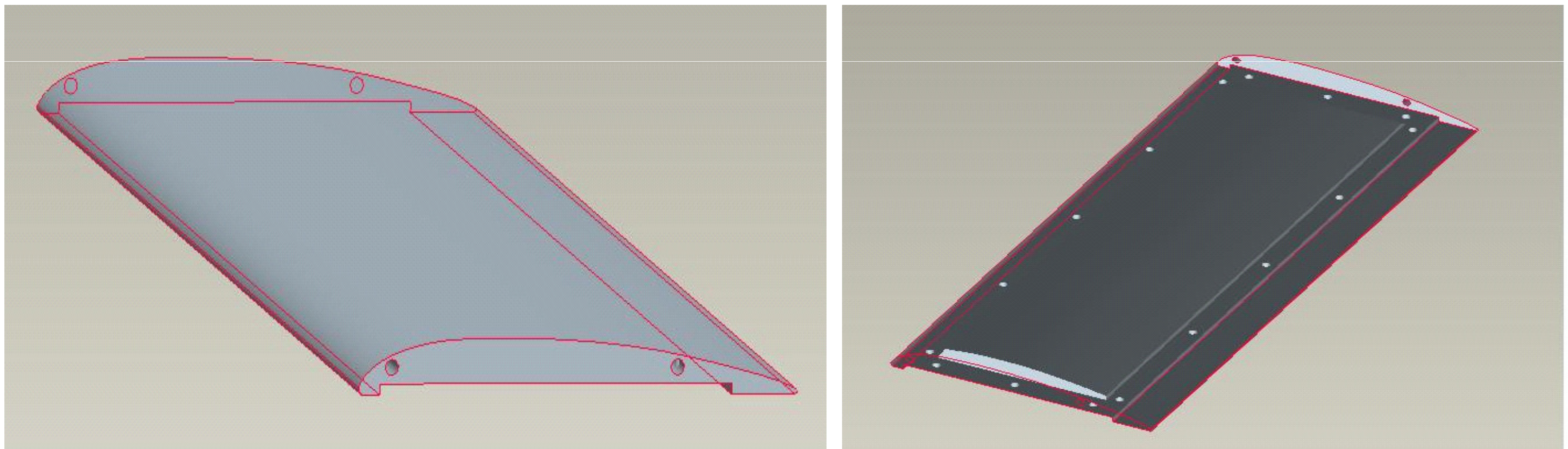
Garment trade velvet: modelling the fuzzy wing surface:
filament length, number / unit area

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)

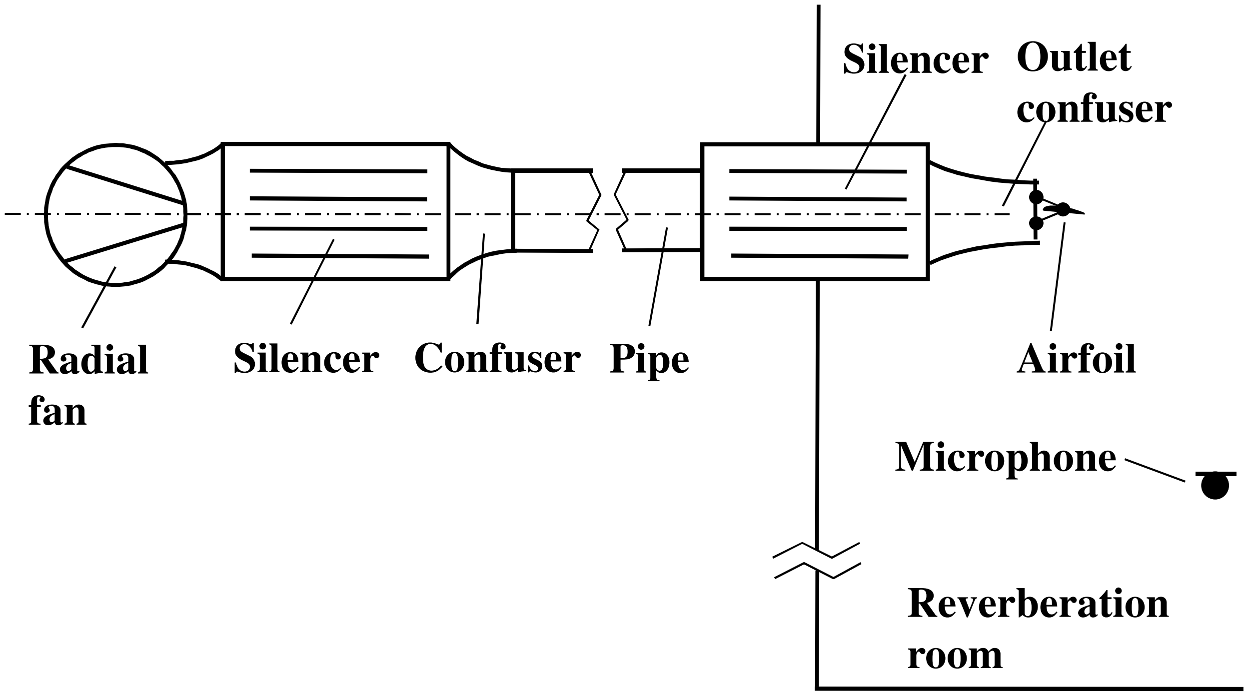


- Static pressure taps at midspan

Velvet coating:
entire surface

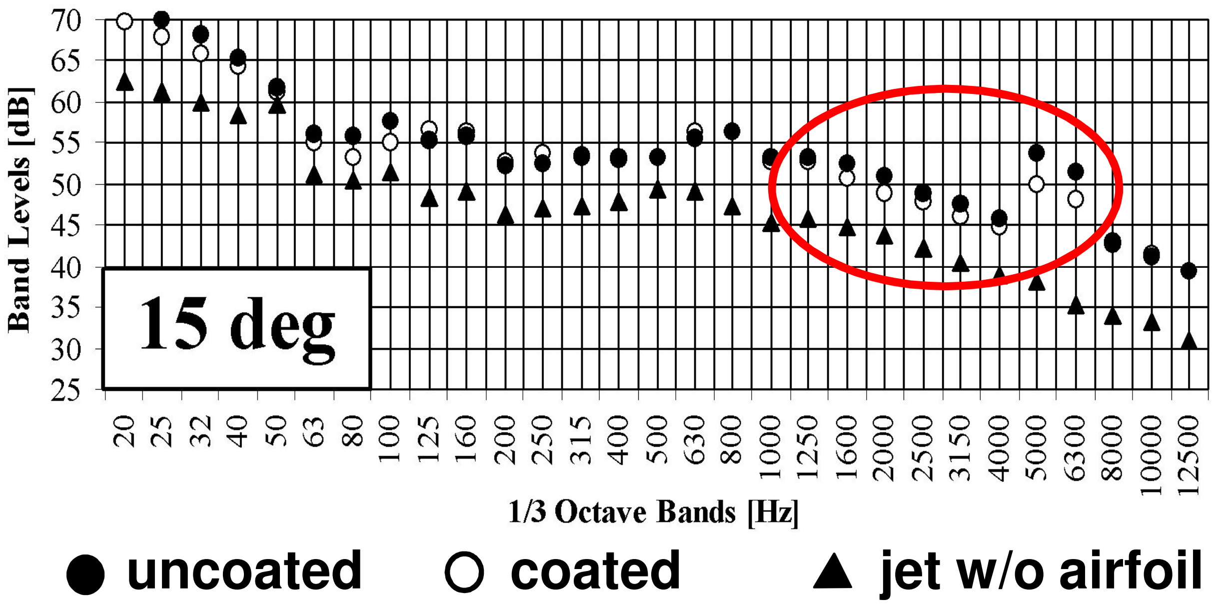
3. Acoustic studies

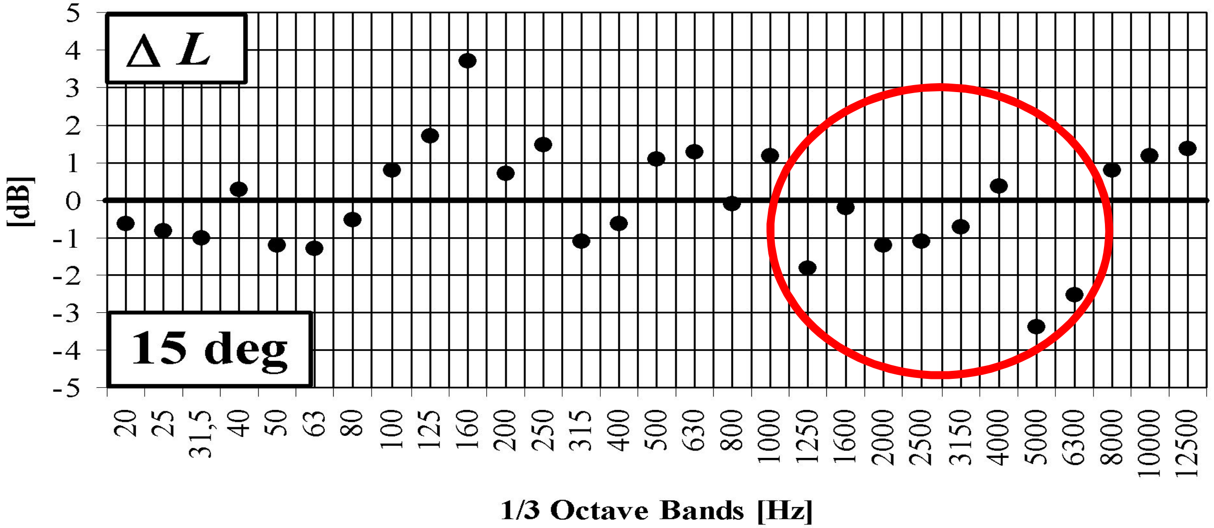
Low-speed fan ⇒ silencer ⇒ confuser ⇒ duct ⇒ silencer ⇒ confuser ⇒ silent free jet ⇒ airfoil ⇒ reverberation room



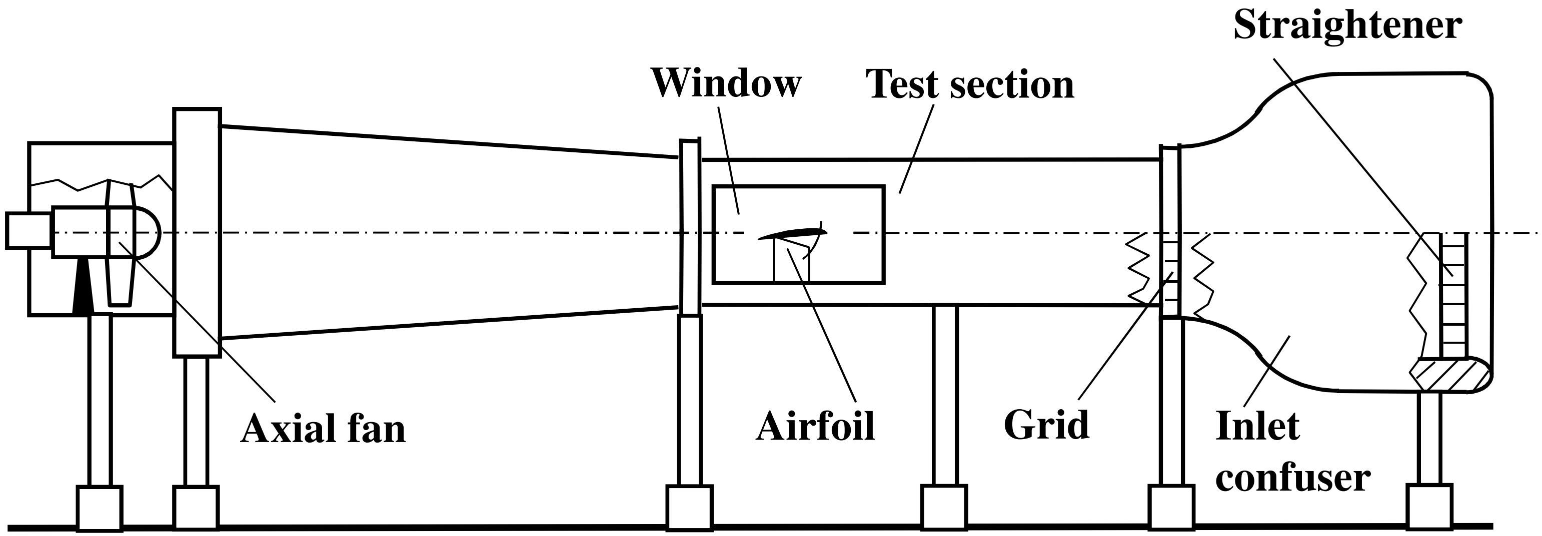
Test case	L_A [dB(A)]
Airfoil uncoated, 0 deg inc.	64.4
Airfoil coated, 0 deg inc.	63.0
Airfoil uncoated, 5 deg inc.	63.0
Airfoil coated, 5 deg inc.	62.7
Airfoil uncoated, 15 deg inc.	74.7
Airfoil coated, 15 deg inc.	73.8

- **An example: 15 deg**


70
65
60
55
50
45
40
35
30
25
Band Levels [dB]
15 deg
20 25 32 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500
1/3 Octave Bands [Hz]
uncoated
coated
jet w/o airfoil

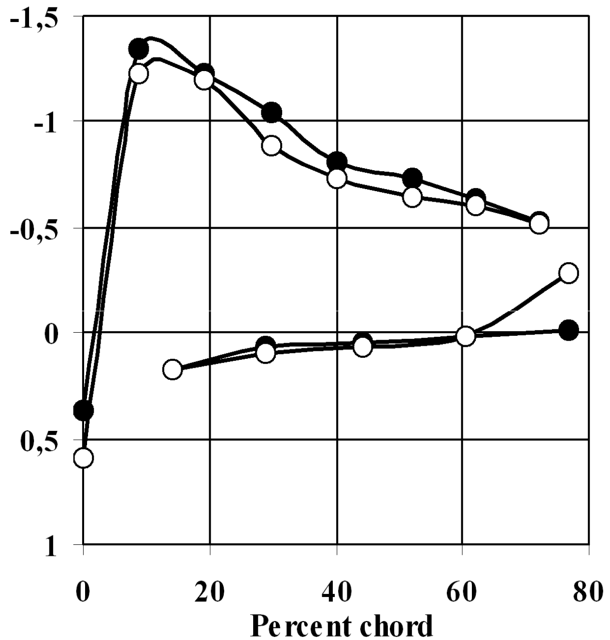

5
4
3
2
1
0
-1
-2
-3
-4
-5
[dB]
Δ L
15 deg
20 25 31,5 40 50 63 80 100 125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000 6300 8000 10000 12500
1/3 Octave Bands [Hz]

4. Wind tunnel studies

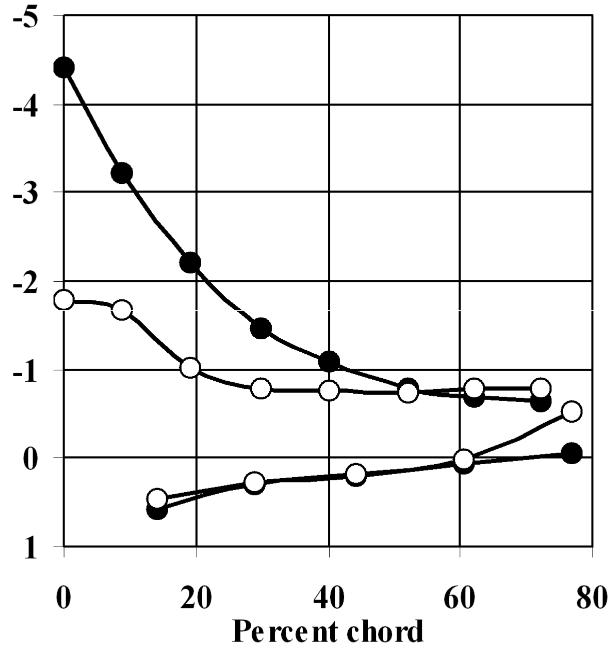


•**Surface static pressure distribution**

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



5 deg incidence

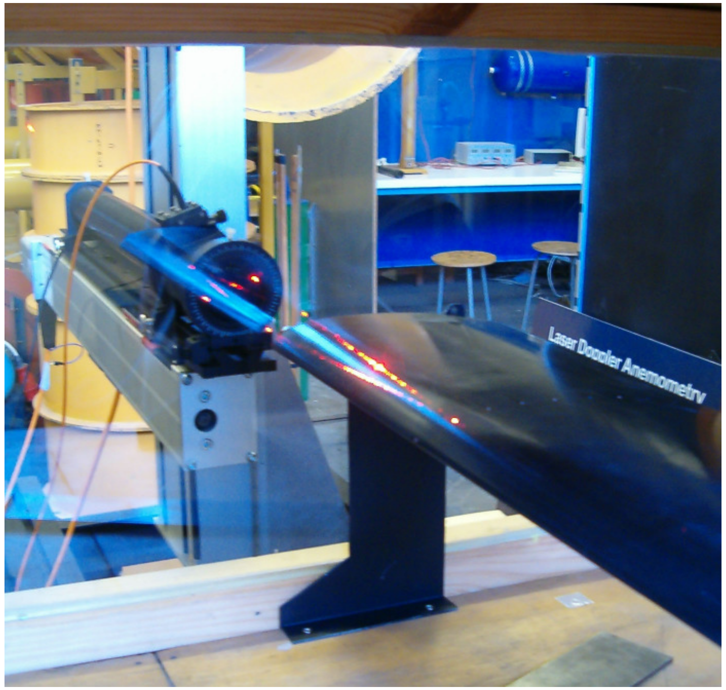


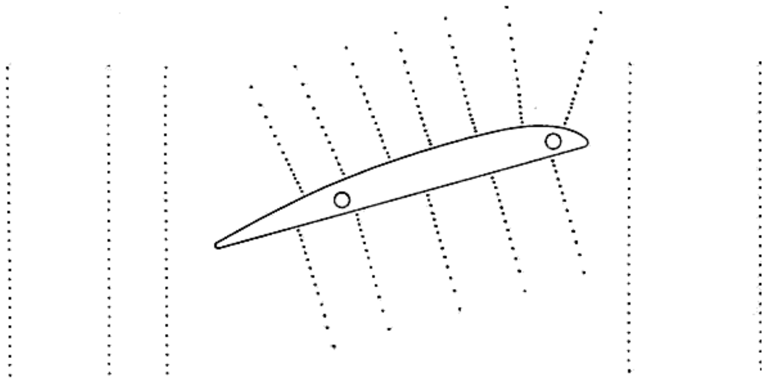
15 deg incidence

● **uncoated** ○ **coated**

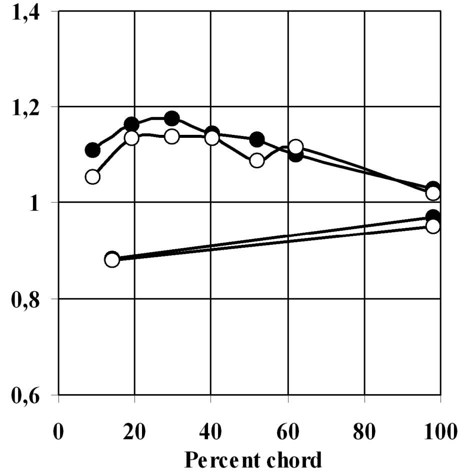
Laser Doppler anemometer measurements

• v_b / v_{in}

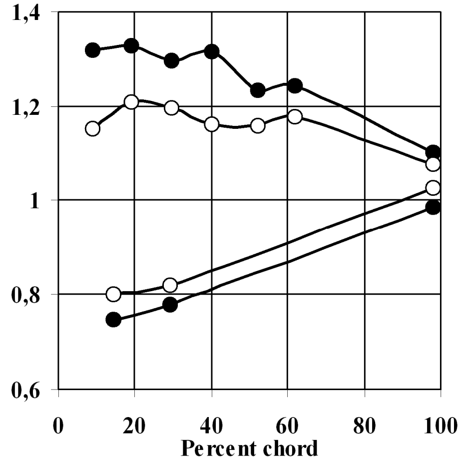




5 deg inc.

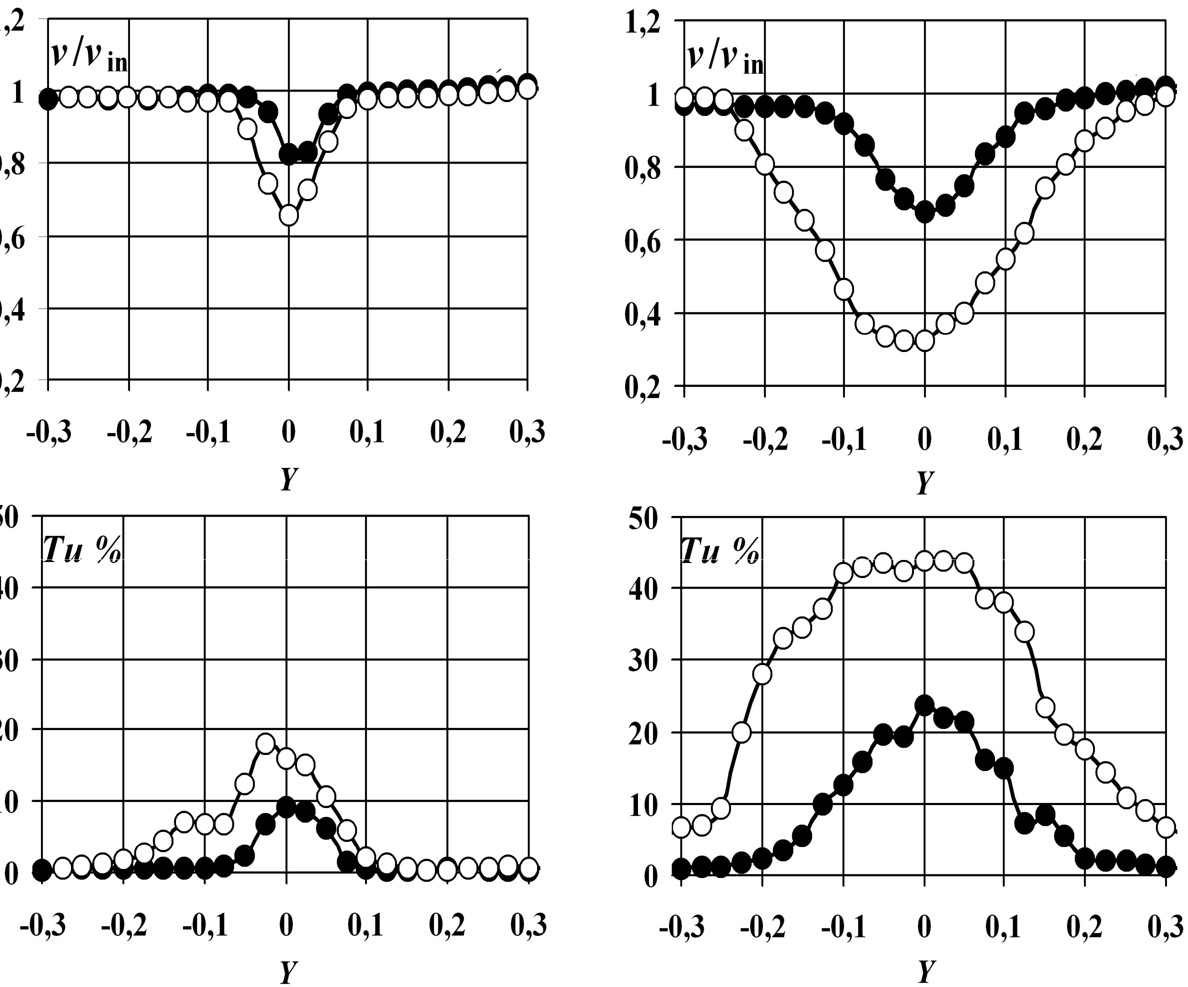


15 deg inc.



● uncoated ○ coated

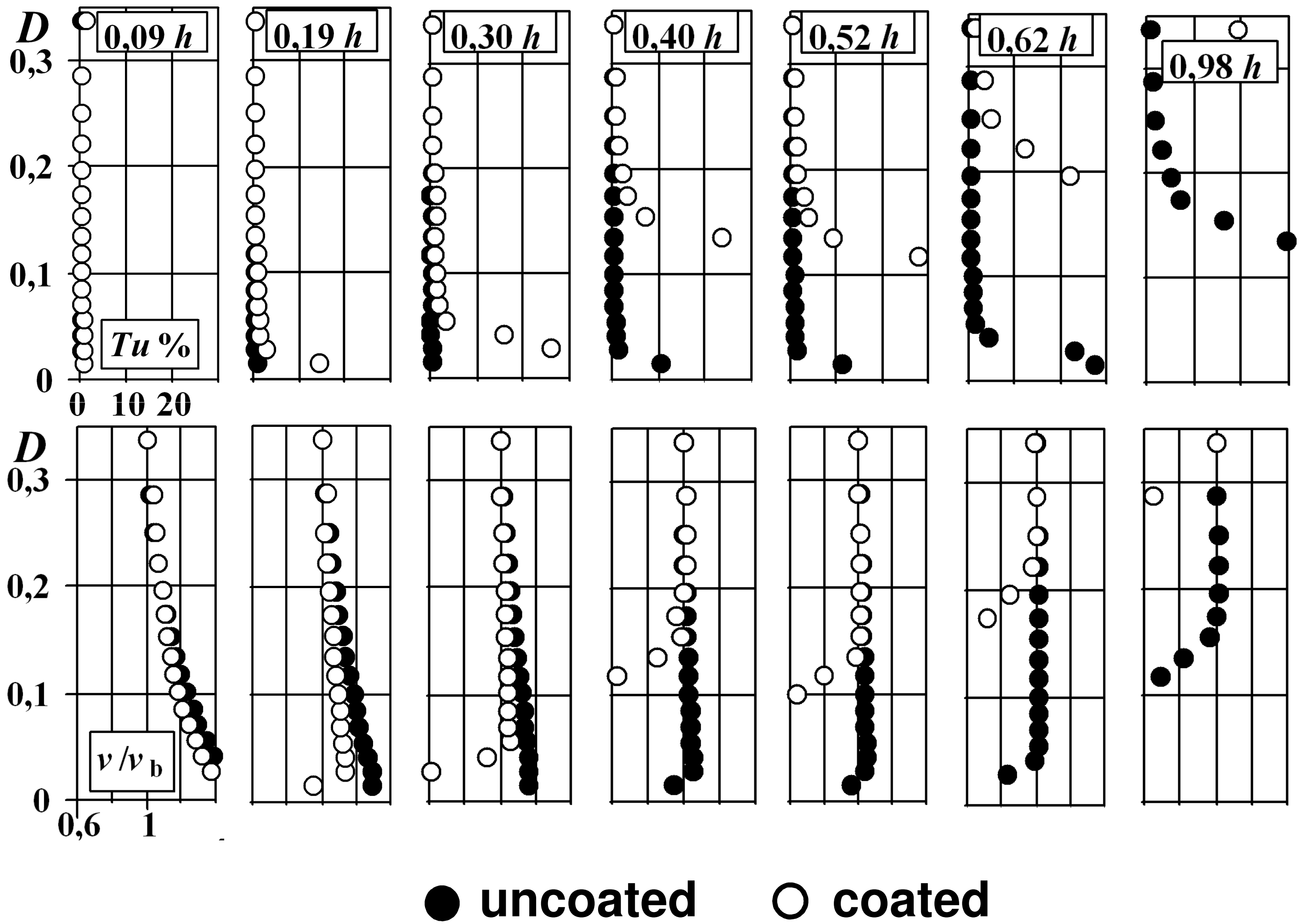
•**Wake data**



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