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# Flaps for wind turbine applications: Results of an acoustic study

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## ABSTRACT


- Trailing edge flaps → high potential as dynamic load reduction system for wind turbines
- Experimental set-up to study flap acoustics
- Results:
  - (1) Flaps are a significant sound source
  - (2) Correlations: flap deflection, angle of attack
  - (3) Side edge noise only in high frequency band
  - → Acoustic recommendation for flap applications


## INTRODUCTION

- Unsteady wind conditions (e.g. gusts)
  → short-term: high blade loads
  → long-term: potential blade failure
- Dealing with highly dynamic loads → major challenge
- Common pitch system too inertial
  → new load reduction concept necessary
- New concepts: negative impacts must be considered
- Wind industry: turbine noise main problem

## FLAP CONCEPT

- Load reduction concept: plain flap at the trailing edge

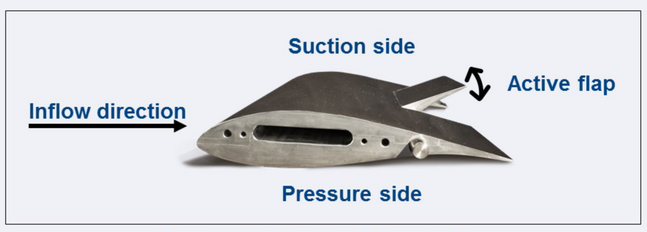



Fig. 1: Airfoil with active trailing edge flap

- Flap towards suction / pressure side → flow less / more deflected → de- / increase lift [1]
- Flaps at wings → known as significant noise source [2]

**Flaps for wind turbines: acoustic study necessary**

## OBJECTIVES

Provide plain flap acoustics:

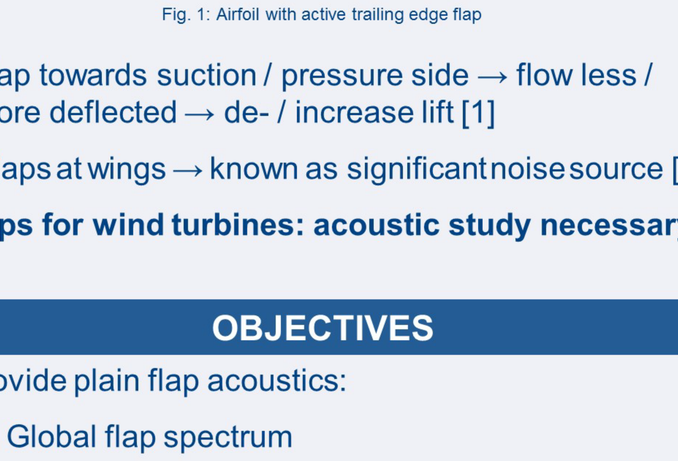
(1) Global flap spectrum

(2) Contribution of side edge noise

## APPROACH: EXPERIMENTAL SET-UP

(1) Test airfoil with active flap (c.f. Fig. 1):

(2) Set-up in acoustic wind tunnel:




1. Test airfoil, 2. Microphone array, 3. Anechoic chamber

Fig. 2: Test section at the German Aerospace Center, Brunswick

Tab. 1: Flow data in the experiment

| | |
|---|---|
| Reynolds number | $1.4 \cdot 10^6$ |
| Mach number | 0.17 |
| Turbulence intensity | 0.3 % |

## APPROACH: ACOUSTIC METHOD

- Record noise emission with microphone array
- Convert from time domain into frequency domain
  → Global flap noise spectrum
- Locate sound source at airfoil with beamforming method (delay-and-sum algorithm) [3, 4]
- Identify sources at side edge
  → Side edge noise spectrum

## RESULTS: FLAP SPECTRA

### Global acoustics of airfoil

→ Flap noise limited to high frequency band

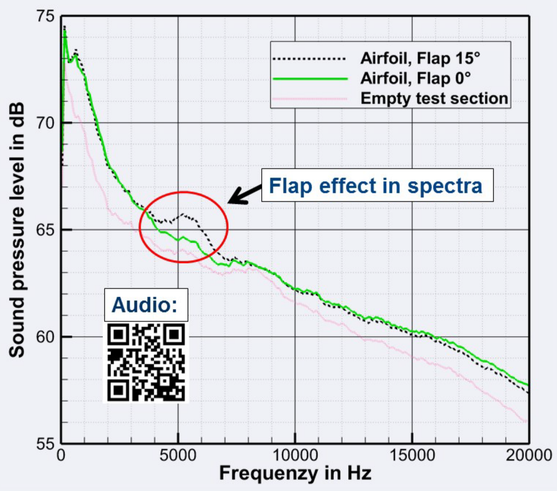



Fig. 3: Global airfoil spectrum (Angle of attack 6° )

### Noise correlation with flap angle

→ Higher flap angle, higher flap noise and broader flap noise

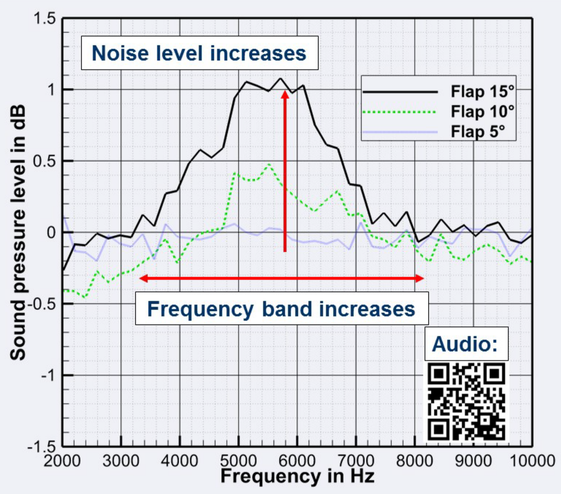



Fig. 4: Flap spectrum and flap deflection (Angle of attack 6° )

### Noise correlation with angle of attack

→ Higher angle of attack, lower flap noise and smaller lower-limit of frequency band

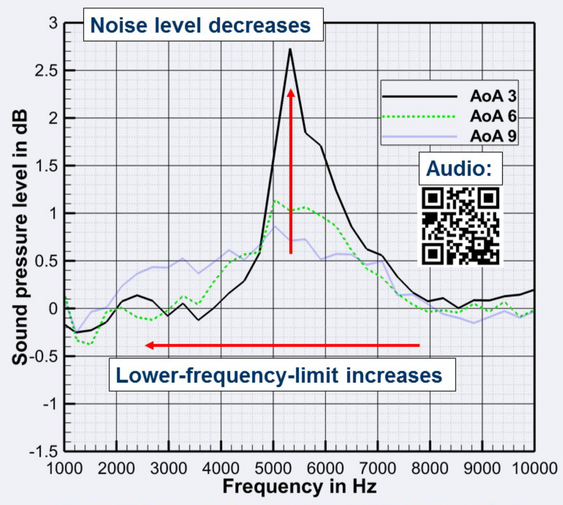



Fig. 5: Flap spectrum and angle of attack (Flap angle 15° )

## RESULTS: FLAP SPECTRA

### Noise correlation with flap deflection side

Suction side → Narrow-band noise
Pressure side → Broad-band noise

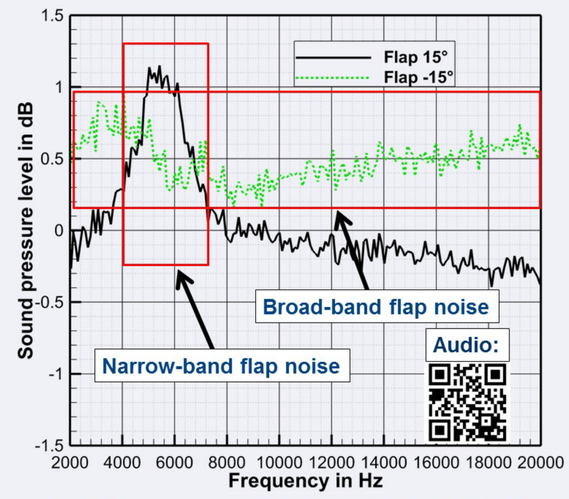



Fig. 6: Flap spectrum and deflection side (Angle of attack 6° )

### Noise correlation with side edge noise

Comparing to global flap spectra → Side edge noise contributes to flap spectra in high frequency range

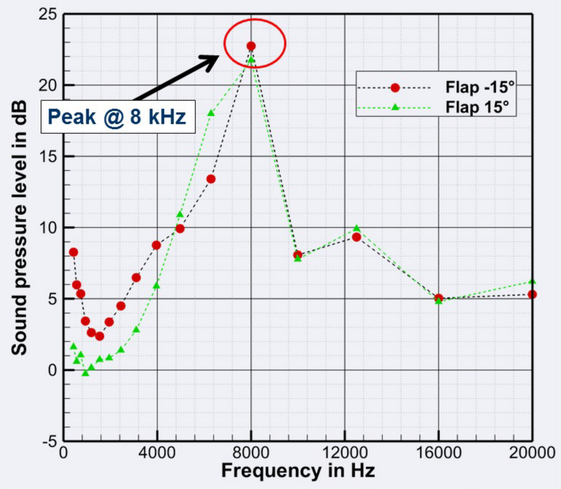



Fig. 7: Side edge noise spectrum (Angle of attack 6° )

## CONCLUSIONS

- Flaps are a significant sound source
- Acoustic recommendation for flap applications:
  - (1) Deflection angle as low as possible
  - (2) Prefer flap deflection towards suction side
  - (3) Flap deflection at high angles of attack

## OUTLOOK

Aerodynamic studies for details about noise generation mechanisms at plain flap

## REFERENCES


[1] Wolff, T.; Ernst, B.; Seume, J.R. (2014): Aerodynamic Behavior of an Airfoil with Morphing Trailing Edge for Wind Turbine Applications, The Science of Making Torque from Wind 2014, 18-20 June 2014, Copenhagen, Denmark

[2] Fink and Schlinker, 1980. "Airframe noise component interaction studies". J. Aircraft, 17, pp. 99–105

[3] Johnson, D., 1993. Array signal processing : concepts and techniques. Upper Saddle River, NJ.

[4] Brand, C.R.; Seume, J.R. (2014): Flaps for Wind Turbine Applications: First Results of the Experimental Investigations, Wind Turbine Sound 2014 - EWEA Technology Workshop, Malmö, Schweden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