Flaps for wind turbine applications: Results of an acoustic study

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Introduction

Wind speed varies substantially over time, with gusts and the atmospheric shear layer generating unsteady wind conditions detrimental to wind turbine operation. The unsteady wind conditions lead to highly dynamic loads on the wind turbine blades. High loads cause short and long-term rotor failures which may result in a reduced operation time and a non-reparable failure of the entire turbine. Hence, dynamic load reduction concepts become necessary, especially as the critical forces at the blade root will grow significantly the rotor diameter increases.

Trailing edge flaps at the rotor have been proven to be an effective load reduction concept [7, 4]. The flaps are similar to the flaps used on aircrafts. There, the flaps are employed to increase the lift during take-off and landing. However, the flaps lead to a significantly higher global sound emission along the wing [3]. Investigations of the flap flow have shown a highly turbulent flow around the side edges of the flap which interacts with the flap surface. The interaction creates a sound source, emitting noise in the low and high frequency range [6, 2, 5].

Consequently, these sound sources can also emerge when using flaps for wind turbine rotors, in addition to well known wind turbine noise sources such as the trailing edge noise [6]. Higher noise emissions will adversely affect the residents who live close to the wind turbines. Since the power of the noise is the key driver for their acceptability, further social conflicts may occur. However, the results of flap acoustics for aircraft wings cannot be directly copied across to wind turbines flaps. Aircraft flaps are placed downstream of the main wing, such that the turbulent structures which produce noise develop freely without any interferences. In contrast, wind turbine flaps are integrated into the main rotor. The flap surroundings may reduce the turbulent structure's development, leading to less noise emission.

Approach

The flap acoustics for wind turbine applications were experimentally investigated in the frame of the joint project Smart Blades. The experimental investigations were performed in an acoustic wind tunnel of the German Aerospace Center (s. fig. 1).

A test airfoil with an active trailing edge flap was placed in the test section. The study of the acoustic flap properties was performed by using two different acoustic measurement techniques. One method recorded the global noise emission of the test airfoil using free-field microphones placed at different positions in the test section while, the presumed sound sources at the flap were localized with a microphone array and beamforming algorithm. With the second method, the main source positions and frequency range were identified in the flap area. The microphone array was focused on the flap's pressure and suction side in order to identify the main emission side.

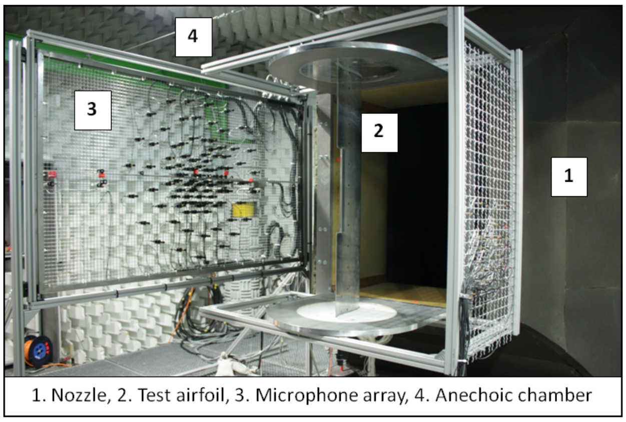

Figure 1: Test section - German Aerospace Center [1]

Results

The results of the experimental investigation will be shown in the presentation. First, the global noise spectrum and related acoustic maps will be presented for selected operating points. For example, the global noise spectrum for the operating point at Reynolds number $Re = 1.4 \cdot 10^6$, an angle of attack $\alpha = 6°$, and with a focus on airfoils suction side is shown in fig. 2.

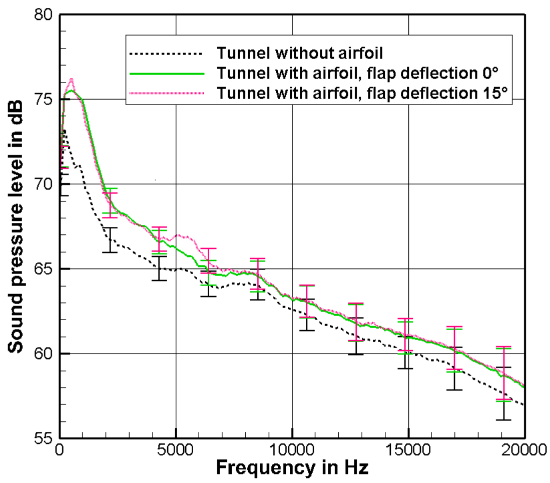

Figure 2: Overall noise spectrum in the test section

An increase in the overall sound pressure level ($\approx \Delta 1.5 dB$) becomes obvious when the condition are compared with and without the airfoil. A significant increase in the noise spectrum is identified by comparing two different deflection angles of the active flap (0° against 15°) with focus on the frequency range 4,500...7,000 Hz. The related acoustic map for the airfoil with active flap (deflection 15°) is shown in fig. 3. Two significant sound sources are visible at each flap side edge for the mid-band frequency $f = 6,300Hz$.

Secondly, the results of the flap properties will be presented, which are derived by analyzing the acoustic maps. The effect of varying the operating points (in terms of Reynolds Number, angle of attack, flap deflection) on the flap noise emission are studied (s. e.g. fig. 4). The details of these results will be shown in the presentation.

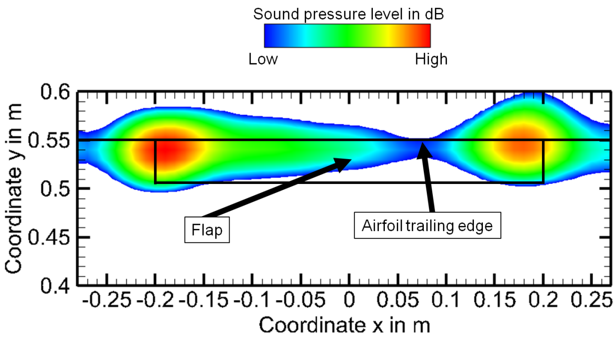

Figure 3: Acoustic map of the airfoil with the active flap (mid-band frequency $f = 63000Hz$)

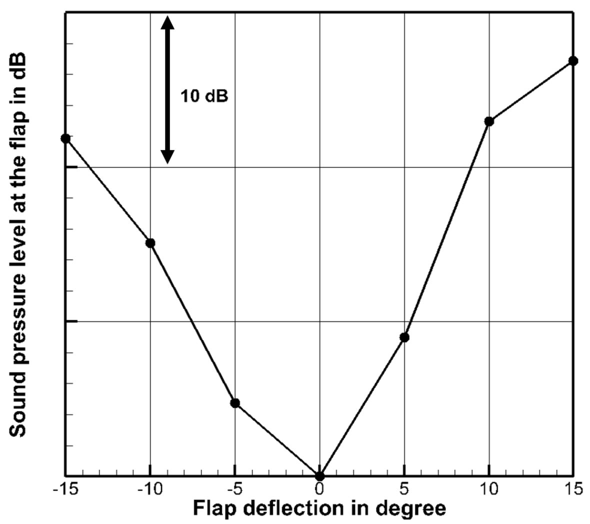

Figure 4: Acoustic properties: Varying flap deflection

Conclusions

An acoustic investigation of a flap for wind turbine applications is performed. The study proves an increase in the overall sound pressure level by increasing the flap deflection. A detailed analysis identifies major sound sources at the flap side edges. These side edge sources are also detected at the aircraft flaps. The frequency and the sound power of the side edge sources strongly depend on the operating point conditions such as Reynolds Number, angle of attack, flap deflection and focus area. However, the flap deflection turns out to have the strongest impact on the emitted noise power.

Learning objectives

The results of this experimental investigation provide an excellent data base for further acoustic studies. First, the data can be merged with aerodynamic flow data to study the fundamentals of noise generation mechanisms. Secondly, the results provide a data base for testing noise reduction systems. These tests can be performed by further experimental investigations and / or numerical simulations.

References

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