Wind turbines – could they be too noisy?

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Introduction

At the University of Applied Sciences in Düsseldorf investigations are being carried out as fundamental preparation for a research proposal on wind turbine noise effects and noise reduction methods.

In public news coverage wind turbines are still being reported upon as being a nuisance. The audible sound and low frequency pressure waves can be disturbing for residents. Scientifically based research work on that topic has been done but receives little attention in such coverage. This can be accounted for by the political brisance of the subject (change from nuclear to wind power supply) and by the fact that manufacturers do not want to be associated with noisy wind turbines.

Wind turbines and vibrations

A 350m off wind turbine is supposedly responsible for the cracks in the walls of a French house shown in Figure 1. It is possible that the vibration of the tower propagates through the ground to the point of the house, Figure 2. Often infrasound is rumored to be responsible for such damages, but normally the transported energy of infrasound is very low.

Figure 1: Cracks in a house occur in a distance of app. 350 m to wind turbines [1].

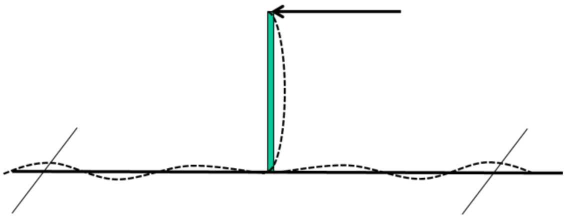

Figure 2: Tower vibration propagates along the ground.

Wind turbines and infrasound

For example Figure 3 shows an infrasound measurement attributed to having generated pain in a human being. The infrasound component was only detected with a correlation measurement technique of noise and vibrations on a pane of glass (window). The amplitudes in the coherence spectra were exactly the dimension of the pain, Figure 4. The sound pressure level is less than -20 dB(A) in the relevant frequency range of 20 Hz – an extremely low level! These results match with several measurements close to wind turbines [2],[3]. Sometimes misinterpretation of scientific work is being used to connect dangerous to health infrasound and wind turbines [4].

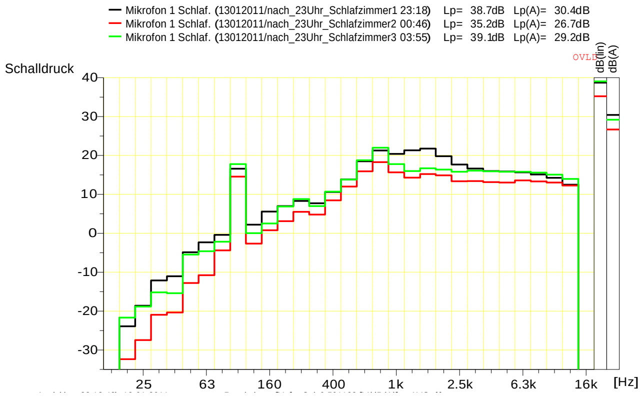

Figure 3: Example of sound pressure spectra with low frequency noise components (Here, the source mechanism is not a wind turbine!).

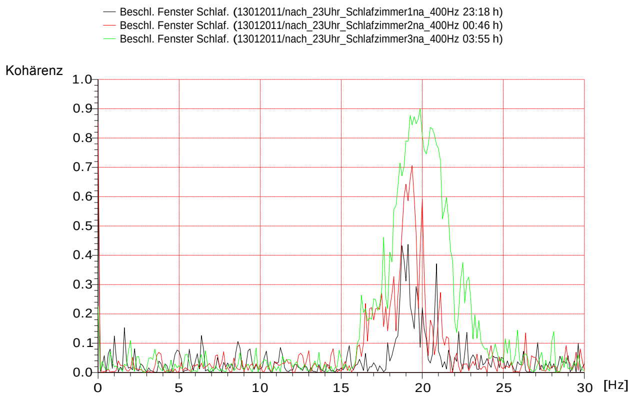

Figure 4: Coherence spectra of sound pressure and acceleration on the window pane show a relation to noise (Here, the source mechanism is not a wind turbine!).

Measured wind turbine noise

A real noise measurement of a wind turbine is shown in Figure 5. Low frequency pressure fluctuations occur below 25 Hz in a non optimised operations condition at this 2 MW site (left). Responsible for this low frequency noise could be the atmospheric layer which generates different inflow conditions for the turbine blade in top and bottom positions, Figure 6.

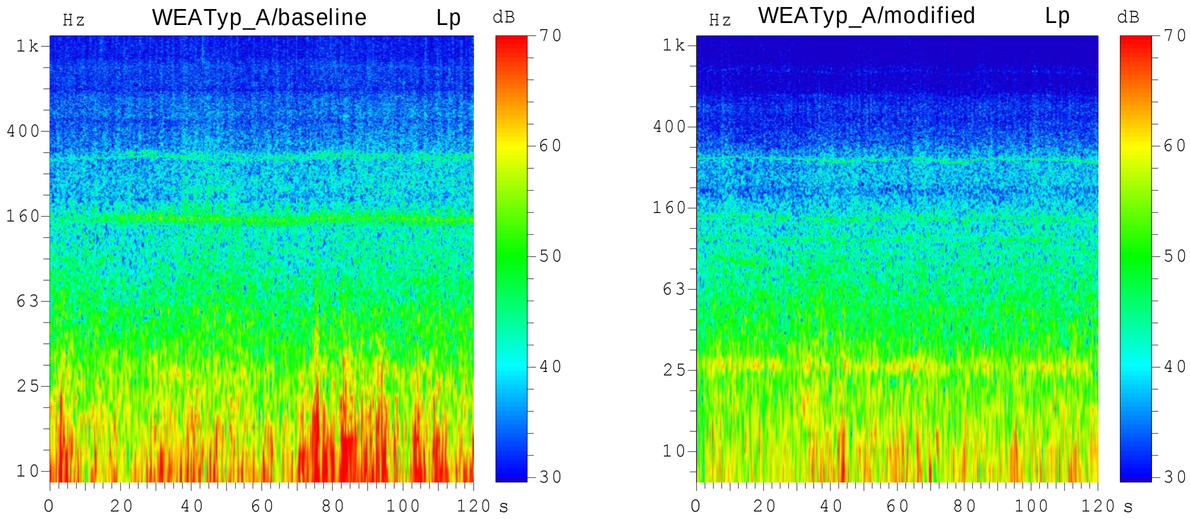

Figure 5: Sound pressure measurement of a 2MW wind turbine, noise occurs at app. 155 Hz and 310 Hz.

Atmospheric wind profile and CFD calculations

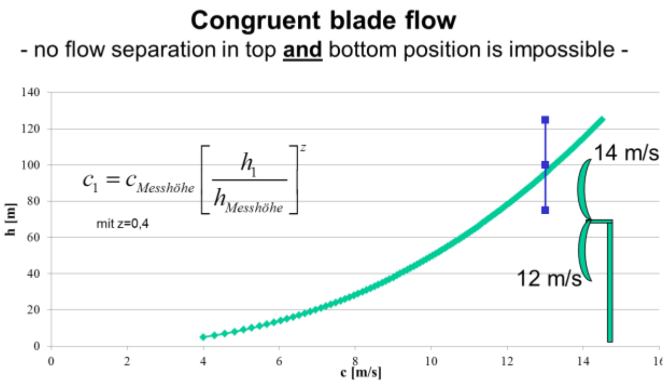

Figure 6: Atmospheric wind profile is responsible for different inflow conditions at the rotor blade at top (14m/s) or bottom positions (12 m/s).

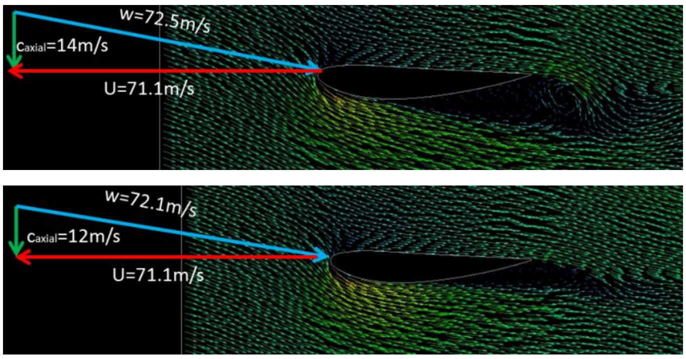

Figure 7: Inlet flow conditions on top and bottom positions of the blade generate different flow separation results, r/R=0.9, n=28 rpm.

An unsteady CFD simulation demonstrates the flow separation on the blade suction side, Figure 7. In Figure 8 and 9 the unsteady Q-criterion are calculated with a resolution of 6 kHz time steps and it shows periodical vortex separation at 48 Hz (blade top position) and 70 Hz (blade bottom position). The measured wind turbine in Figure 5 and the wind turbine of the 2-D simulation are completely different – the comparison should only show that aerodynamically caused and periodical flow separation occur according to the atmospheric profile of the wind. Exact frequency values are only predictable with 3-D CFD calculations [5]. The flow separation can be affected by varying the rotor speed or the blade pitch. But for reducing the periodical separation mechanism, active control is needed during a single blade cycle.

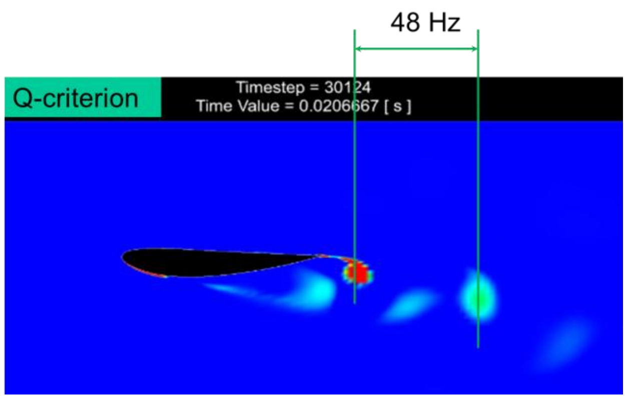

Figure 8: Unsteady CFD, 6 kHz sampling rate, Q-Criterion as a measure of loss, blade top position, r/R=0.9, n=28 rpm.

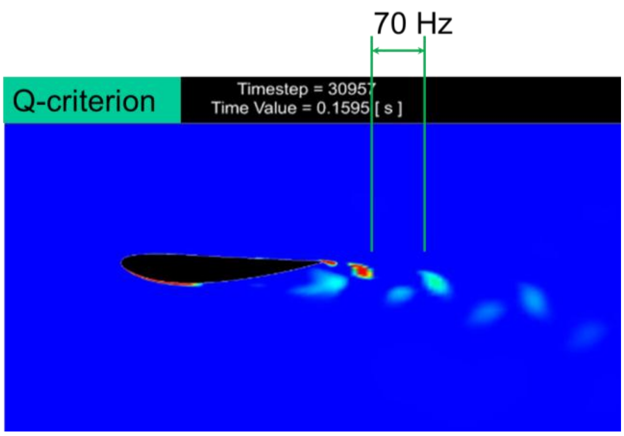

Figure 9: Unsteady CFD, 6 kHz sampling rate, Q-Criterion as a measure of loss, blade bottom position, r/R=0.9, n=28 rpm.

Optimised operation

In Figure 5 rotational speed and blade pitch have been optimised for a low noise operation mode at almost one and the same inflow condition. The sound pressure reduction come up to app. 4 dB A-weighted overall level shown in Figure 10.

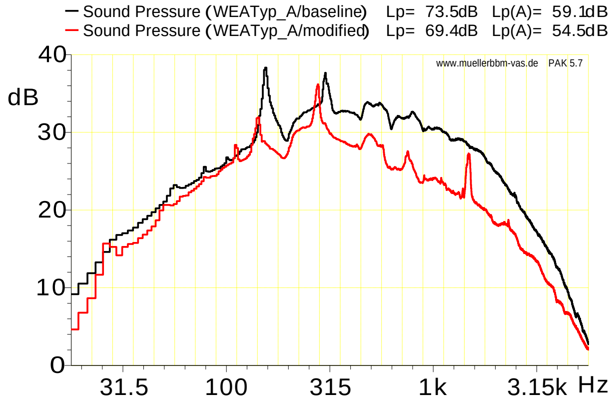

Figure 10: Sound pressure level reduction of app. 4 dB A-weighted overall level with optimised operating conditions (speed and pitch) on a 2 MW wind turbine

Active control – a method for the future?

Several active and passive flow control methods are investigated and summarized by Heinzelmann in 2011[6]. Effects of the unsteady aerodynamics or acoustical phenomenon of separated flow were not been taken into account.

Perhaps a progressive way of active controlling flow separation is with a variable blade profile shown in Figure 11. The blade trailing edge can be moved very fast along several centimeters. The company TEMBRA in Berlin actually investigates the flexible trailing edge. They will find out whether the movements of the trailing edge are a fast enough way to compensate the different values and directions of the incoming flow speed.

Figure 11: Blade with a flexible trailing edge – flap is shown in top position (invention of TEMBRA, http://www.tembra.com [7]).

In a wind tunnel test at Technical University of Berlin in February 2013 noise measurements were carried out by the University of Applied Sciences Düsseldorf with several pressure transducers and a microphone with a B&K turbulence screen UA0436. This measurement technique reduces the influence of turbulent pressure fluctuations in a wide frequency range so that sound pressure values can be estimated. Figure 12 shows more than 11 dB unweighted and 3.5 dB A-weighted overall levels noise reductions between bottom and top position of the flap. The flow speed variation was limited up to 20 m/s otherwise the blade passing frequency of the wind tunnel fan was a prominent tone. The shown noise reduction is not significantly influenced by the Reynolds-Number.

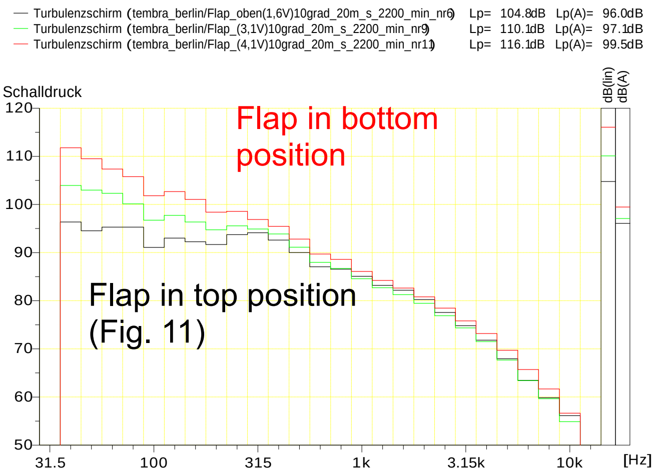

Figure 12: Sound pressure level reduction of the variable TEMBRA flap. Bottom, top and zero positions are shown, wind tunnel test at 20 m/s flow speed, angle of attack of the blade profile 10°.

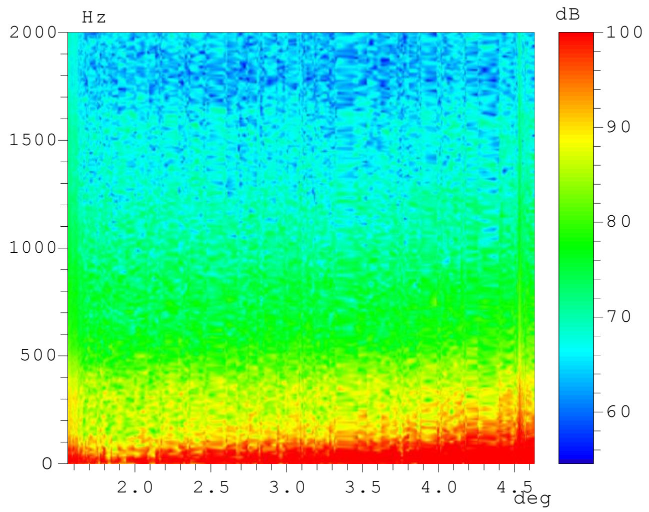

Figure 13: Sound pressure spectrogram of a TEMPRA flap variation from left=top position, shown in Fig. 11, to bottom position=right (4.5 deg), 20 m/s flow speed, angle of attack of the blade profile 0°.

A test result of this wind tunnel measurement campaign with vortex generators is shown in Figure 14. Vortex generators on the suction side of the blade profile influence flow separation and reduce the noise emission in the frequency range below 200 Hz in the current case study. Vortex or turbulence generators are well known for noise optimisation in automotive and aircraft industries [8],[9].

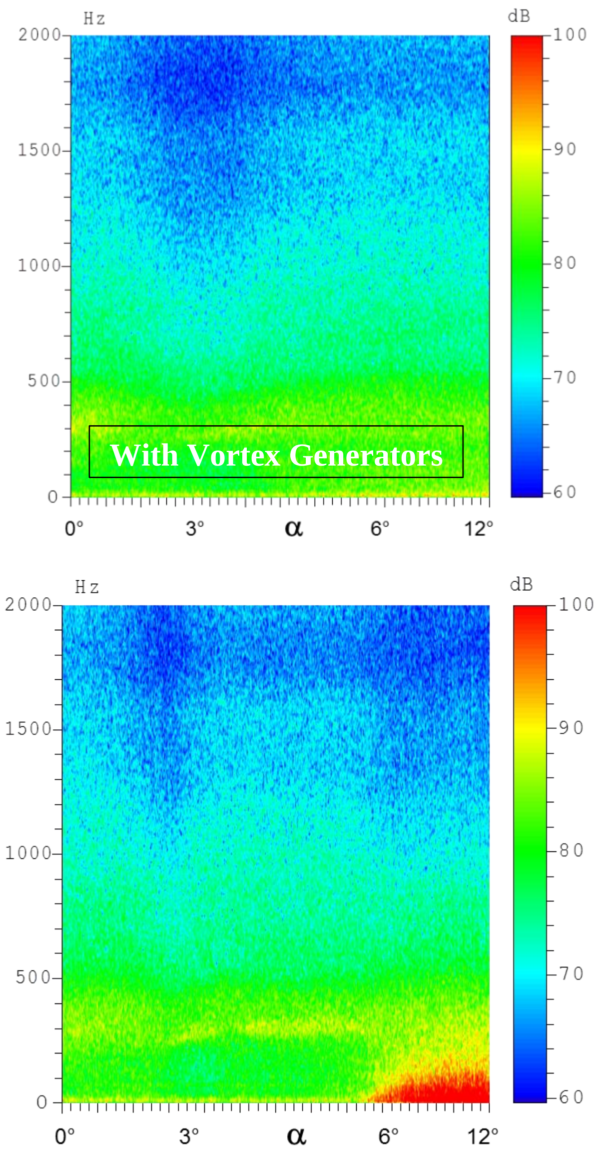

Figure 14: Sound pressure spectrogram with and without vortex generators, wind tunnel test, 20 m/s flow speed, angle of attack of the blade profile 0°.

Summary

For example this survey shows physical causes of annoying sounds and summarises the unused sound reduction potential from an aerodynamic point of view. Hence flow induced sound is being spotlighted for noise reduction methods. CFD calculations in the rotor area were carried out for a better understanding of the flow topology. To avoid or to reduce flow separation and vortices, numerical case studies are helpful. In order to visualise unsteady vortices, the Q criterion was used in the CFD post processing.

Infrasound will not be considered a relevant source of noise for wind turbines, however low frequency vibrations can occur and propagate through the ground.

The audible sound of a wind turbine could be reduced by influencing unsteady aerodynamics with smart blades. Therefore research needs to be sponsored by the wind turbine industry. At this point in time one could have the impression that not enough people are aware of the effects of this technology. From a technical point of view, low noise design of wind turbines must be tackled. A better aerodynamic performance and lower mechanical loading is attended with the noise reduction!

References

[1] ARTE Oct. 23rd 2012 ARTE “Kampf gegen Windparks“ http://www.youtube.com/watch?v=_7EVgd_LE50

[2] Bayerisches Landesamt für Umwelt: Windkraftanlagen – beeinträchtigt Infraschall die Gesundheit? Augsburg, 2012.

http://www.lfu.bayern.de/umweltwissen/doc/uw_117_windkraftanlagen_infraschall_gesundheit.pdf

[3] KÖTTER CONSULTING ENGINEERS KG: Schalltechnischer Bericht Nr. 27257-1.002 über die Ermittlung und Beurteilung der anlagenbezogenen Geräuschimmissionen der Windenergieanlagen im Windpark Hohen Pritz. 2010.

http://www.lung.mv-regierung.de/dateien/infraschall.pdf

[4] Ceranna, L., Hartmann, G., Henger, M.: Der unhörbare Lärm von Windkraftanlagen – Infraschallmessungen an einem Windrad nördlich von Hannover, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, 2005.

http://www.buerger-fuer-eggebek.de/downloads/wkainfraschallanwka.pdf

[5] Heinze, R.: The flow over a cylinder-plate-configuration: FSI-Simulation of the hysteresis-effect and conclusions for the acoustic phenomenon, AIA-DAGA, Merano, 2013.

[6] Heinzelmann, Barbara Souza: Strömungsbeeinflussung bei Rotorblättern von Windenergieanlagen mit Schwerpunkt auf Grenzschichtabsaugung , Dissertation, TU Berlin, 2011.

http://opus.kobv.de/tuberlin/volltexte/2011/3247/pdf/souzaheinzelmann_barbara.pdf

[7] Entwicklung einer flexiblen Hinterkante und Prototypentest im Windkanal, Projektförderung durch Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin, 2012. http://www.tembra.de

[8] Kameier, F.: Low Noise Design – Beispiel aus der Strömungstechnik, DAGA, Dresden 2008. http://mv.fh-duesseldorf.de/d_pers/Kameier_Frank/c_veroeffentlichungen/DAGA_2008_kameier_stand040108.pdf

[9] Kameier, F., Steinert, M., Vranjes, D.: Outflow valve for an Aircraft, international Patent, WO 2009/019264 A2, http://www.sumobrain.com/patents/wipo/Outflow-valve-aircraft/WO2009019264A2.pdf