UNIVERSITÄT SIEGEN

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# Abschlussbericht

**Nr. F114 101 A der Forschungsstelle**
**zum Forschungsvorhaben**

## DFG CA170/9-1 und CA170/9-2

# Drehton bei freilaufenden Rotoren von Axialventilatoren: Experimentelle und numerische Untersuchung der Entstehungsmechanismen

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# Summary

Due to increasing demands from both legislation and end users, modern fans have to be both energy-efficient and quiet.

The acoustic spectrum of a fan is often dominated by annoying tones at blade passing frequency and their higher harmonics, whose values are determined by the product of speed and number of blades. While the tonal noise of fans with up- or downstream stators or struts is due to the interaction of the rotor with the disturbed flow, the source mechanism of a fan with an obviously undisturbed in- and outflow was still unknown. Based on the current state of research, three hypotheses regarding the source mechanism of tonal noise at blade passing frequency have been postulated and investigated: (i) the inflow contains large turbulent eddies that interact with the rotating blades, (ii) the rotating impeller causes upstream vortex type structures and recirculation patches that interact with the blades, (iii) tip vortex/blade interaction.

A fan unit was designed, manufactured and investigated experimentally on standardized test rigs. For variation of the tip clearance/diameter ratio the fan unit was equipped with three rotors of different diameter. An extra set of blades have been instrumented with flush mounted pressure transducers to capture the blade pressure fluctuations which are the acoustic sources. A hemispherical inflow control device was used to homogenize the natural free inflow and hence to vary the inflow conditions. Devices for smoke based flow visualization allowed visualization of the flow at the inlet of the fan. A quantitative acquisition of the inflow conditions has been realized by 3D hot wire anemometry and a sophisticated probe traverse. Classical Navier Stokes solver as well as the Lattice Boltzmann method have been used to study the flow field from both an aerodynamic and acoustical point of view.

The results proved that the unexpected spatially inhomogeneous inflow and not the tip clearance or any self-induced vortices are the essential sound mechanism for the emergence of the tonal noise at blade passing frequency. Experimental modal analysis, smoke visualizations, hot wire measurements as well as simulation data revealed unexpectedly turbulent flow structures in the inflow that cause a signature on the rotating blades in terms of pressure fluctuations and hence. The interaction of the rotating blades with these flow structures are the source of the tonal sound at blade passing frequency. Simulations of the coupled system, i.e. fan unit and surrounding large suction chamber, showed that the interaction takes place at the outer radius of the blades with flow structures in the vicinity of the duct wall.

Usually the inflow from a large suction chamber to a relatively small fan is assumed to be undisturbed, especially if the size of the unblocked flow regime upstream of the fan is within the current international standards. However, this project revealed an unexpected but considerable effect of the large scale environment on the inflow and eventually the acoustic emission of a fan. It seems that the current standards are insufficient to obtain test-rig independent acoustic emission data of a specific fan. An additional device that generates defined inflow conditions, such as the inflow control device used in this project, would be recommended to achieve test-rig independent, hence comparable and reproducible sound emission data.