Fluid Mechanical and Acoustic Characterization of Low-Pressure Axial Fans with different Blade Skew

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HIGHLIGHTS

- LDA measurements on two axial fans showed that the flow-field is substantially influenced by the fan blade skew.
- The radial velocity component was found to be directed inwards by the forward-skewed fan blades and outwards by the backward-skewed fan blades.
- High turbulent kinetic energy in the tip region of the backward-skewed fan indicated that there exists a complex flow-field.
- Broadband and tonal components in the acoustic spectra were assigned to different flow phenomena.
- Differences in the characteristic of tonal and broadband components for both fans were assigned to the blade design.

ABSTRACT

Both the flow-field inside the fan and the sound emission of axial fans is governed by the fan blade skew. In order to assign different parts in the acoustic spectrum to specific flow mechanisms, it is necessary to consecutively characterize the aerodynamics and the aeroacoustics of a fan. Hence, two fans with backward- and forward-skewed fan blades were investigated to identify differences in the flow-field and the acoustic spectrum. The flow-field at the suction and pressure side of the fans was measured with a laser Doppler anemometer, the acoustic field at the suction side was recorded with seven microphones. Results of the ensemble-averaged flow properties at the suction side showed that the axial velocity is clearly influenced by the fan angular position and that the distribution from hub to tip is dependent at the fan blade skew. There was hardly any influence of the angular position on the axial velocity at the pressure side. The distribution of the radial velocity at the pressure side showed that the flow is directed outwards by backward-skewed fan blades and directed inward by forward-skewed fan blades. Values of the turbulent kinetic energy at the pressure side of the backward-skewed fan were significantly increased in the tip region.

Broadband components in the acoustic spectra from 0.5 to 2 kHz were higher for the backward-skewed fan. Due to the outwards directed radial component, a longer flow path develops over the blade surface, resulting in a thicker boundary layer and consequently an intensified sound emission. For frequencies greater than 2 kHz, broadband components of the forward-skewed fan were more prominent. This sound mechanism is governed by vortex shedding on the fan blade trailing edges. It is illustrated that forward-skewed fan blades tend to induce a higher velocity perpendicular to the trailing edge which leads to an increased acoustic source strength on the trailing edges. Besides this, significant subharmonic components, i.e. non-corresponding to the blade passing frequency, were found in the spectrum of the backward-skewed fan. The source mechanism for this phenomenon was linked to the complex flow field in the tip region. Backflow from pressure to suction side can interact with the fan blades which results in tonal noise radiation.