Static pressure recovery of axial fans

Scale resolving simulations of the mixing jet outflow of free-blowing axial fans

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A significant share of the worldwide energy consumption is due to the operation of low pressure axial fans. With typical applications in for example air conditioning or in thermal management of electronics, there additionally is a prediction of strong growth in the next decades [1]. Consequently, possible improvements in efficiency of such machines are getting increasingly urgent in the context of climate change. Furthermore, the impact of such improvements will be large due to the excessive widespread use of low pressure axial fans.

Figure 1: *Meridional slice of a DES simulation of a low pressure axial fan with the instantaneous density distribution as contour, where brighter areas indicate higher values.*

Typically installed in a rotor-only configuration, low-pressure axial fans are discharging directly into a free atmosphere and the discharge shows a strong swirl component. Since such designs without guide vanes cannot convert the dynamic pressure in the swirl component back into static pressure, the dynamic pressure is usually considered as loss. However, considerations of the radial equilibrium show, that a significant part of the kinetic energy contained in this swirl component is recovered as static pressure in the free atmosphere. Figure 2 qualitatively schematizes this process: At a position immediately downstream of the trailing edge (location 0), the circumferential velocity component (blue) results in a decreasing pressure distribution towards the hub (red). Consequently, at this position the average pressure is sub-atmospheric. At a position far downstream of the fan (position 0), the pressure is equal to the ambient pressure. Therefore, a static pressure increase must take place from location 0 to location 1. While this additional pressure increase is directly acting on the total-static efficiency of fans in a free-discharging configurations, it has been sparsely researched.

Available experimental investigations on the achievable static pressure recovery downstream of rotor-only axial fans are first found by Marcinowski [2]. Here, for a free vortex fan design with a hub-to-tip ratio of $\nu = 0.5$ the measured static pressure recovery in the free discharge corresponds to an increase of efficiency of 4-7$\%$. To the knowledge of the authors the static pressure recovery was not investigated in detail in other publications up to this date.

To properly utilize and evaluate the static pressure recovery, an evaluation criterion was formulated by the authors through a comparison between two configurations with and without outlet guide vanes. Utilizing this evaluation criterion, previous investigations considering highly idealized discharge velocity profiles show a promising potential in terms of pressure recovery for new designs depending on the hub-to-tip ratio and the vortex design of the.

However, the numerical verification of this potential for real fan designs is still pending. Preliminary studies have shown, that RANS computations are not capable of correctly depicting such flows discharging into a free atmosphere developing massive shear layers and the subsequent mixing processes. Consequently, scale resolving simulations will be performed to properly predict these complex flow features. In the scope of the superordinate research project, in which context these simulations are performed, several fan designs will be manufactured and experimentally investigated using five-hole-probes and particle image velocimetry. These experiments will yield high value data to properly validate the simulations. Building up on this, additional fans will be designed and investigated numerically. The overall goal of these numerical investigations is the verification of the idealized results and a better

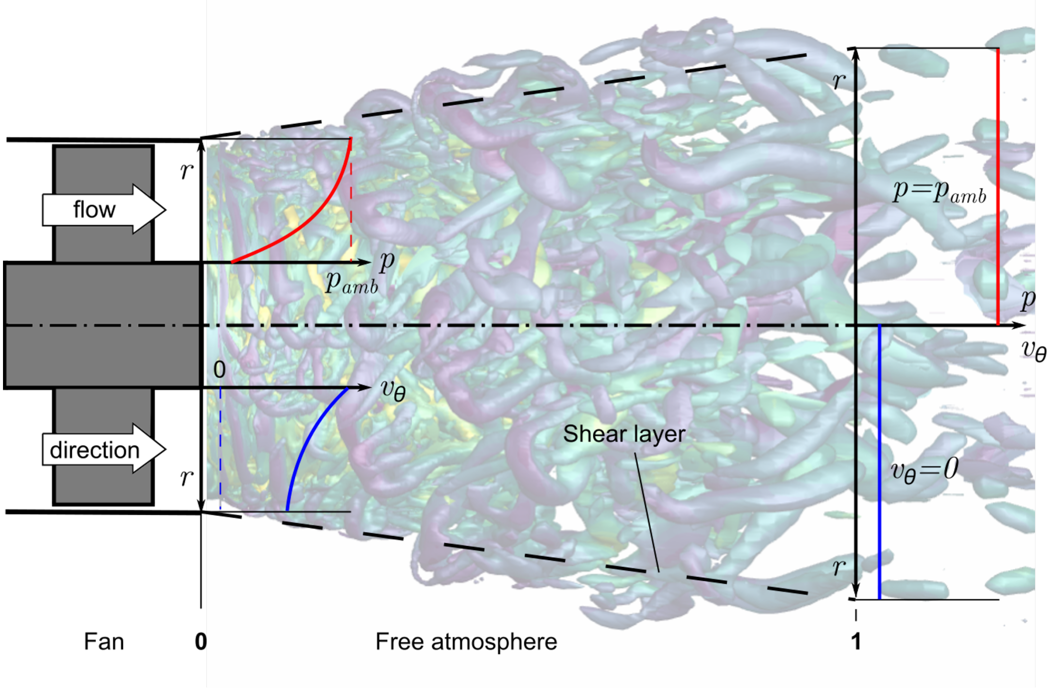

Figure 2: *Schematic illustration of the static pressure recovery in the discharge of rotor-only axial fans. From location 0 immediately downstream of the trailing edge of the fan to location 1 far downstream the average static pressure muss increase to ambient pressure.*

understanding of the basic process of static pressure recovery in the mixing jet outflow of low pressure axial fans.

WWW

https://www.tu-braunschweig.de/ifas

More Information

[1] https://www.iea.org/reports/the-future-of-cooling

[2] H. Marcinowski, Druck- und Geschwindigkeitsverteilung hinter dem Laufrad eines Axialventilators *Voith Forschung und Konstruktion* **2** (1957).

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