Aeroelasticity in Axial Fluid Machines

Investigation of the aeroelastic behavior of axial fluid machines

Student

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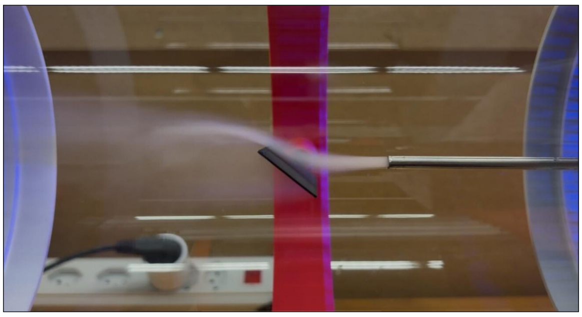
Introduction: Aeroelasticity describes the interaction between aerodynamic forces and the elastic deformation of technical structures, and is particularly relevant in aircraft and turbomachinery engineering. While aeroelastic principles are well established in large-scale structures, their application in small, low-cost fans and pumps remains largely unexplored. The potential to achieve efficiency gains through deliberately flexible designs opens up new avenues for innovative fan concepts in consumer products. This work experimentally investigates whether flexible rotor blades in small axial fans provide measurable benefits in pressure, flow, and efficiency compared to rigid designs, as well as limitations and challenges at laboratory scale.

Approach: The study begins with a literature review and an analysis of existing aeroelastic concepts to derive relevant design principles and benchmarks. Various fan geometries, including very thin and complexly curved profiles, are produced from different materials (PLA, TPU) using additive manufacturing. A modular test bench is used to record pressure difference, volume flow, efficiency, and power consumption. In addition, numerical flow simulations are conducted, while structural simulations remain limited to simple couplings due to computational constraints.

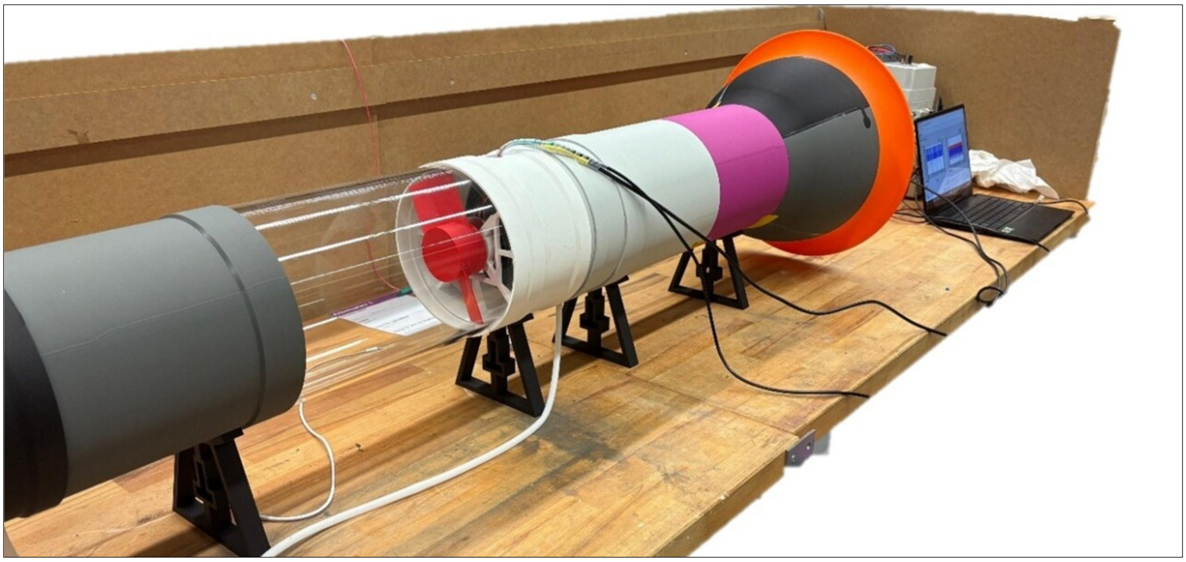
Result: The experiments show that extremely thin and flexible flat, rectangular rotor blades exhibit significant aeroelastic deformation and, in some cases, failure at higher speeds, resulting in reduced pressure rise and volume flow. In contrast, thicker or more complex geometries and material variations show little effect on aeroelastic behavior at small scale, with pressure and force values remaining below the threshold for significant deformation. No systematic performance advantage over conventional designs is observed. Additive manufacturing constraints, measurement uncertainties, and limited control over structural stiffness are identified as central limiting factors, while constructive optimizations through internal structures remain challenging at this scale.

Red blade, 0.2 mm, 45°: Significant bending due to the flow, reduced turbulence behind the trailing edge.
Own presentment

Black blade, 0.8 mm, 45°: No visible deformation, pronounced turbulence in the wake.
Own presentment



Complete test bench for the dynamic investigation of fan geometries.
Own presentment



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