

Evaluation of Bladeless Fan with Wavy Ledge Design for Noise Reduction and Efficiency

Mohd Danial Ibrahim^{1,2)*}, Sitti Aishah Najamudin^{1,2)}, Herbert Ian B Juhan³⁾, Muhammad Alzam Amrun @ Ajis^{1,2)}, Abang Mohammad Nizam Abang Kamaruddin¹⁾, Norlida Jamil¹⁾, Ahmad Adzhar bin Mohd Khairulzaim^{1,2)}, M Azlan B Mas'od⁴⁾, Ahmad Beng Hong Kueh^{1,2)}

¹⁾Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Sarawak, Malaysia

²⁾UNIMAS Water Centre (UWC), Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS), Malaysia

³⁾Project Programme Matters Sdn Bhd, 93300 Kuching, Sarawak, Malaysia

⁴⁾PETRONAS Research Sdn Bhd, Petronas Research & Scientific, Selangor, Malaysia

*Corresponding author: imdanial@unimas.my

Bladeless fans offer quieter operation and improved efficiency, but noise reduction at higher speeds remains challenging. This study evaluates a modified bladeless fan design with a wavy ledge to enhance noise reduction and aerodynamic performance. Experimental tests showed a reduction in sound pressure levels (SPL) by 1.67 dBA to 3.69 dBA, along with an increase in maximum outlet velocity from 14.3 m/s to 16.5 m/s, compared to conventional blades. The wavy ledged design provides an effective noise reduction solution, ideal for noise-sensitive environments. Future research should focus on real-world testing and further optimization of blade geometry.

Keywords: Bladeless fans, noise reduction, aerodynamic efficiency, wavy blades, CFD

1. Introduction

Bladeless fans are known for their quieter operation and energy efficiency. However, noise reduction, especially at high speeds, continues to be a challenge. Understanding these acoustic signatures is critical, as they not only dictate user comfort but can also serve as indicators for flow stability and operating conditions [1]. Recent studies on aerodynamic noise and geometric modifications have shown that adjustments in blade design can significantly reduce vortex shedding and improve flow dynamics [2]. This study explores the potential of wavy ledged blades for reducing noise while maintaining aerodynamic performance, applying both experimental testing and CFD simulations to evaluate effectiveness.

2. Methodology

Bladeless fan blades were modified by adding a wavy ledge at the blade tips. Experimental tests were conducted to measure the sound pressure levels (SPL) of fans with both conventional and wavy ledged blades. CFD simulations were performed to model airflow behavior, pressure distribution, and vortex shedding, assessing the impact of the wavy ledge on noise reduction and aerodynamic efficiency. These simulations focused on improving fluid dynamics and reducing vortex formation, which are critical for achieving quieter operation and better airflow performance.

3. Results

Aerodynamic Performance: The wavy ledged blade demonstrated improved airflow characteristics, achieving an increase in maximum outlet velocity of approximately 15.4% (reaching 16.5 m/s compared to 14.3 m/s for the conventional blade). Regarding pressure distribution, CFD results indicated a marginal reduction in pressure ratio of only 0.012% at high speeds (9789 RPM). This negligible difference confirms that the wavy design effectively maintains the fan's pressure-generating capabilities while converting potential energy into higher kinetic energy (velocity).

Vortex Shedding Analysis: CFD analysis links blade geometry to noise mechanisms. Figure 1(a) illustrates vortex shedding in the Conventional Blade at Knob 1, where intense shedding near the blade tip correlates with increased tonal noise. In contrast, Figure 1(b) shows the Wavy Ledge Blade under the same conditions. Despite a larger shedding area, the wavy design promotes rapid vortex dissipation. This efficient energy dissipation mitigates acoustic emissions, directly supporting the lower Sound Pressure Levels (SPL) observed in experimental data.

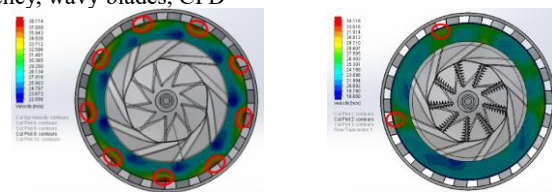


Figure 1 Velocity streamline comparison at Knob 1 showing vortex shedding characteristics for a) Conventional Blade and b) Wavy Ledge Blade

Noise Reduction: The wavy ledged blade achieved a reduction in SPL ranging from 1.67 dBA to 3.69 dBA. Figure 2 illustrates this performance gap, where the wavy ledged blade (red line) consistently maintains lower noise levels compared to the conventional blade (green line) across increasing RPM settings.

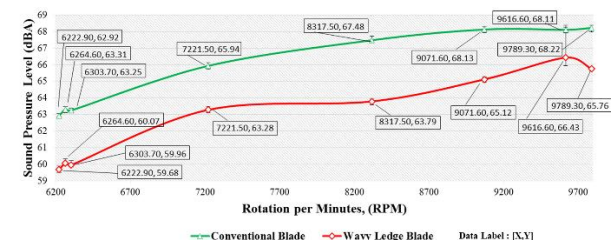


Figure 2: SPL vs. RPM for Conventional and Wavy Ledge Blades, showing SPL differences

4. Conclusions

The wavy ledged blade modification significantly reduces noise, particularly in noise-sensitive environments, while simultaneously increasing outlet velocity. This study provides evidence that passive flow control via wavy ledges offers a promising avenue for concurrent noise and aerodynamic performance improvement in bladeless fan technology. Future studies should focus on real-world validation and further optimization of the blade design.

References

- [1] Toth, D., Divinyi-Zsoldos, T., Lendvai, B., and Vad, J., "Preliminary case studies to acoustics-based condition monitoring of industrial fans," *Proceedings of the 15th European Conference on Turbomachinery Fluid Dynamics & Thermodynamics (ETC15)*, Budapest, Hungary, 2023. DOI: 10.29008/etc2023-123.
- [2] Ibrahim, M. D., Marusman, N., Sunami, Y., Amran, S. N. A., Musa, S. S., and Ochiai, M., "Characteristics of modified spiral thrust bearing through geometries and dimension modifications," *Tribology Online*, 13, 6, 334-339, 2023.