Algerian Journal of Research and Technology
https://doi.org/10.58681/ajrt.26100102
A.J.R.T Volume 10 (N°01) (2026) 12- 18

Design and realization of a Small-Scale Horizontal Wind Turbine with a Novel Blade Configuration

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Received. January 30, 2026. Accepted. March 01, 2026. Published. July 25, 2026.

DOI: https://doi.org/10.58681/ajrt.26100102

Abstract. This study presents the design and the realization of a small-scale horizontal-axis wind turbine (HAWT) featuring a novel blade configuration aimed at rural electricity generation. The new blade design was derived from a 200 mm diameter PVC tube with a 3 mm wall thickness. Each of the three blades has a circular camber section with a 25° twist angle between the root and the tip, where the local pitch angle equals zero. The turbine, with a rotor radius of 1295 mm, was mounted on a conical hub and tested under real wind conditions.
The prototype was developed to validate previous numerical simulations that demonstrated good aerodynamic performance compared to conventional blade geometries. Although no precise measurement instruments were available, visual observations confirmed stable operation and effective wind energy capture. The numerical investigation, based on the Reynolds-Averaged Navier–Stokes (RANS) equations with a realizable k–ε turbulence model, predicted a maximum power coefficient (Cp) of 0.344 — slightly higher than similar configurations reported in the literature. This experimental implementation highlights the feasibility of low-cost fabrication using PVC material while maintaining satisfactory aerodynamic efficiency for different applications.

Keywords. Horizontal-axis wind turbine, Prototype fabrication, PVC blade; Renewable energy, Aerodynamic performance.

INTRODUCTION

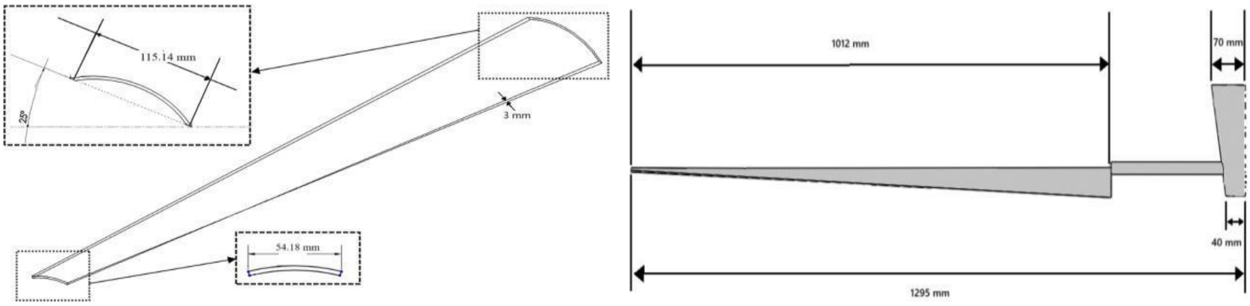
Small-scale wind turbines represent an attractive solution for decentralized electricity generation in rural or remote areas, where connection to the national grid is often impractical or costly. In such contexts, the development of efficient and low-cost wind energy systems is of particular importance. Recent studies have focused on optimizing the aerodynamic performance of turbine blades through geometric innovations and material selection, aiming to enhance the power coefficient while ensuring mechanical simplicity (Marini et al., 1992; Ferreira et al., 2007; Beri and Y, 2011 ; Singh and Ahmed, 2011; Azad and Kaysar, 2012; Pratama and Paranchis, 2022). In this research, a new horizontal-axis wind turbine with three blades was designed and numerically investigated (Akram et al., 2025).

The novelty of the design lies in the blade configuration, which consists of circular caber profiles obtained from a 200 mm PVC tube. Numerical simulations demonstrated that this configuration could achieve a maximum power coefficient of 0.444, which is slightly higher than comparable experimental data available in the literature (Krogstad and Lund, 2012). Building upon these promising numerical results, a small-scale prototype was fabricated to experimentally assess the feasibility and performance of the proposed design under real conditions. This communication focuses on the fabrication process, material selection, and preliminary experimental observations.

DESIGN PROCEDURE

The blade tested in this investigation has circular camber sections that were taken from a 200 mm diameter and 3 mm thick tube. As shown in Fig. 1(a), the blade's length is 1012 mm, and its cutting from the tube is oriented so that the extreme profiles have different twist angles by 25◦. It is noted that at the blade's tip, the pitch angle, Φ, equals zero. The wind turbine has a radius, Rp, of 1295 mm due to the blade's attachment to the conical hub using a stem, Fig. 1(b).

The chord, pitch, and camber distributions are required in order to define the tested blade geometrically. The complete set of the blade's attributes is shown in Table 1.



(a) (b)

Fig.1. Tested blade geometry: (a) Blade curve. (b) Wind turbine radius.

Table 1. Blade geometrical features.

r (mm)	**300**	**388.50**	**518**	**647.50**	**777**	**906.50**	**1036**	**1165.50**	**1295**
X=r/Rp	0.23	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1
Cr(mm)	115.15	109.20	100.42	92	83.82	75.88	68.22	60.97	54.18
Φ(◦)	25	23.78	21.92	19.76	17.20	14.11	10.36	5.77	0.01
Fmax/Cr	0.16	0.15	0.13	0.12	0.11	0.10	0.09	0.08	0.07

The design of the wind turbine was created in Solid Works. The software was used to model the rotor, blades, and hub assembly with precise dimensions and angles, ensuring that the prototype could be easily manufactured. This 3D modeling step was essential for verifying the alignment of components and defining the exact geometry before the physical realization of the turbine as shown in the Fig 2.

Fig.2. The designed wind turbine in Solid Works.

PROTOTYPE FABRICATION

The experimental prototype was developed to validate the numerical findings and demonstrate the feasibility of constructing a small-scale horizontal-axis wind turbine (HAWT) using low-cost materials. The most innovative feature of this work lies in the blade configuration and fabrication technique. Each of the three blades was obtained by cutting a single 200 mm diameter PVC tube (3 mm thick) into three equal parts following a specific orientation, which produced the desired 25° twist angle between the root and the tip. This method allowed the fabrication of three identical blades from one tube; ensuring an efficient use of material and reduced cost (Fig. 3).

Fig.3. Three blades obtained from a single 200 mm diameter PVC tube after cutting.

To assemble the rotor, a metal shaft recovered from a washing machine was used as the main hub axis (Fig. 4). A custom metal adapter was then designed to connect each blade to the shaft while maintaining the appropriate inclination. The blades were fixed to the adapter using four bolts, and the adapter itself was attached to the shaft with a single bolt, providing a rigid and reliable connection capable of withstanding operational loads. Two bearings were installed along the shaft to support the rotor and ensure smooth rotation during operation.

Fig.4. Metal shaft recovered from a washing machine used as the main hub axis for the prototype.

Due to the unavailability of a large wind tunnel, a mobile testing system was devised to simulate real air flow conditions. The turbine was first mounted on a special support fixed to the top of a moving car, effectively acting as an open-air wind tunnel (Fig. 5). This setup allowed the turbine's rotation and stability to be observed under various simulated wind speeds. In a second phase, the prototype was installed on the rooftop of the laboratory building, where it was exposed to natural wind conditions for additional observation (Fig.6). In both testing configurations, the rotor exhibited smooth and stable rotation, confirming the practical efficiency and structural integrity of the design.

Fig.5. Mobile testing configuration: wind turbine mounted on the top of a moving car to simulate real airflow conditions.

Fig.6. Prototype installation on the rooftop of the laboratory building for testing under natural wind conditions.

Discussion and future work

During the experimental phase, the prototype exhibited excellent starting behavior, as it was able to self-start under natural wind conditions without any external assistance .This observation confirms the numerical prediction of improved aerodynamic efficiency, particularly at low wind speeds. When mounted on the car-top support (Fig. 4), the turbine achieved steady rotation even at moderate vehicle speeds, with only minor vibration observed in the hub and support structure. The source of this vibration was attributed mainly to slight misalignment during assembly and the flexibility of the PVC blades.

Further testing on the laboratory rooftop (Fig. 5) demonstrated continuous and stable rotation under varying natural wind conditions, visually confirming the good aerodynamic performance and structural stability of the system. Although no quantitative measurements of torque or electrical output were recorded due to the lack of measuring instruments, the prototype’s behavior clearly validated the feasibility and efficiency of the proposed blade configuration. The visual comparison between simulation predictions and real-world performance is showing strong qualitative agreement between the two approaches.

The numerical results provided key performance indicators, such as torque and power coefficients, which guided the subsequent experimental prototype design (Akram et al., 2025).

The numerical investigation predicted that the new blade configuration could achieve a maximum power coefficient (Cp) of 0.344 under an inflow velocity of 10 m/s (Fig. 7), which is slightly higher than the performance of similar small-scale turbines reported in the literature (Krogstad and Lund, 2012).

The computational results also indicated smooth pressure distribution along the blade surface and effective energy extraction near the mid-span region as illustrated in Fig 8.

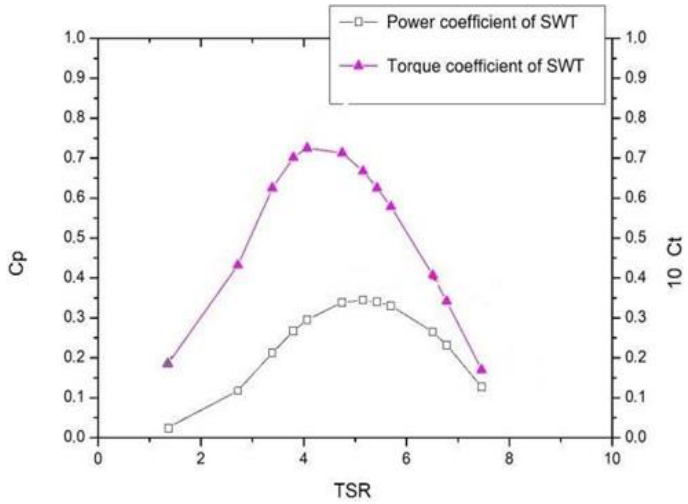


Fig.7. Power coefficient and torque coefficient of the wind turbine (Akram et al., 2025).

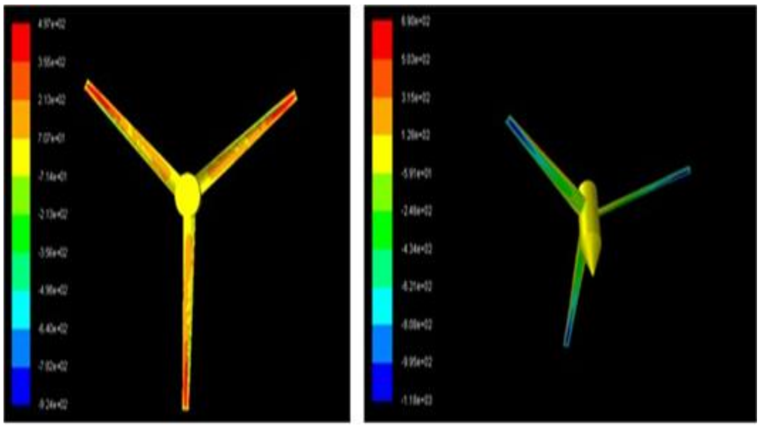


Fig.8. Pressure contours for both Pressure and suction surface (Akram et al., 2025).

Conclusion

This study presented the design, fabrication, and preliminary testing of a small-scale horizontal-axis wind turbine (HAWT) featuring a novel blade configuration derived from a PVC tube. The originality of the approach lies in its simplicity and cost-effectiveness: three identical blades were produced from a single PVC tube, providing both material efficiency and excellent aerodynamic characteristics.

The prototype demonstrated self-starting capability under natural wind and stable rotation during both mobile and stationary tests, confirming the validity of the numerical predictions. Despite the absence of precise measuring instruments, the observed behavior of the turbine clearly indicates that the new blade geometry effectively captures wind energy even at low wind speeds.

The work highlights the feasibility of using low-cost materials such as PVC for small wind turbine applications in rural areas, without compromising aerodynamic performance.

Based on the numerical Cp and an estimated generator efficiency of 80%, the prototype is expected to produce around 0.89 kW at 10 m/s wind speed.

Further experimental tests are currently being conducted to obtain quantitative performance data, refine the mechanical assembly, and validate the energy output under different operating conditions.

REFERENCES

Adjlout, A., Ladjedel, O., Yahiaoui, T., Šikula, O., Imine, O., Adjlout, L. “A numerical investigation of a new horizontal-axis wind turbine performance for rural use.” *International Journal of Modern Physics C*, vol. 36, 2025, p. 2450205. https://doi.org/10.1142/S012918312450205X.

Azad, K., and Kaysar, M. “Design of a horizontal axis wind turbine for electricity generation in low speed windy sites.” *International Journal of Advanced Renewable Energy Research*, vol. 1, 2012, pp. 363–373.

Beri, H., and Yingxue, Y. “Numerical simulation of unsteady flow to show self-starting of vertical axis wind turbine using Fluent.” *Journal of Applied Sciences*, vol. 11, 2011, pp. 962–970. https://doi.org/10.3923/jas.2011.962.970.

Ferreira, C. J. S., Bijl, H., van Bussel, G., van Kuik, G. “Simulating dynamic stall in a 2D VAWT: Modeling strategy, verification and validation with particle image velocimetry data.” *Journal of Physics: Conference Series*, vol. 75, 2007, p. 012023. https://doi.org/10.1088/1742-6596/75/1/012023.

Krogstad, P. Å., and Lund, J. A. “An experimental and numerical study of the performance of a model turbine.” *Wind Energy*, vol. 15, 2012, pp. 443–457. https://doi.org/10.1002/we.482.

Marini, M., Massardo, A., Satta, A. “Performance of vertical axis wind turbines with different shapes.” *Journal of Wind Engineering and Industrial Aerodynamics*, vol. 39, 1992, pp. 83–93. https://doi.org/10.1016/0167-6105(92)90535-I.

Paranchis, M., and Pratama, H. “The wind turbine design and test.” *Teknomekanik*, vol. 5, 2022, pp. 13–27.

Singh Rathore, A., and Ahmed, S. “Design and analysis of horizontal axis wind turbine rotor.” *International Journal of Engineering Science and Technology*, vol. 3, 2011, pp. 7975–7979.