International Journal of Application on Sciences, Technology and Engineering (IJASTE)
Volume 1, Issue 1, 2023. ISSN 2987-2499

# Experimental Study of Gurney Flap on Darrieus Wind Turbine Performance

Feta Kukuh Pambudi[1] , Dominicus Danardono Dwi Prija Tjahjana[1*], Budi Santoso[1],

[1]*Mechanical Engineering Department, Faculty of Engineering, Sebelas Maret University, Surakarta, Indonesia*
[a)]Corresponding Author: ddanardono@staff.uns.ac.id
[b)]fetakukuh@gmail.com

*Submitted: November-December 2022, Revised: January 2023, Accepted: February 21, 2023*

**Abstract.** Wind energy is a renewable energy that is easily obtained and friendly to the environment. The Darrieus wind turbine is a turbine model that is suitable for use in areas with low wind speeds. A Gurney Flap can be added to an aerodynamic device, such as a car spoiler, to improve the spoilers performance. In this study, Gurney Flaps were added to the Darrieus wind turbine to increase the turbines performance. The research objective was to study the effect of the Gurney Flap addition on the Darrieus wind turbine characteristics and the optimum geometry of the Gurney Flap. An experimental study was conducted on conventional Darrieus wind turbines and modified Darrieus wind turbines with the addition of Gurney Flaps, with angle variations of 90°, 120°, and 150° at the height of the Gurney Flap at 2% of the chord length. Each variation was tested at wind speeds of 7 m/s, 8 m/s, and 9 m/s. The experiment result angle variation of 120º obtained the best (*Cp*) power coefficient of 0.228 at a TSR of 1.166.

## INTRODUCTION

The continuous use of fossil fuels results in future fuel scarcity and causes air pollution. Therefore, renewable resources are needed as a breakthrough to reduce environmantal pollution. Very promising energy sources include wind, hydro, biomass, solar and geothermal [1]. Wind turbines are devices that are used to extract power from wind energy. The principal of a wind turbine is to convert mechanical to electrical energy. Generally, wind turbines are divided into two types: Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT) [2]. The significant differences between the two types of wind turbines HAWT is usually used in large-scale energy generation: otherwise, VAWT is usually used in small and micro-scale energy generation [3].

The VAWT has the disadventage of low power efficiency. The research is starting to be in great demand because VAWT is suitable for use in areas that have low wind speeds and the advantages of low production cost, low operating noise, and large-scale compatibility [4]. The most interesting VAWT are the Darrieus wind turbine and the Savonius wind turbine, each of which has advantages and disadvantages. High efficiency is a benefit of the Darrieus and Savonius wind turbines. Low starting-torque is one of the Darrieus wind turbine drawbacks [5].

One of the methods used to increase the performance of the Darrieus wind turbine is by adding devices to the airfoils. The devices used are passive and active flow control. The Gurney Flap is a category of passive flow devices used to effectively increase the design lift coefficients of airfoils [6]. The Gurney Flaps that are attached to the airfoil can separate the characteristic vortices that result in an increase in the suction on the airfoil upper surface and pressure on the airfoil lower surface. Therefore, there is a substantial increase in the lift coefficient [7]. Systematic experiments on a Newman airfoil (which is a summetrical airfoil shape) showed that at the height of the Gurney Flap, 2% of the chord length can maximize the aerodynamic benefits [8]. Another study considers the simulation of a modified airfoil with variations in Gurney Flap at 2%, 5%, and 7% chord length to improve turbine performance [9].

*Bianchini et al.* conducted a simulation by modifying the Gurney Flaps on a three-blade Darrieus wind turbine. Adding inboard, outboard, and both Gurney Flap in a 2% chord of the length as a result, there is an increase in the power coefficient by 20% compared to conventional turbines. The dominant effect of adding a Gurney Flap is the lower Tip Speed Ratio. A Gurney Flap on the Darrieus wind turbine airfoil with a variation Angle Of Attack also increases the power coefficient on the Darrieus wind turbine [11].

In previous research, the addition of a Gurney Flap on the Darrieus turbine was carried out at a 90° angle mounted on the trailing edge airfoils. In this study, experiment variations of 90°, 120°, and 150° were carried out to find the highest power coefficient. The Gurney Flap is attached to the trailing edge in the outboard position at the high Gurney Flap, 2% of the chord length.

## IMPORTANT PARAMETER

Wind turbine performance can be determined using several parameters. Tip Speed Ratio ($\lambda$) by using Eq.1.

$$\lambda = \frac{\pi D n}{60 v} \tag{1}$$

Where,

$\lambda$ = Tip speed ratio
$D$ = Rotor diameter (m)
$n$ = Rotor rotation speed (rpm)
$v$ = Wind velocity (m/s)

The torque coefficient ($C_m$) can be determined by using Eq.2 and the power coefficient ($C_p$) by using Eq.3.

$$C_m = \frac{M}{0.25\, \rho v^2 D_1 S} \tag{2}$$

$$C_p = \frac{P}{0.5 \rho S' v^3} \tag{3}$$

Where,

$C_m$ = Torque coefficient
$M$ = Torque ($Nm$)
$\rho$ = Air density ($kg/m^3$)
$v$ = Air velocity ($m/s$)
$D_1$ = Turbine outside diameter ($m$)
$S$ = Rotor swept area ($m^2$)
$C_p$ = Power coefficient
$P$ = Turbine output power ($watt$)

## EXPERIMENT EQUIPMENT AND MEASUREMENT METHODOLOGY

An experimental study was conducted on a wind tunnel scale wind turbine of a certain size [12]. The wind tunnel (Fig.1) equipment consists of a contraction section and a test section. The contraction section consists of a diffuser, a settling chamber, and a fan to control the flow velocity. The test section has dimensions and a place for turbine test torque. The torque was calculated using the difference in the forces of the turbine as measured by the scale and the drive shaft radius. The turbine power can be obtained from the torque, which was combined with the turbine rotational speed of the turbine, which was taken from a one-turn optical tachometer [13]. The wind tunnel parts are shown in Table 1.


**FIGURE 1.** Wind tunnel.

**TABLE 1**
**Wind Tunnel Parts**

| Number | Description |
|---|---|
| 1 | Wind direction |
| 2 | Diffuser |
| 3 | Anemometer |
| 4 | Test section |
| 5 | Darrieus Turbine |
| 6 | Diffuser |
| 7 | Fan |
| 8 | Load cell |
| 9 | Prony brake |

For the experiments in this study, we used a Darrieus wind turbine with the specifications listed in Table 2. The prototype Darrieus wind turbine with Gurney Flap is shown in (Fig. 2 (a)) and the 3D view in (Fig. 2 (b)).

**TABLE 2**
**Turbine Specification**

| Parameter | Value |
|---|---|
| Airfoil | NACA 0024 |
| Diameter | $200\ mm$ |
| Turbine high | $200\ mm$ |
| Angle of Attack | $15°$ |
| Gurney flap height | $2\%\ of\ the\ chord\ length$ |
| Number airfoil | $3$ |

The Darrieus wind turbine was constructed airfoil using 3D printed airfoil made of PLA (Poly Lactic Acid) material and articulation connection with 2 mm thick aluminium material. The Darrieus wind turbine with outboard Gurney Flap. This also varied the number of blades using three airfoils with an angle variations of 90°, 120°, and 150° at the high Gurney Flap 2% of the chord length (Fig. 3).

(a) (b)

**FIGURE 2.** (a) Prototype Darrieus wind turbine; (b) 3D view.

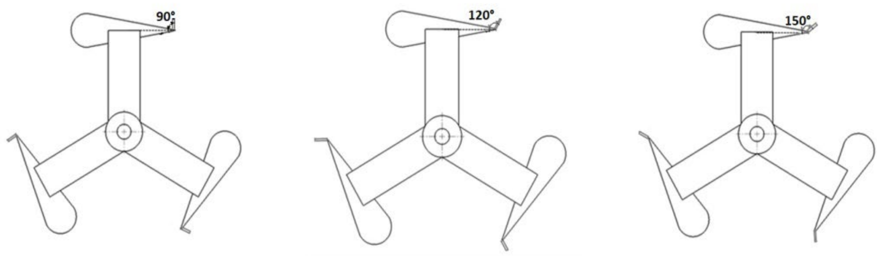
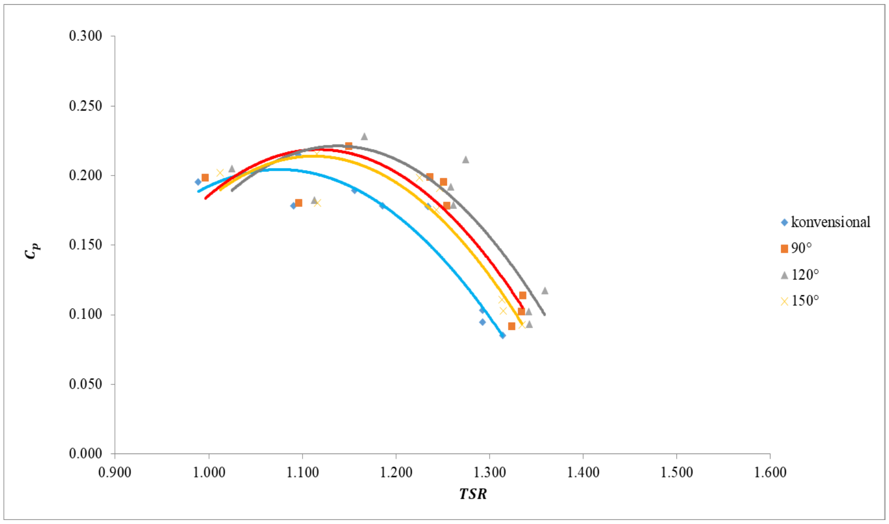



**FIGURE 3.** Darrieus wind turbine configuration 90°, 120°, and 150° angle variations.

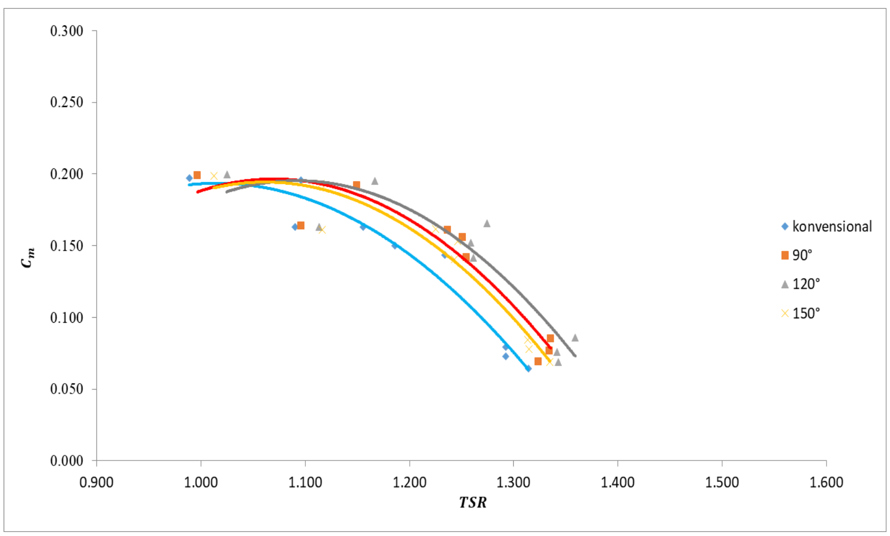
## RESULTS AND DISCUSSION

Angle variations of the Gurney Flap on Darrieus wind turbine were obtained as experimental results ($Cp$) and ($C_m$) (Fig. 4). The results obtained show $Cp$ and $C_m$ values toward TSR. The result showed that all angle variations in increasing the power coefficient, if compared to conventional Darrieus wind turbines, increase until a certain TSR begins to decline. The turbine showed the best performance with Gurney Flap on angle variation of 120° generating the highest power coefficient value of 0.228 at a TSR of 1.166. In addition, the torque coefficient decreases with an increasing Tip Speed Ratio. The turbine with the Gurney Flap at various angles produces the heighest torque coefficient value of 0.200 at a TSR of 1.025.

The results reveal that adding a Gurney Flap lengthens the airfoil chord, which affects the area of wind power extraction. Furthermore, the installation of a Gurney Flap, bubble separation occurs on the trailing edge, which can increase lift force on the airfoil of 120°. At a particular range TSR, the Darrieus with an added outboard Gurney Flap is successful in increasing the $Cp$ with each solidity [14].




(a)




(b)

**FIGURE. 4.** (a) Graph Of The Relationship Of $\boldsymbol{C_p}$ With TSR In Gurney Flap Variation; (b) Graph Of $\boldsymbol{C_m}$ The Relationship Of With TSR In Gurney Flap variations

## CONCLUSIONS

The additional outboard Gurney Flap, as well as angle variations of 90°, 120°, and 150° at the high Gurney Flap, account for 2% of the chord length and influence *Cp* and $C_m$ of the Darrieus wind turbine. Each variation was tested at wind speeds of 7 m/s, 8 m/s, and 9 m/s. The maximum *Cp* and $C_m$ produced by the Darrieus wind turbine with Gurney Flap have an angle variation of 120°. The wind turbine with an angle variation of 120º the maximum *Cp* of 0.228 at a TSR of 1.166.

## REFERENCES


1. M. Hassanpour and L. N. Azadani, "Aerodynamic optimization of the configuration of a pair of vertical axis wind turbines," *Energy Convers. Manag.*, vol. 238, p. 114069, 2021, doi: 10.1016/j.enconman.2021.114069.

2. E. Leelakrishnan, M. Sunil Kumar, D. Selvaraj, N. Sundara Vignesh, and T. S. Abhesheka Raja, "Numerical evaluation of optimum tip speed ratio for darrieus type vertical axis wind turbine," *Mater. Today Proc.*, vol. 33, no. xxxx, pp. 4719–4722, 2020, doi: 10.1016/j.matpr.2020.08.352.

3. M. F. Ismail and K. Vijayaraghavan, "The effects of aerofoil profile modification on a vertical axis wind turbine performance," *Energy*, vol. 80, pp. 20–31, 2015, doi: 10.1016/j.energy.2014.11.034.

4. H. Zhu, C. Li, W. Hao, Q. Ding, and W. Yu, "Investigation on aerodynamic characteristics of building augmented vertical axis wind turbine," *J. Renew. Sustain. Energy*, vol. 10, no. 5, 2018, doi: 10.1063/1.5028198.

5. D. D. D. P. Tjahjana, P. Purbaningrum, S. Hadi, Y. A. Wicaksono, and D. Adiputra, "The study of the influence of the diameter ratio and blade number to the performance of the cross flow wind turbine by using 2D computational fluid dynamics modeling," *AIP Conf. Proc.*, vol. 1931, pp. 2–7, 2018, doi: 10.1063/1.5024093.

6. Y. Zhang, V. Ramdoss, Z. Saleem, X. Wang, G. Schepers, and C. Ferreira, "Effects of root Gurney flaps on the aerodynamic performance of a horizontal axis wind turbine," *Energy*, vol. 187, p. 115955, 2019, doi: 10.1016/j.energy.2019.115955.

7. L. Tianshu and J. Montefort, "Thin-airfoil theoretical interpretation for gurney flap lift enhancement," *J. Aircr.*, vol. 44, no. 2, pp. 667–671, 2007, doi: 10.2514/1.27680.

8. R. H. Liebeck, "Design of subsonic airfoils for high lift," *J. Aircr.*, vol. 15, no. 9, pp. 547–561, 1978, doi: 10.2514/3.58406.

9. Y. Amini, M. Liravi, and E. Izadpanah, "The effects of Gurney flap on the aerodynamic performance of NACA 0012 airfoil in the rarefied gas flow," *Comput. Fluids*, vol. 170, pp. 93–105, 2018, doi: 10.1016/j.compfluid.2018.05.003.

10. A. Bianchini, F. Balduzzi, D. Di Rosa, and G. Ferrara, "On the use of Gurney Flaps for the aerodynamic performance augmentation of Darrieus wind turbines," *Energy Convers. Manag.*, vol. 184, no. September 2018, pp. 402–415, 2019, doi: 10.1016/j.enconman.2019.01.068.

11. S. Salcedo, F. Monge, F. Palacios, F. Gandía, A. Rodríguez, and M. Barcala, "Gurney flaps and trailing edge devices for wind turbines," *Eur. Wind Energy Conf. Exhib. 2006, EWEC 2006*, vol. 2, no. January 2006, pp. 1180–1186, 2006.

12. L. A. Danao, J. Edwards, O. Eboibi, and R. Howell, "A numerical study on the effects of unsteady wind on vertical axis wind turbine performance," *ASME Int. Mech. Eng. Congr. Expo. Proc.*, vol. 6 B, 2013, doi: 10.1115/IMECE2013-62493.

13. R. Howell, N. Qin, J. Edwards, and N. Durrani, "Wind tunnel and numerical study of a small vertical axis wind turbine," *Renew. Energy*, vol. 35, no. 2, pp. 412–422, 2010, doi: 10.1016/j.renene.2009.07.025.

14. H. Zhu, W. Hao, C. Li, and Q. Ding, "Numerical study of effect of solidity on vertical axis wind turbine with Gurney flap," *J. Wind Eng. Ind. Aerodyn.*, vol. 186, no. August 2018, pp. 17–31, 2019, doi: 10.1016/j.jweia.2018.12.016.