Reduces blade shaft deflection with improved mount design to increase vertical hybrid wind turbine performance

E Erwin¹,²*, T P Soemardi², N Ikhsan M Y¹ and K Nugraha¹.
¹ Department of Mechanical Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Indonesia.
² Department of Mechanical Engineering, Universitas Indonesia, Depok, Indonesia.

*E-mail: erwin@untirta.ac.id

Abstract. In a vertical hybrid turbine with a shaft bearing holder on one side, it has a shaft deflection problem that interferes with turbine performance. This study aims to improve the design of the turbine holder. The methodology used in this study is to analyse the deflection behaviour of the turbine when rotating. Next in the turbine design review, and the result is to increase the distance of the shaft holder bearings and increase the bearing diameter in the triangular frame. Deflection testing with the help of tracker software that’s able to measure deflection distance in one field when the shaft rotates. The results of the deflection comparison before and after the design improvement show a significant deflection reduction.

1. Introduction
This study is to optimize the vertical turbine prototype shaft mount design [1]. The factor is fulfilling the vibration boundary conditions represented by deflection values that occur when the shaft rotates and the minimum weight of the structure is fulfilled. The design structure is optimized by planning a design that includes:

a. Revise the seat structure design on the prototype of the wind turbine by increasing rotating stability.
b. Analyse the strength of static structure with Computer Aided Engineering (CAE).
c. Analyse the stability of the top seat and prototype of the wind turbine rotor shaft by measuring deflection in several rpm ranges using the help of Tracker software.

One recent development on superconducting wire to implement in wind turbine wiring is applied of Nano-tube carbon [2]. The development of wind turbine plants in this study is part of the development of renewable energy hybrid plants with thermal biomass systems [3], and other biomass applications [4]. Investigation of rotor support and its influence on deflection and on turbine performance, with blade tips recommendations support and overhang support [5]. The shaft diameter can affect turbine performance due to shaft resistance and surface roughness [6].

InVESTigation of blade structure with overhang support under the workload to obtain a blade structure that is safe to load has been carried out with the result that bending stress and deflection are predominantly caused by centrifugal force [7].

This study aims to obtain a bearing configuration design that can withstand the aerodynamic load of the force from the Savonius-Darrieus hybrid turbine design as shown in figure 1.
The novelty is the design of hybrid structure of *Savonius-Darrieus*, omnidirectional nature and the model of rotation and revolution in the blade [8], along with the newly propose bearing structure included is a novelty too.

To measure the deflection on a rotating shaft due to the load that occurs it takes a measuring instrument that is capable of measuring without using cables; one method that can be done is the method of video analysis and modelling tools. Some mechanical monitoring applications work well using this method of video analysis [9, 10]. Utilization of images taken from mounted cameras to monitor the dynamic motion of turbine structures [11], measure wind turbine deflection with an opto-mechanic platform [12]. In this research video analysis and motion tools, are used to measure deflection that occurs in several turbine rpm rotation ranges.

2. Research methodology

In this study, the method used treatment by subject design which is a study focusing on a complete report and analysing the problems that occur. In this study, attention was paid to the re-approval of the new improvement type seat on the Sultan Wind Turbine V.4.5 and then gave an assessment and compared an old design with a new design in computer-aided design (CAD) software.

![Figure 1. Hybrid vertical wind turbine Savonius Darrieus](image)

Experiment are carried out using the experimental method and data retrieval using a recording camera to record the movement of the rotor shaft and top frame. The data generated is a video of the deflection movement of the rotor shaft and the motion of the cradle of the seat frame.

Data video from experiment is processed using tracker software to get analogue data. Processing with manual tracking method. The results of the data analysis are deflection(x)-time(t) graphs and deflection(y)-time(t) graphs which can then be amplitude of the two designs.

This study uses tools for retrieving the data needed. The following are the test equipment used:

1. Camera.
   Digital cameras function as recording or perpetuating an event. In this study, the camera records the deflection of the rotor shaft and the instability in the turbine seat frame.

2. Tripod.
   Tripod is a tool for placing cameras where we can leave. Tripod functions as an image recording stabilizer that does not move up and down or vibrates

3. Tachometer.
   Tachometer is a tool to detect the rotational speed of a rotating object.

4. Meter.
Measuring instrument to measure the distance of an object to another object.

5. Laptop
   The tool for analyzing design data is designing the top frame framework through Solidworks software and analyzing video data through freeware Tracker software.

3. Improvement Design
Based on the spindle bearing model applied to the turbine shaft, there are several disadvantages to the initial bearing seat design. Design development carried out is to give a distance of 10 cm between the two bearing shaft holders, and enlarge the diameter of the axial bearing on the triangular holder, figure (1). This distance change will also cause friction problems, so it should be noted that this bearing resistance changes [13], Bearing configuration also has an influence on the self starting ability of the turbine [14]. In addition, the shaft diameter also affects the turbine performance, so it is necessary to pay attention to reducing shaft diameter, reducing shaft weight and increasing shaft stiffness.

![Figure 2. Bearing improvement design](image)

Changes in bearing position are expected to increase shaft stability and stiffness when rotating at high rpm.

Experiment for improving stiffness performance are carried out by testing by helping Tracking software to record deflection that occurs during rotating shaft observations.

4. Data Collecting Procedure
Data collecting procedure is:
1. Place the camcorder parallel to the end of the observation point.
2. Take data for a minimum of four hours and a maximum of eight hours to get data that can be processed.
3. Obtain data with Tracker software, display it in a spreadsheet [15].
4. Perform descriptive statistical tests.
   The experiment was carried out by placing the camcorder in front of the wind turbine, and used to record the movement of the turbine when moved by the wind, and data generated by software as shown in figure 2 to 6, below:
Figure 3. Testing the top frame seat of version 4.5

To measure deflection on seat frame, camcorder use the reference point at the right end of the frame as shown in figure 3. Movement data as shown at right top graphic and table below.

Figure 4. Rotor shaft tip tracking version 5.0

To measure deflection on shaft, camcorder take the reference point is at the top end one of the shaft as shown in figure 4. Movement data as shown at right top graphic and table below.
4. Result
The static CAE test on the frame that supports the weight of the turbine showed results a minimum FOS of 4.2, its indicating that this structure is safe in static loading, figure 5.

![Factor of safety distribution](image)

**Figure 5.** Static simulation result

---

![Graph of deflection comparison](image)

**Figure 6.** Graph of deflection comparison that occurs in the top seat at range 50-100 rpm
Figure 7. Graph of deflection comparison that occurs in the shaft tip at 50-100 rpm (a), 100-150 rpm (b), 150-200 rpm (c).
6. Discussion
Vertical turbine performance is influenced by an aerodynamic force consisting of centrifugal force which affects the deflection and bending stress on the top seat, shaft and blade. The blade position of Savonius at the top also contributes to increasing centrifugal force, need to consider lower position but not decrease Savonius performance.

Improvement shaft bearing structure (figure 6) and top seat bearings (figure 5), the deflection on the top seat can be reduced by up to 20.8% and the deflection at the tip of the shaft is reduced by 72.3% at range 50 rpm to 100 rpm, 71.2% at range 100 rpm to 150 rpm, and 53.4% at range 150 rpm to 200 rpm. Vibration adversely affects performance [16], this reduced deflection also reduces the vibrations that occur. With reduced deflection and vibration, the shaft turns smooth and improves turbine performance. A simulation experiment by implementing a tuned liquid column damper can reduce deflection up to 55%, and a tuned mass damper can reduce deflection up to 40% [17].

7. Conclusion
In this study, it has successfully implemented a video analysis and motion tools method to measure deflection in rotating rotors. From the data processing and analysis shows that the new design of shaft bearing holder can reduce deflection at tip of the shaft 53.4%, and top seat 20.8%. This shows that with changes in the shaft bearing holder design and changes in the bottom seat bearing diameter it increases the shaft and bottom seat stiffness and lower the vibration potential. Mounting several bearings on one turbine shaft integrated into one section can give better results to increase stability and shaft stiffness.

Acknowledgment
This research is funded by a grant research program TaDOK (Tugas Akhir Mahasiswa Doktor) Universitas Indonesia no. NKB-0177/UN.3R3.1/HKP.05.00/2019.

References
[1] Erwin E, Surjosatyo A, Sulistyo N J, Meurahindra M T, Soemardi T 2018 The effect of hybrid savonius and darrieus turbine on the change of wake recovery and improvement of wind energy harvesting Journal of Applied Engineering Science 16 (3):416-23
[2] Iman S 2018 Manufacture and Analysis Of MgB2 Superconducting Wire With Addition Carbon Nano Tube (CNT) By In-Situ Mechanical and Production Engineering Research and Development 9 p. 7
[3] Erwin E, Soemardi T P, Surjosatyo A, Nugroho J, Nugraha K, Wiyono S 2018 Design optimization of hybrid biomass and wind turbine for minropolitan cluster in Domas, Serang, Banten, Indonesia. InIOP Conference Series: Earth and Environmental Science (Vol. 105, No. 1, p. 012010)
[4] Satria D, Haryadi, Austin R, Kurniawan B 2016 Design of drying chamber and biomass furnace for sun-biomass hybrid rice-drying machine InAIP Conference Proceedings (Vol. 1717, No.1, p. 050015). AIP Publishing.
[5] Bin LY, Zhang LX, Li EX, Liu XH, Yang Y 2014 Design considerations of rotor configuration for straight-bladed vertical axis wind turbines Adv Mech Eng
[6] Rezaeiha A, Kalkman I, Montazeri H, Blocken B 2017 Effect of the shaft on the aerodynamic performance of urban vertical axis wind turbines Energy conversion and management Oct 1;149:616-30.
[7] Hameed M S, Afaq S K 2013 Design and analysis of a straight bladed vertical axis wind turbine blade using analytical and numerical techniques Ocean Engineering 1;57:248-55
[8] Erwin E 2016 "Omnidirectional Vertical Axis Wind Turbine," Indonesia Patent.
[9] Cadmus Jr R R 1990 A video technique to facilitate the visualization of physical phenomena American Journal of Physics 58(4):397-9
[10] Klein P, Gröber S, Kuhn J, Müller A 2014 Video analysis of projectile motion using tablet computers as experimental tools. Physics Education 49(1):37
[11] Ozbek M, Rixen D J, Erne O, Sanow G 2010 Feasibility of monitoring large wind turbines using photogrammetry Energy 1:35(12):4802-11
[12] Zendehbad M, Chokani N, Abhari R S 2017 Measurements of tower deflections on full-scale wind turbines using an opto-mechanical platform Journal of Wind Engineering and Industrial Aerodynamics 1:168:72-80.
[13] Aso T, Aida T, Seki K 2016 Bearing Resistance of Wind Turbine Generator System Electrical Engineering in Japan 194(2):64-73
[14] Gallego-Calderon J, Natarajan A, Dimitrov NK 2015 Effects of bearing configuration in wind turbine gearbox reliability Energy Procedia 1:80:392-400
[15] Lee B H, Park H Y 2018 HybTrack: A hybrid single particle tracking software using manual and automatic detection of dim signals Scientific reports 9;8(1):212.
[16] Kusiak A, Zhang Z 2010 Analysis of wind turbine vibrations based on SCADA data Journal of Solar Energy Engineering 1;132(3):031008
[17] Rahman M, Ong ZC, Chong WT, Julai S, Khoo SY 2015 Performance enhancement of wind turbine systems with vibration control: A review Renewable and Sustainable Energy Reviews 1;51:43-54