

# An overview of horizontal-axis Magnus wind turbines

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**Abstract.** Magnus force shows extraordinary results in producing lift force, hence gives rise to its application. One of the applications is by replacing airfoil-shaped blades of wind turbine with the rotating cylinder blades. This is known as Magnus Wind Turbine (MWT), where it generates lift force on the rotating cylinder that perpendicular to the incoming wind flows. Due to high consumption of fossil fuel, natural gas and coal that risk our and earth health. Thus to overcome this conundrum, MWT is one of the innovative approaches to harvest the low wind speed energy. This paper presents an overview of the horizontal-axis MWT state-of-the-art.

## 1. Introduction

Sustainable energy is a necessity to meet the current and future generation needs of energy. The basic principle of harvesting wind energy is by converting the incoming wind flow to kinetic energy through mechanical mechanism and using a generator to generate electricity [1–3]. As one of natural resources, wind energy can be used repeatedly and will never be depleted. However, availability of wind energy resources is dependent on the geographical location and topography [4–5]. Nowadays, harvesting high speed wind energy is mainly dominated by horizontal axis wind turbine (HAWT) with airfoil-shaped blades. The airfoil-shaped-blades wind turbine requires a minimum wind speed of 4 meters per second (m/s) to generate minimal power and wind speed of 16 m/s to generate optimum power [6]. Due to this limitation, an innovative type of wind turbines is researched and designed for harvesting wind energy at lower wind speeds that can produce optimum power.

One of the types of wind turbines that can harvest wind energy at lower wind speed condition is the horizontal-axis Magnus Wind turbines (MWT) [7]. The main difference of MWT in comparison to the wind turbine utilizing airfoil-shaped blades lies in the means of extracting wind energy. By utilizing rotating cylinder blades, MWT can harvest wind energy at low wind speed condition. Additionally, the performance of MWT can be increased by enhancing the surface of the rotating cylinder blades. There are several ways that researchers have innovated the MWT rotating cylinder blades performance such as by utilizing dimple and fin [8–9]. Moreover, the use of sandpaper to add surface roughness on the rotating cylinder blades can further improve the torque generated by the MWT rotor [10–12]. Figure 1 shows the MWT with spiral fins coiled around the rotating cylinder blades that has been developed in Japan.

This paper offers an overview of the state-of-the-arts for horizontal-axis MWT that can be used for reference in developing low wind speed wind energy harvester. This paper also aims to uncover some of operational principles surrounding MWT such as with regard to the number of blades and types of surface roughness on the rotating cylinders.



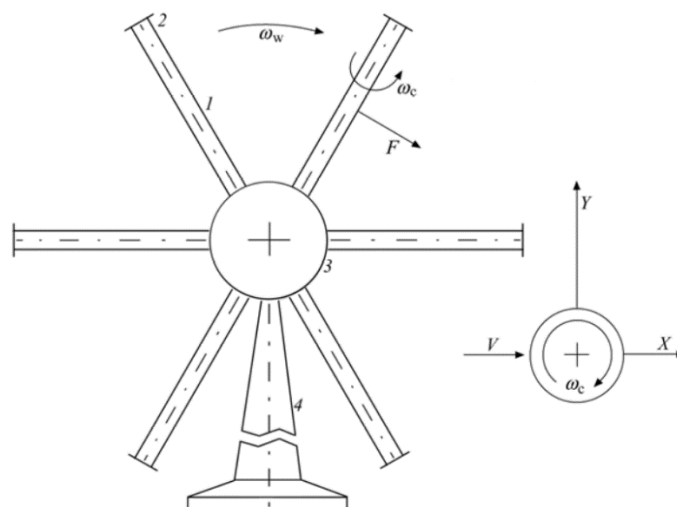


**Figure 1.** Magnus wind turbine with fin-like on rotating cylinder blades [13]

## 2. Magnus wind turbine

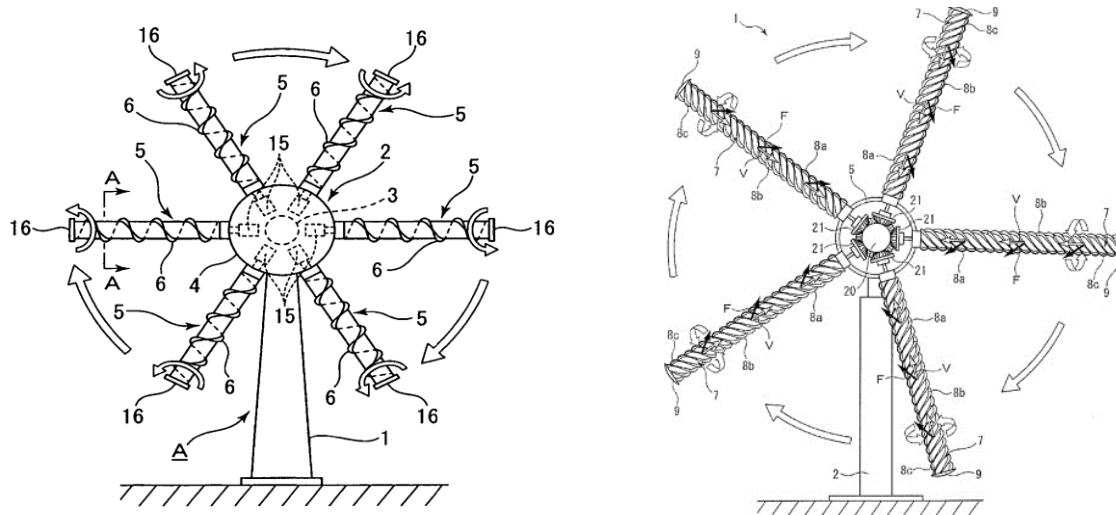
Commonly, a wind turbine with airfoil-shaped blades utilizes and prioritizes a smooth surface blades to produce high lift and optimum power at high wind speed condition. However, the lift performance drops considerably when there are some irregularities to the surface of the airfoil-shaped blades [14]. In addition, high noise level is produced by the wind turbine due to the rotor rotating at a high speed [15]. Hence, the application of MWT as an alternative of the wind turbine using airfoil-shaped blades is taken into deliberation. As the MWT uses rotating cylinder as blade, it can generate high torque and lift at low wind speed condition by further increasing the cylinder blades rotation speed as compared to the airfoil-shaped blades that is limited by the angle of attack. Besides, in comparison with the wind turbine with airfoil-shaped blades, the MWT can also reduce environmental hazard and noise due to a slower rotor rotation [7].

To overcome the drawback of the wind turbines with airfoil-shaped blades, Bychkov *et al.* [7] have demonstrated an experiment on the MWT using 6 smooth rotating cylinders blades with endplates as shown in Figure 2. They have concluded that 6 rotating cylinders blades and the cylinder aspect ratio of 15 are the most optimized for MWT [16]. Moreover, they have proposed that MWT will produce higher performance in low wind speed condition than the wind turbine with airfoil-shaped blades. On the other hand, based on Bychkov *et al.* [7], MWT rotating cylinder blades are designed by using computational fluid dynamics while Mara [17] has offered the rotating cylinder blades design profile characteristics for MWT blades.



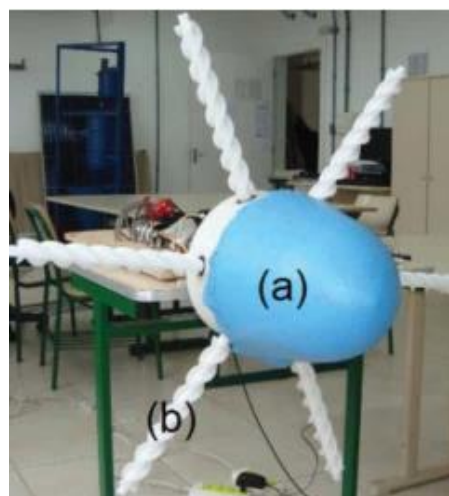
**Figure 2.** Magnus wind turbine with 6 smooth surface rotating cylinder blades and endplates [7]

Murakami and Ito [18] have patented a MWT with 6 spiral fins rotating cylinder blades known as Spiral MWT. Afterwards, they have upgraded the patent for the Spiral MWT with 5 spiral fins rotating cylinder blades [9]. They have demonstrated that the rotating cylinder blades with spiral fins coiled around the cylinder can produce more than 2 times higher lift coefficient and torque as compared to the smooth surface rotating cylinder blades. Figure 3 depicts the Spiral MWT patents from 6 rotating cylinder blades to 5 rotating cylinder blades. Later on, Kato *et al.* [19] and Murakami *et al.* [20] have conducted Particle Image Velocimetry (PIV) experiment to investigate the effectiveness of MWT that uses spiral fins coiled around the rotating cylinder blades.



**Figure 3.** Spiral MWT patents upgraded from 6 to 5 rotating cylinder blades [9,18]

Based on prior patents of MWT using spiral fins [18], the researchers have fabricated MWT model with 6 spiral fins coiled around cylinder blades to find the optimize value of power generated based on the cylinder blades speed rotation [21–23] and proposed an algorithm to control the rotating cylinder speed [8]. Moreover, Corrêa *et al.* [24] have proposed a performance emulator for MWT. Figure 4 shows the MWT model utilized in their performance optimization experiment with an oversized rotor hub.



**Figure 4.** MWT model with spiral fins coiled around cylinder blades [22]

Giudice and La Rosa [25] have presented a MWT prototype that is also developed for harvesting water stream energy known as Chiral Rotor. This MWT prototype utilizes 4 smooth surface rotating cylinder blades and it is designed to harvest energy from water channels like drainage and irrigation. They have concluded that the Chiral Rotor prototype has a great prospect toward hydroelectricity as an alternative to wind energy harvester. Figure 5 shows the Chiral Rotor prototype with 4 short rotating cylinder blades. Moreover, they emphasize that, the Chiral Rotor prototype use smooth surface on the cylinder blades due to the absence of knowledge and research regarding the surface roughness effect on rotating cylinder blades. Meanwhile, Ito *et al.* [26] have investigated a prospect of 3 cylinder blades shaped like Savonius wind turbine with endplates and concluded it as one of the possible combinations as shown in Figure 6.



**Figure 5.** Chiral rotor prototype with 4 smooth surface rotating cylinder blades [25]

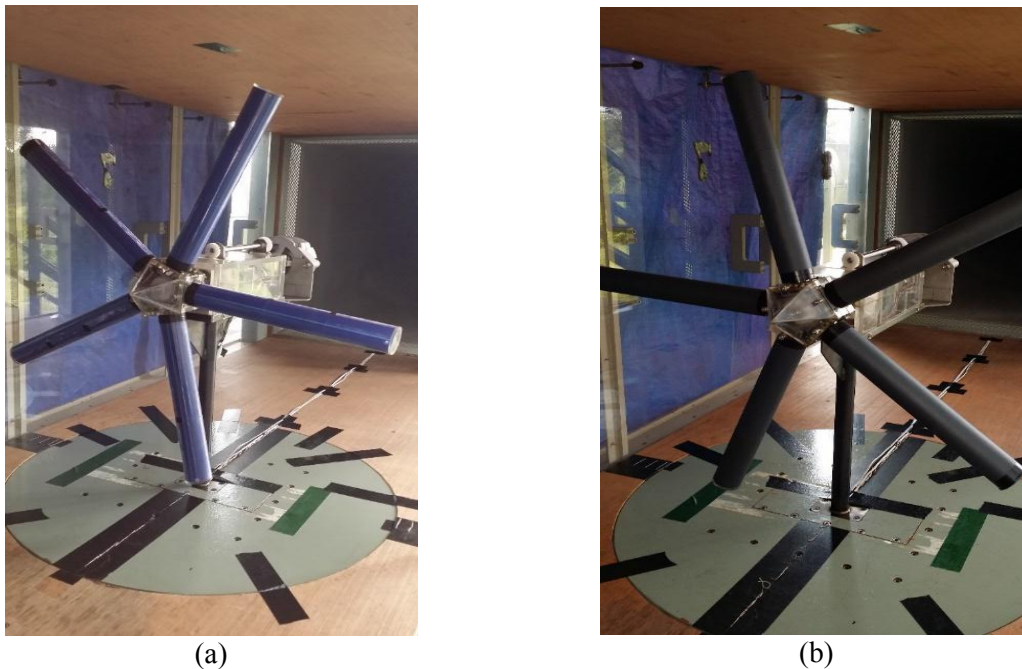


**Figure 6.** MWT with Savonius shaped as cylinder blades [27]

Marzuki *et al.* [10, 28, 29] have investigated the torque performance impact of sandpaper surface roughness types on MWT with 5 rotating cylinder blades. The finding highlights that, as the surface



roughness is changed from smooth to rough sandpaper, the torque produced by the MWT significantly increases up to 5 times compared to that with smooth surface [10]. Figure 7 shows the MWT model without and with sandpaper enhancement inside wind tunnel. Meanwhile, researchers Sakipova *et al.* [12, 30] have investigated the performance of MWT with porous surface roughness with 3 cylinder blades and later on with 2 cylinder blades as shown in Figure 8. In an analysis of the effect of porosity surface on the rotating cylinder, Kussaiynov *et al.* [31] have found that it gives a notable improvement of lift force around 1.5 times in comparison to the smooth surface cylinder.



**Figure 7.** MWT model with (a) sandpaper attachment, (b) smooth [10]



**Figure 8.** MWT with large and short cylinder diameter [12, 30]

There are various researchers that have proposed numerical theories and run analytical analysis on MWT [32–37]. In additional, Ogretim *et al.* [38] have proposed solar enhanced MWT by covering the rotating cylinder surface with solar cells. However, with the absence of MWT experimental approach, restraints must be made when implementing the proposed theories. Sedaghat [33] has reviewed and concluded that, as more experimental study on MWT are being conducted, it will have bright prospect in harvesting wind energy.

### 3. Conclusion

Overall, this overview strengthens the idea that horizontal-axis MWT is feasible as sustainable energy harvester. There are several ways to improve the MWT performance and one of them is by utilizing the surface roughness effect on rotating cylinder that include fins, dimples, groove, porous, sandpapers and so on. Moreover, considering all evidences, it seems that there is no fixed number of cylinder blades for MWT. Despite its exploratory nature, this overview offers some insights into current state-of-the-art horizontal-axis MWTs. Further research could also be conducted to determine the power usage and the power produced from the MWT, and the effect of number of rotating cylinder blades. A reasonable approach to tackle this issue could be to do an experimental research.

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