Wind Turbine Cylinders with Spiral Fins

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***Abstract*- Paper describes the world's first wind turbine system that rotates with cylinders which have spiral-shaped fins coiled around instead of common propeller-type blades. When the spiral cylinders catch the wind, rotating force is generated due to the aerodynamic properties caused by Magnus Effect. On the basis of experiments make by MECARO Co.Ltd it is possible to state that this type of power station is better than propeller type - more effective, cheaper the construction cost and stronger in the strong wind.**

I. INTRODUCTION

The Magnus effect is the phenomenon whereby a spinning object flying in a fluid creates a whirlpool of fluid around itself, and experiences a force perpendicular to the line of motion and away from the direction of spin. The overall behavior is similar to that around an aerofoil with a circulation which is generated by the mechanical rotation, rather than by aerofoil action [1]. In many ball sports, the Magnus effect is responsible for the curved motion of a spinning ball. The effect also affects spinning missiles, and is used in some flying machines.

German physicist Heinrich Magnus first described the effect in 1853, but according to James Gleick [2], Isaac Newton described it and correctly theorized the cause 180 years earlier, after observing tennis players in his Cambridge College.

A. Principle

When a body (such as a sphere or circular cylinder) is spinning in a fluid, it creates a boundary layer around itself, and the boundary layer induces a more widespread circular motion of the fluid. If the body is moving through the fluid with a velocity V the velocity of the fluid close to the body is a little greater than V on one side, and a little less than V on the other. This is because the induced velocity due to the boundary layer surrounding the spinning body is added to V on one side, and subtracted from V on the other. In accordance with Bernoulli's principle, where the velocity is greater the fluid pressure is less; and where the velocity is less, the fluid pressure is greater. This pressure gradient results in a net force on the body, and subsequent motion in a direction perpendicular to the relative velocity vector (i.e. the velocity of the body relative to the fluid flow).

B. Calculation of lift force

The Kutta–Joukowski theorem relates the lift generated by a right cylinder to the speed of the cylinder through the fluid, the density of the fluid, and the circulation.

Equation (1) demonstrates the manipulation of characteristics needed to determine the lift force generated by inducing a mechanical rotation on a ball.

$$F = \frac{1}{2} \cdot \rho \cdot V^2 \cdot A \cdot l \qquad (1)$$

F = lift force
ρ = density of the fluid
V = velocity of the ball
A = cross-sectional area of ball
l = lift coefficient

The lift coefficient l may be determined from graphs of experimental data using Reynolds numbers and spin ratios. The spin ratio of the ball is defined as ((angular velocity * diameter) / (2 * linear velocity)).

For a smooth ball with spin ratio of 0.5 to 4.5, typical lift coefficients range from 0.2 to 0.6.

The lift coefficient can be approximated using the Thin Airfoil Theory or Lifting-line theory.

II. MECARO

MECARO Co. was founded in 1998 as MECARO Akita, and started as the company mainly dealing with designing and manufacturing machinery used in the production line of factories.

Wind changes its course so irregularly in Japan that it is said that Japanese wind "pulsates". Akita is a windy region with the wind blowing from Sea of Japan, and yet almost all the wind turbines standing here are foreign-made.

With the collaboration of the partnership with the government, industry and academia, and four years of trial and error, they were finally able to transform the Magnus theory into the wind turbine. This was a moment when MECARO Akita came into being as the wind turbine manufacturer.

MECARO Co., in Akita Prefecture (in northern Japan) launched large-scale production and sales of the Vortes-model wind turbine, in April 2007. It is the world's first wind turbine based on the principle of the Magnus effect, enabling the turbine to turn using lift generated by spinning cylinders with spiral fins instead of the usual propeller-like blades.

The wind turbine effort of this company in northern Japan, where fairly stiff winds often blow, began when the Akita

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government supplied its founder with information about efforts in Russia [3] (where turbine power generation has been ongoing for years) to use the surface effect for power generation. Mecaro carried out experiments on wind turbine generators and found a way to enhance the Magnus effect on the wind turbine "blade" surface by making "striations" on it.

The effect had been identified several centuries ago in Europe, but Mecaro made an adaptation for wind turbine use wherein "fins" arrayed into a spiral design were added to cylinders that have replaced conventional blades. The five-cylindered product markedly improves wind power generation efficiency even if rotated at a slow pace and furthermore can withstand gale force weather. Moreover, it is responsive to the wind's fluctuations while also being quieter than other turbines available, since the greater lift provided by the fins allows for lower speed rotation of the propellers.

Theoretical analysis had not been fully developed on the Spiral Magnus turbine, so the Japanese firm then contacted the NASA Ames Research Center in California in order to utilize their giant wind tunnel for testing, which was conducted in January and February of 2007. The results verified the efficacy and safety of the system. More improvement work is being carried out with assistance from Kogakuin University as well as the University of Tokyo. Mecaro has obtained patents in Japan and Korea in relation to the Spiral Magnus turbine, in addition to having other applications pending elsewhere.

According to New Energy and Industrial Technology Development Organization (NEDO) which partially subsidized the Mecaro endeavor, there are more than a thousand wind turbine power generators operating in Japan now, but problems such as noise pollution and the need to comply with new building codes to ensure such facilities can withstand typhoons as well as tremors have cropped up recently.

Considering that other Asian countries prone to typhoons, cyclones and other natural phenomena would still want to make use of wind power, it is foreseen that the Mecaro system will soon gain adherents outside of Japan.

The lift of the Vortes is four times that of conventional propeller-type wind turbines, and the turbine operates at any wind speed. Thanks to the greater lift, its rotational speed can be lowered to around 25 percent of that of propeller-type turbines, resulting in lower noise levels.

Its cylindrical, durable blades and low rotational speed reduces this wind turbine's vulnerability to damage caused by aerial objects. In addition, since the spinning cylinders are controlled depending on wind speed, the Vortes can operate without a brake, and there is no concern about excess rotational speed in the case of strong wind--another safety feature. These technical improvements make it possible to install the Vortes even in or near residential areas, where there would otherwise be noise or safety concerns.

Until now, wind power generation has not been considered a viable investment for electricity generation except for large megawatt-scale turbines. In the case of a 10 kilowatt turbine (equivalent to electrical power consumption of five or six typical households), however, the Magnus wind turbine has succeeded in reducing the power-generating cost to 45 yen (about U.S. 38 cents) per kilowatt, below the cost of solar power generation.

III. Propeller Type Wind Turbine

A common propeller type wind turbine catches wind by the propeller-shaped blades, and rotate the rotor Fig. 1.

Propellers pick up the wind and generate aerodynamic lift Fig. 2 (lifting force / rotating force). Fig. 3 shows influence of Wind Flux Distribution.

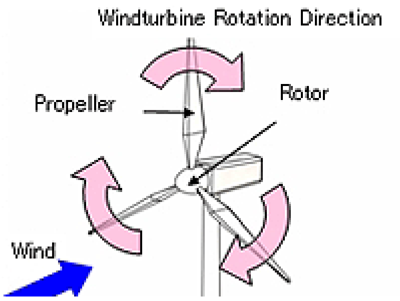

Figure 1. A common propeller type wind turbine.

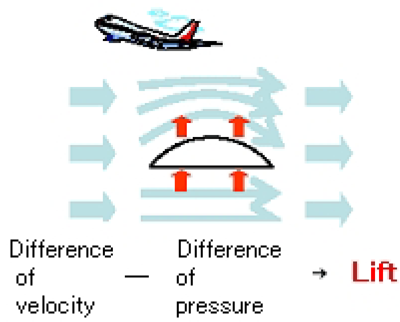

Figure 2. Aerodynamic lift.

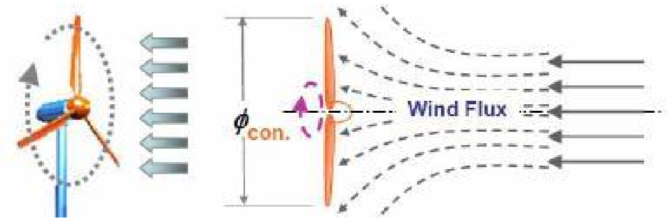

Figure 3. Influence of Wind Flux Distribution.

IV. Spiral Magnus Wind Turbine

Spiral Magnus is the world’s first wind turbine system that rotates with cylinders which have spiral-shaped fins coiled around instead of common propeller-type blades. When the spiral cylinders catch the wind, rotating force is generated due to the aerodynamic properties caused by Magnus Effect. With this principle applied, Spiral Magnus is a product with high power generation capability and safety.

Each of the five blades (cylinders) of Spiral Magnus Wind Turbine spins driven by the built-in motor and wind blowing through the cylinders rotates the rotor (Fig. 4).

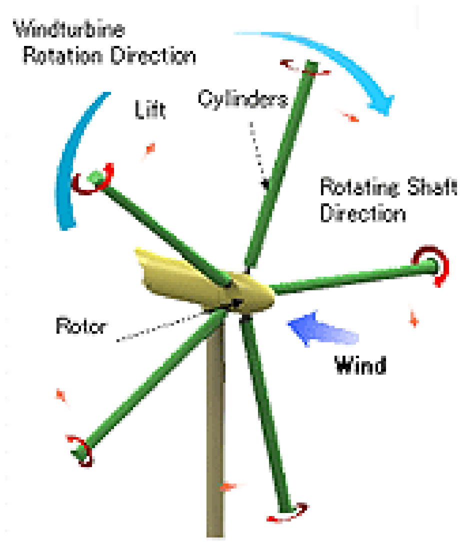

Figure 4. Spiral Magnus Wind Turbine.

This system uses a mechanism to generate more lift (lifting force / rotating force) from the wind power captured by the cylinders by effectively utilizing the aerodynamic properties of Magnus Effect (Fig. 5).

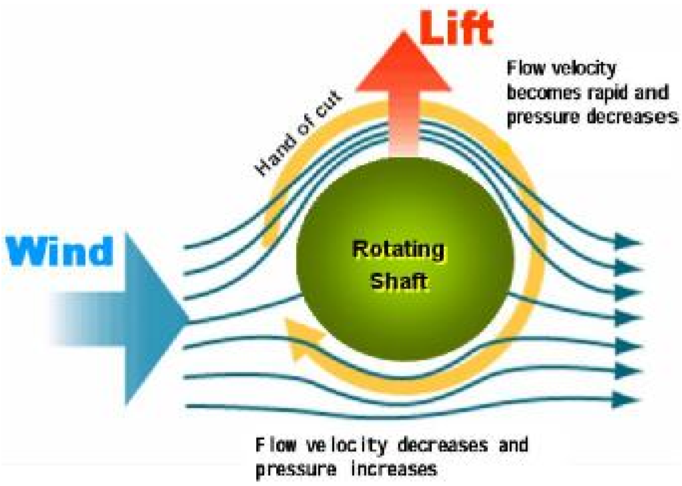

Figure 5. Aerodynamic lift of Magnus Effect.

Each cylinder alone can produce small power, but the five cylinders working together can generate enough power to rotate the wind turbine that has a heavy generator in it. The aerodynamic lift force works in the same way on a propeller-type wind turbine and an airplane although the force is created differently. Fig. 6. shows influence of Wind Flux Distribution.

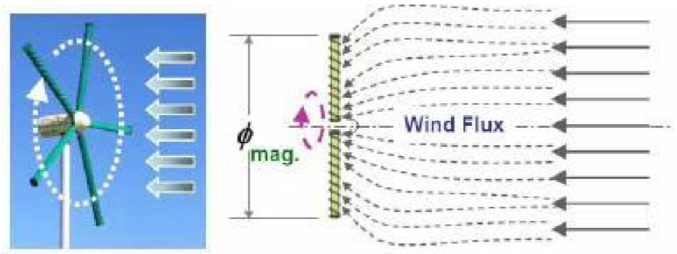

Figure 6. Influence of Wind Flux Distribution.

V. History

The first application was a power ship. 1852 A German scientist Heinrich Gustav Magnus discovered the phenomenon of the Magnus Effect. 1926 A German-born aviation engineer Anton Flettner built a rotor-ship harnessing the power of Magnus Effect to make the ship move, and made a successful voyage across the Atlantic (Fig. 7).

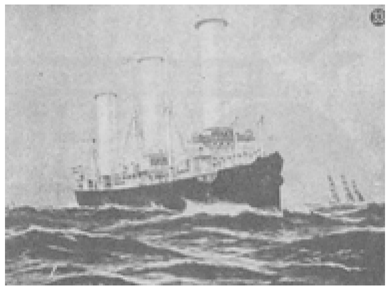

Figure 7. Anton Flettner's rotor-ship.

1983 The Barrel-blade windmill experiment in U.S. (Fig. 8)

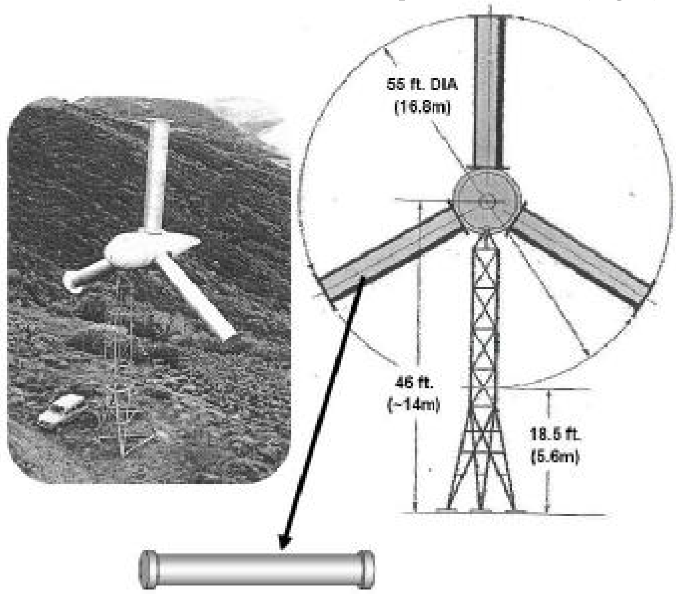

Figure 8. Hanson's Wind Turbine.

Since then, many countries have tried to develop the cylinder-blade windmill, but have not been successful to put into practical use. There was a problem to overcome that the smooth surface of the cylinders required top speed spinning of the cylinders, which consumed more power than the wind turbine could generate.

MECARO tried to solve this problem by coiling the spiral fins around the cylinders, and tested at Akita Prefectural University (Fig. 9).

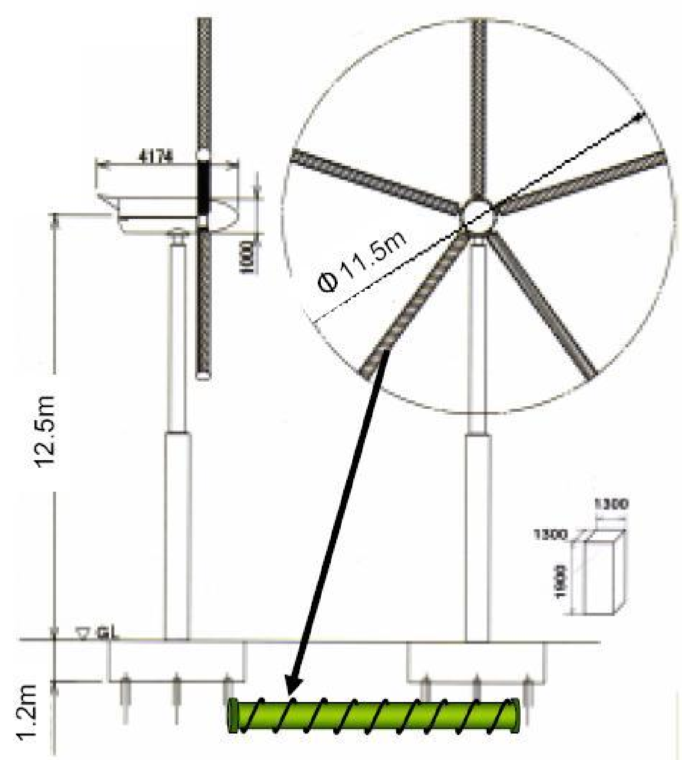

Figure 9. Spiral Magnus.

Result was that lifting forces gained from the spiral cylinders was several times larger than those from non-spiral cylinders (Fig. 10).

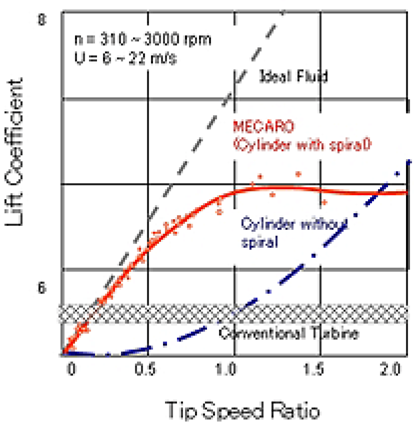

Figure 10. Data per one cylinder.

That is because the spiral fins capture more of wind stream, and effectively harness the wind as the lifting force. Based on this finding, there were good possibilities that they might be able to develop an efficient wind turbine that is safe and stable with low rotational speed, and yet capable of generating high power. From this point, we set out our long, process of trial and error and evolution.

VI. Application

Spiral Magnus is less intimidating because rotational speed is about a one-sixth of common propeller types. Noise level is so low that you can hardly hear it through the breeze of natural wind. There is less chance of bird strike because of the slow rotational speed.

The rotating cylinders (blades) have excellent power generating stability since they are automatically optimized to various wind velocities for efficient wind capturing. The generating capacity is determined reflecting Japan characteristic wind pattern of fluctuating air stream and wind velocities, based on actual field data accumulated through proof tests at Ogata Village, Akita.

There are two possibilities of connection to system:

1) On-grid System (Interconnection Type) - system interconnects Commercial Power Supply, working as Sub Power Supply for Factory or Building

2) Off-grid System (Stand Alone Type) - system is working as Stand-alone Type Power Supply, or Emergency Power Supply.

VII. Conclusion

The experiment plant of 11.5 m in diameter was constructed in the Akita Prefecture Ogata village Japan for the proof of the power generation efficiency of a new Magnus Windmill.

There is a big feature that a new Magnus Windmill is better than past propeller type wind power generation the power generation efficiency and cheaper the construction cost. A wind turbine with Magnus effect can be used in a wide range of wind velocities including storm winds.

Application of the Magnus Effect is a relatively new area which still leaves plenty of room for analysis to be made. In parallel with commercializing product, MECARO will continue to work on the analysis through the joint research with Tokyo University and Kogakuin University in their pursuit of product innovation. How can be further improved efficiency? What shape shall be ultimately perfect? These are the questions we are seeking answer for.

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