An Experimental Study on a Windheat Generation System with a Savonius Wind Turbine

Y. J. Kim, Y. S. Ryou, G. C. Kang, Y. Paek, J. H. Yun, Y. K. Kang

Abstract: A windheat generation system with a Savonius windturbine was developed and the performance was evaluated through field tests. The system consisted of a heat generation drum, heat exchanger, water storage tank, and two circulation pumps. Frictional heat is created by rotation of a rotor inside the drum containing thermo oil, and was used to heat water. In order to estimate the capacity of this windheat generation system, weather data was collected for one year at the site near the windheat generation system. Wind Power from the savonius wind turbine mill was transmitted to the heat generation system with an one-to-three gear system. Starting force to rotate the savonius wind turbine and the whole system including the windheat generation system were 1.0 and 2.5 kg, respectively. Under the outdoor wind condition, maximum speed of the rotor in the drum was 75rpm at wind speed 6.5 m/sec, which was not fast enough to produce heat for greenhouse heating. Annual cumulative hours for wind speeds greater than 5 m/sec at height of 10, 20, 30 m were 190, 300 and 1020 hrs, respectively. A 5℃ increase in water temperature was achieved by the windheat generation system under the tested wind environment.

Keywords: Wind Energy, Windheat Generation System, Heat Generation Drum, Savonius Wind Turbine, Fluid Frictional Energy

Introduction

Recently fossil-fuel price increases every year that put a lot of burdens to greenhouse farmers. Thus, this expensive heating cost demands urgent energy saving technology developments for greenhouse, where energy can be saved either by increasing thermal efficiency of heating equipments or using substitute energy for fossil-fuel. Improving thermal efficiency of existing heating equipments has some limitations-most heating equipments for greenhouse heating already reached nearly maximum thermal efficiency such as recovering heat from (Kim, 2004). We invented two types of exhaust heat recovering heat exchanger and they are disseminating in the greenhouse farming complex in Korea. However, this conventional energy saving technology innovation could not be a fundamental remedy for conventional fossil-fuel consumption practice of greenhouse heating, though it can cut fossil-fuels cost by 10 to 20% Alternative energies for agricultural production are solar thermal, solar cell, and wind energy. Recently geothermal energy also can be categorized in this context. Solar energy has been the most promising alternative energy so far that has been used for drying and supplemental heating greenhouse, especially soil bed heating. However, solar thermal quality and quantity in the greenhouse heating season, early autumn to late spring, could not be reasonably justified when we consider the required costs including solar collectors and facility installation and their maintenance problems caused by seasonal use and technical reliabilities of the facility installation. Geothermal usage and solar cell electricity production have also the same difficulties : costly installation prices and thermal aspects.

In the view of broad picture, wind energy, like biomass, is another form of solar energy, and it is created by temperature difference of earth air movements. But, wind is quite different from solar thermal energy or solar radiation where solar energy is available only sun is on sky, however, wind energy can be extracted in anywhere and anytime regardless of sun's presence. Mankind history has been shown that human has been used wind energy for many purposes-navigation power for ships, power for grain milling, water pumping for irrigation, recently electricity production using wind turbine and so on. Fossil-fuels are depleting rapidly in this century, and future of mankind civilization

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based on massive fossil-fuel consumption is unpredictable that have some countries develop wind energy technology. So far, some European countries have accomplished a lot and are providing some portion of electricity demand of their countries with wind power generation system.

Some wind power generation systems have been installed in Korea also, mainly Jeju island. And, more wind power generation systems are building and will be built in the wind potential abundant areas including islands, seashores and highland area. But, those are just for electricity production purpose.

Transformation of wind power to heat can be achieved either by a hydraulic circuit in which wind energy is used as a power source pressuring fluid or by a heat generation drum where frictional fluid is used to create heat. In this aspect, utilization efficiency of wind power is superior to that of solar or any other alternative energy. At this time wind speed of 3 m/sec or above can rotate a wind turbine for generating 10 kW of heat, but with less wind speed 10 kW heat can be easily achieved in the area of direct transformation of wind energy to heat. According to Mohri et al. (1982) the wind power system consisted of hydraulic circuit and vertical axis wind turbine could produce accumulative energy of 24.19 MJ/year at average daily wind speed of 8.1 m/sec and 3.59 MJ/year at 4.3 m/sec, at which the energy transformation efficiency was 68% exceeding the theoretical maximum efficiency, called Betz limit, of 59%, for horizontal axis wind turbine. The study conducted by Matzen (1978) reported that the wind power with a water brake could produce 67℃-130 ℓ of hot water for a long term outputting 25,000 kW in a year, and he developed experimental equations employing relationships between rpms and diameters of water brakes and powers.

Last few years our research team has been worked on windheat generation system (WGS). And, we had some meaningful research outputs in which we have developed a WGS consisted of a heat generation drum (HGD), a rotor and stator, thermal oil and a motor. With rotating the rotor by the motor-instead of wind power-in the drum containing thermo oil, the heat generation system could produce 32,760 kJ/hr of heat in the form of hot water through a flat plate type heat exchanger. In order to use this WGS in the actual atmosphere condition, we could only replace the motor to wind turbine. In this paper, we have tested and discussed the WGS under actual climate condition for a period of one year.

Materials and Methods

1. Windheat generation system

Figure 1 shows the windheat converting system that is composed of a HGD, heat exchanger, motor and inverter, two circulation pumps, water storage tank, a savonius wind turbine, a coupling, and a power transmission gear. The WGS system was located in the National Institute of Agricultural Engineering, Suwon, Korea. Savonius wind turbine was selected in this study since vertical type wind turbine is proper for extracting small power from wind energy and easy to construct and transfer to power mechanical devices such as this kind of wind energy-heat generation system. Another vertical type wind turbine is Darrieus type that was tested and showed no better performance than savonius type.

Principle of heat generation is that rotor rotating by wind power makes friction heat with the working fluid in the drum. The generated heat is transferred to the circulating water that is stored in a tank for later use.

Amount of thermo fluid in the HGD was about 60 liters and is the same as in the previous research conducted in the National Institute of Agricultural Engineering (2002, Kim et al.). Heat exchanger was a plate type and its heat transferring capacity was 84,000 kJ/hr. The heat generation system was developed and tested in the first project of this research (Kim et al. 2001). According to the performance test the heat generation system could provide 31,500 kJ/hr at motor speed 600 rpm and water circulation rate 500 ℓ/hr. And, electric power consumption was 14 kW resulting out 62% of power efficiency. At this experiment, we subst-

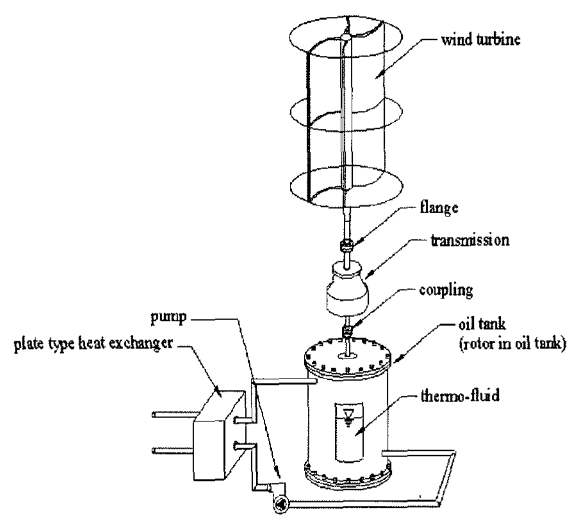

Fig. 1 Heat generation and exchange system.

ituted the motor for the savonius wind turbine to use wind power and generated windheat with the system. Connection between savonius wind turbine and the heat generation system was accomplished an epicycle gear, gear ratio of one to three (Figure 2). Dimension of the Savonius wind turbine was determined after investigating the curve of heat generation amount versus wind speed (Solar energy Handbook, 1991), where the diameter and height were decided as of 180 cm and 600.8 cm, respectively. It has four rotors made of stainless. Temperature was measured at the center of the drum, ambient temperature was measured at one point, wind speed was measured at 10, 20, 30 m above ground near the system.

2. Weather data Analysis

Weather data, i.e., wind speed and hours, is crucial to utilize this type of mechanical power conversion system in the farm sites, so we located NRG weather system just besides the WGS. Weather data including three points wind speed at 10, 20, 30 m above ground level were collected by NRG weather data system. The wind speed data were collected every five minutes and stored the NRG logger 9300SA stand alone logger (NRG Systems, Hinesburg, VT 05461, USA). The NRG system and the WGS are shown in Figure 3. In this experiment, we have used the wind speed data at 10 m in the NRG system.

Results and Discussions

1. Performance of the windheat generation system

Rotor speeds were measured when wind impacted the wind turbine. Starting force to rotate the wind turbine was measured by a digital balance with or without the lower part of WGS, in which the starting force was 0.5～0.7 kg_f for the whole system and 0.2～0.4 kg_f for just the wind turbine only. It seemed a very little force was needed to move the WGS and that indicted the system was built with no mechanical obstructions. Theoretical analysis on the wind power received by the wind turbine will be discussed in later opportunity after wind tunnel test of savonius wind turbine would finished.

As shown in Figure 4, the wind turbine started to rotate at wind speed 1.5 m/sec where wind turbine speed was about 7 rpm and the rotor in the HGD was about 20 rpm at the epicycle gear ratio of one to three. As wind speed increased, the rotor speed increased proportionally. When the wind speed measured was 6.5 m/sec the rotor speed was 70 rpm which was not fast enough to generate substantial heat to get hot water. According to the motor driven heat generation experiment, the system could provide 32,760 kJ/hr at the best heat generation condition (Kim et al. 2002).

A regression equation, Y=11.227X, where, Y is rotor speed and X is wind speed, m/sec, depicted the relationship between wind speed and rotor speed (Figure 4) .

2. Thermo oil temperature increases by wind power

Thermo oil temperatures were measured on the particular day, may 1st, 2002. Figure 5 shows the temperature changes of thermo oil inside the HGD along with variations of wind speed.

The highest wind speed was about 3.5 m/sec on the may 1, 2002, and wind speed varied a lot in a single day from 0.4 to 3.5 m/sec. As wind speed increased, the temperature of thermo oil in the HGD increased after some time intervals. Thermo oil temperature in HGD reached 22℃ on the time of around 18:00 hours, but the same oil on the

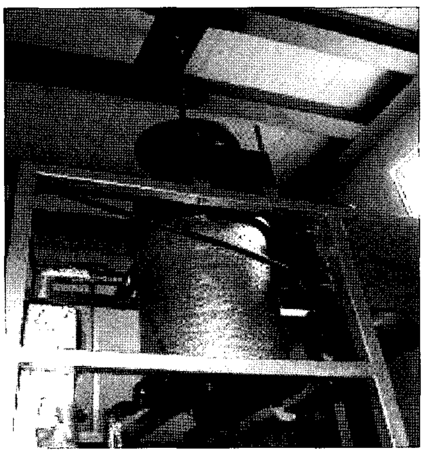

Fig. 2 View of gear box and HGD.

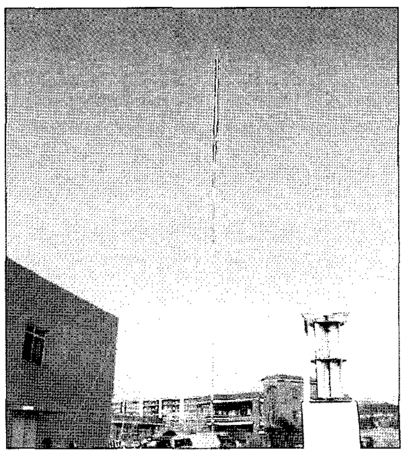

Fig. 3 View of NRG weather system and the WGS.

outdoor was 16℃, resulting 6℃ temperature difference due to wind energy the WGS. As mentioned in Figure 4, 70 rpm at wind speed of 6.5 m/sec is not good enough to provide any meaningful heat we have expected.

If we can get substantial heat, in the form of hot water, number of rpm shall be at least over 300 and temperature increase in the HGD shall be, at least, 10℃ and greater. According to the previous study (Kim, Y. J. 2001) for this research, we observed that 10℃ or greater were gained by the same experiment apparatus with motor driven HGD when the rotor speed was 300 rpm and greater. Since, the temperature gained, 6℃, by wind energy shown in figure 6 seems not big enough to be extracted by water circulation, so we gave up to quantify the heat amount. By this outdoor test of the WGS, we thought we needed more weather data to design appropriate WGS system.

3. Estimating wind energy resource for the WGS

As basic information for designing WGS we have collected weather data with NRG weather system for one year at the WGS site. Figure 6 shows some representative wind speed variations in the month of March, April, October and November, at 10 m height from ground level. As a whole, winter season's wind resource was better and greater than those of summer in terms of winter quality and quantity.

However, by glancing at the graph it is hard to quantify useful wind resources so we made Figure 7 that shows wind energy resources by cumulative hours of winds speeds.

At 10 m height from the ground level, yearly cumulative hours of 3 m/sec or greater wind speed was 1,081, at 20 m 1,659 hours, and at 30m 2,105 hours, which implies that as taller the wind turbine or positioning it at higher place, it could harvest more wind power. If we could operate that WGS for 1,081 hours in a year in order to supply hot water for greenhouse purpose and we could build an efficient wind turbine to run the WGS at wind speed of 3 m/sec or above, it would be a new way to heat greenhouse in this time of energy crisis.

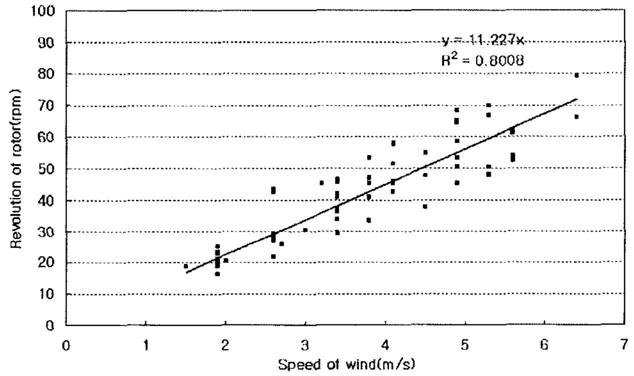

Fig. 4 Relationship between wind speed and rotor rpm of WGS.

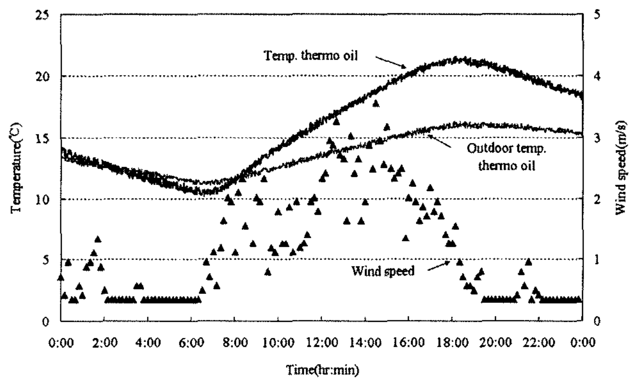

Fig. 5 Temperature changes of thermo oil in the HGD and wind speed.

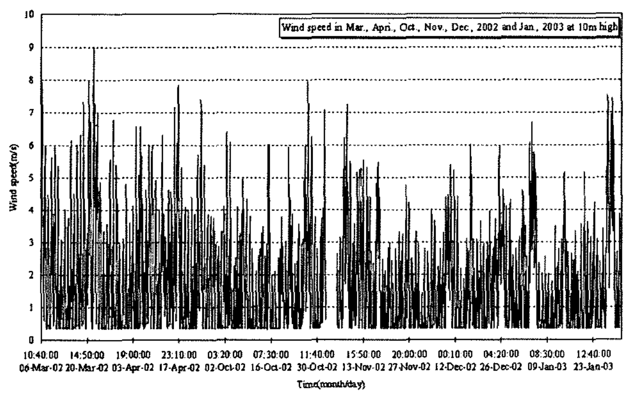

Fig. 6 Weather data collected by NRG weather system in the WGS site.

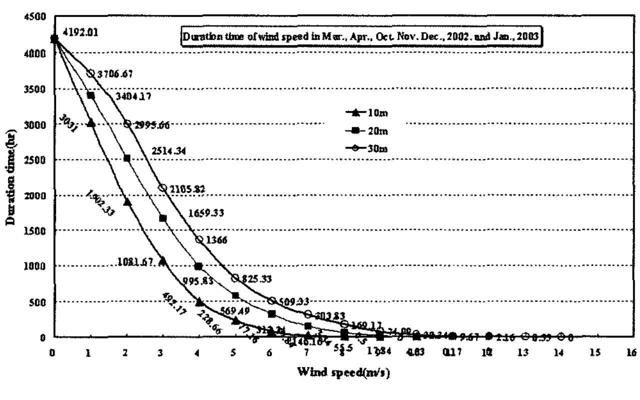

Fig. 7 Yearly cumulative hours of wind speed.

Conclusions

A windheat generation system was built that consisted of a savonius four-impeller wind turbine, heat generation drum and two circulation pumps. The windheat generation system was tested under outdoor weather condition for a year to obtain heat water with wind power. And, NRG weather data monitoring system was installed to collect wind speed data of the windheat generation system site. Savonius wind turbine of 180 cm in diameter and 600 cm in height and a power transmission gear of one to three gear ratio was not good enough to produce hot water by the windheat generation system. Only 6℃ temperature increase by the wind power was monitored in the windheat generation system. The reasons were that the size of savonius wind turbine and the epicycle gear system were not proper for converting wind power to heat water under the test site weather condition. However, temperature increase of thermal oil in the heat generation drum was measured as of 6℃ in a certain day. At 10 m above the ground, yearly cumulative hours of 3 m or higher wind speed was 1,081, at 20 m 1,659 hours, and at 30 m 2,105 hours, which implies that as the taller wind turbine or positioning it higher place, it could convert the more wind power. If we could operate that WGS for 1,081 hours in a year in order to supply hot water for greenhouse heating and we could build an efficient wind turbine to run the WGS at wind speed of 3 m/sec or above, it would be a new way to heat greenhouse in this time of energy crisis.

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