# Maintenance robot for wind power blade cleaning

Minseok Jeon [1], Byunggon Kim [1], Sora Park [1], and Daehie Hong [2]*

[1] Department of Mechanical Engineering, Korea University, Seoul, Korea
[2] School of Mechanical Engineering, Korea University, Seoul, Korea
*Corresponding author (dhhong@korea.ac.kr)

**Purpose** Recently, wind power systems have increased in size as a function of economics of scale and they have become large offshore complexes. Approaching a wind power blade is very hard because not only are the blades set up at the sea but also the winds are very high. Nowadays wind power blades are cleaned by people using ropes and a small water jet. The operation is dangerous and inefficient. Therefore, we need a robot for blade maintenance. **Method** In order to keep the wind power system reliably in operation, both the moving robot mechanism on the blade's curved surface and the bladeclean-up mechanism for maintenance repair are needed. The moving robot mechanism on the blade's curved surface looks like INCHWorm, and it can move vertically on the blade. The vertical moving robot is loaded with a clean-up robotic mechanism. The blade clean-up mechanism on the vertical moving robot can clean the blade surface using a water jet, and brush. The water jet sprinkles water on the blade and cleans the surfaces. The brush moves horizontally and cleans the blade curve surface. **Results & Discussion** This paper suggests the blade-clean-up mechanism robot for maintenance of wind power blades. Not only is this robot automatically workable for blade cleaning, but it also saves time.

***Keywords***: *maintenance, cleaning, robot, rotor blade, wind power system*

## INTRODUCTION

Due to the declining reserve of the oil and accelerating global warming, people started developing various kinds of alternative energy. Among them, the wind power generation is in the spotlight now because, unlike existing generation systems which use fossil fuels or uranium, it is free from air pollution or radiation leakage. This is because the power source of the wind power generation is wind itself, which never gets exhausted and is obviously environmentally-friendly. Capacity of the Wind power generator around the world is growing gradually, as statistics show at Figure 1. This implies both the number and the scale of wind power plants are on increase[1]. While demand of the wind power plant grew, needs for power plant management and cleaning services also rose. Wind power farms these days are moving from lands to offshore regions because winds are stronger and more spaces are available for the construction of power plants at offshore areas. However, management and cleaning of the power plants become hard due to the decreased accessibility when aerogenerators are located offshore areas. Therefore a robot system which automatically cleans and maintains the wind power blades is needed to improve efficiency and safety.

To solve this problem, various researches are in progress right now. One of those researches are RIWEA robot made by Norbert Elkmann[2]. RIWEA robot inspects the blade by using thermographs, ultra sonic, and high resolution camera, then analyzes its status by digits collected from inspection process.

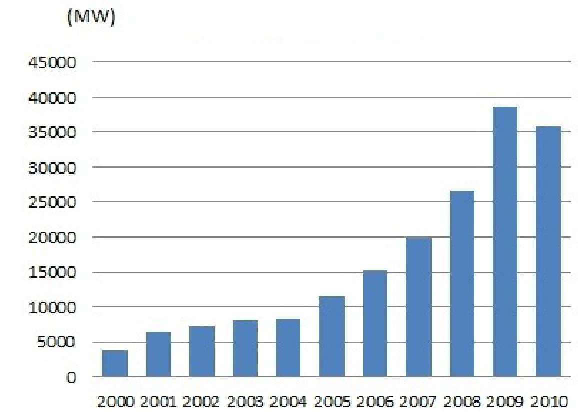



*Fig. 1. Global Annual Installed Wind Capacity 2000-2010*[1]

Furthermore, RIWEA robot can inspect bonded spar joints, leading edges, and trailing edges by using non-destructive inspection system. RIWEA robot can be utilized in blade cleaning because the robot can be fastened to the surface of the blade, regardless of the figure, and can move the blades using wire. RIWEA is an open frame concept robot which uses four ropes to move up and down. It has five main parts automatically adjust to the blade surface during its move. However, there are chances where RIWEA robot can misjudge contaminated parts of the blade as cracks.

'Extreme Wind Services' of British company is a blade cleaning robot that already exists. Extreme Wind Services use brush, water jet, and camera to clean blades. However, Extreme Wind Services requires cranes at ground and needs personnel to control it.

*Fig. 2. Dirt Affected Blade*[4]

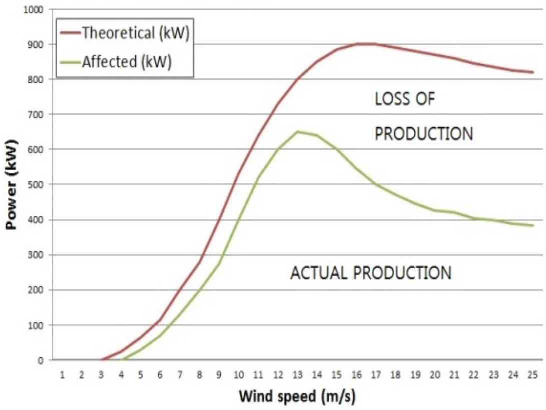



*Fig. 3. Power Curve Typical 900 kw Turbine*[10]

Dirt covering the blade can affect aerodynamic performance of it[3]. Fig.2 shows a bug on the blade[4]. This picture was taken at Magallon26 wind power farm on May, 2005. This single bug can cause double stall effect, which leads to partial loss of theoretical power production [Fig. 3]. This 'dirt' includes flying plankton, mosquitoes, oil, ice, dust, marine salt.

Lengths of the blade are getting longer and locations of it are moving toward offshore areas rather than the lands. However, offshore areas make it harder to clean blades because of the accessibility.

The main purpose of the blade robot designed in this paper is to clean the blades. Those parts that require extra attention are making the robot adjust to the curved configurations of the blade. The robot soaks dirt in water by using water jet and cleans the surface using brush. The water jet can also eliminate certain dirt, and thus makes the process more efficient. In order to move vertically, the robot fastens the wire to brush frame and use crane in nacelle to move. Brush, moving left and right at the brush frame allows the robot to move horizontally. RIWEA is focused on inspection blade. But Blade Cleaning Robot in this paper is focused on cleaning blade. Therefore Robot's cleaning function was designed more efficient then RIWEA.

**WIND POWER BLADE CLEANING OF EXISTING**

(a) Manual Cleaning

(b) BladeCleaning[4]

(c) EXTREME Wind Services[8]

*Fig. 4. Wind Power Blade Cleaning of existing*

A person climbs up and uses water jet to do the manual cleaning as showed in Fig.4-(a). A person tides the wire through the nacelle and uses the wire to move the blade up and down. Turbine should be stopped and no wind should be blowing at this moment. At least 3 personnel are needed at this cleaning process. It takes 4 hours to clean each blade. Losing power is caused due to the stoppage of turbine while cleaning. Lots of jeopardies exist in this cleaning process, so labor costs are expensive. Furthermore, the capacity and tools of the personnel could affect the result.

Fig. 4-(b) shows another method of cleaning. Install a water hose on the pillar, and spray water with detergent. While blade rotates, dirt on its surface would move toward the blade tip by the drag effect[6]. Therefore, the blade gets cleaned[7]. However, a pump is required to pump up all the water from ground to wind power rotor through the pillar. Water moves by centrifugal force which is formed by the rotation of

blade so flow of the water is slow. Therefore this cleaning method is somewhat limited.

Extreme Wind Services can do video analysis, cleaning, non-destructive testing, and blade repair by using crane at ground[8]. Fig. 4-(c) shows it. The brush to blade pressure is closely monitored using laser sensors; this is so that the brush pressure against the blade is applied. Range of the cleaning differs due to the size of the blade, as cleaning tools go up by the cranes. There could be safety problems as personnel should board on the crane and control it.

## Blade Cleaning Robot

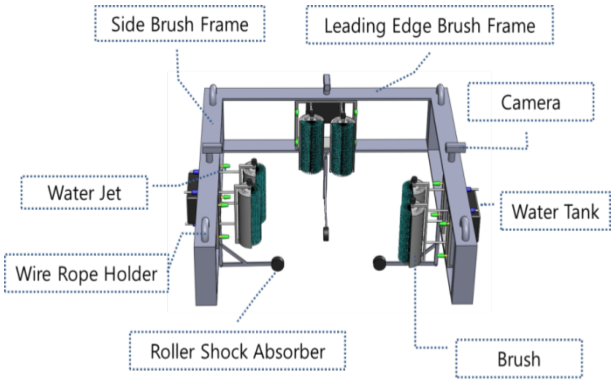



*Fig. 5. Blade Cleaning ROBOT Composition*

Blade cleaning robot is composed of side brush frame, leading edge brush frame, camera, water tank, water jet, wire rope holder, roller shock absorber, and brush (Fig. 5).
Leading edge frame is a frame that guides the brush that cleans leading edge part of the blade. Side brush frame is a frame that guides the brush that cleans both sides of the blade. There are all 3 of them. Cameras are located 1 at the leading edge brush frame, and two at the side brush frame. Water that the brush and water jet use are from water tank, and the limit is up to 350L. 4 Water jets are in 1 brush module. There are all 6 brushes, 2 brushes at each frame. There are all 4 Wire rope holders at frame side. Wire ropes use hoist at the nacelle to move the robot up and down. There are all 3 roller shock absorbers at the middle of the frame. The roller shock absorber consists of rubber roller, absorber and spring.

### 1. Procedure of cleaning

Blade cleaning robot goes up by dropping 4 ropes from nacelle down the power generator and connecting them to the wire rope holder. If the blade is located on land, personnel will do the connection at the ground. If the blade is located on offshore, personnel will do the connection at the deck. When the roller shock absorber is well slung over the fins of the blade, in order to figure out the location, starting point of the rope should be marked. Robot goes up spraying water overall using water jet. Brush cleans the surface of the blade using water from the water jet. It goes up checking the condition, whether it is well cleaned and whether there are any cracks on the surface of the blades. If the robot detects any cracks, it memorizes the height by counting the number of hoist rope rotation. If it gets to the blade tip or the base, the primary procedure is done. The robot goes down untying rope, which is the start of the secondary procedure. The robot remembers the condition of the blade at the primary procedure, and goes down to the parts that need to be cleaned more. When it gets down, it starts the secondary cleaning. The robot can go up the 5MW level blade (65m~70m) in about 12 minutes, as it can move vertically 0.1m/s. Each desorption and installation of the blade take 20 minutes, so considering all the time that procedure needs, it only takes 64minutes per 1 blade to finish the cleaning procedure. This is possible that cleaning time save 3 hours than manual cleaning.

### 2. Part Concept Design

*2.1 Roller Shock Absorber*

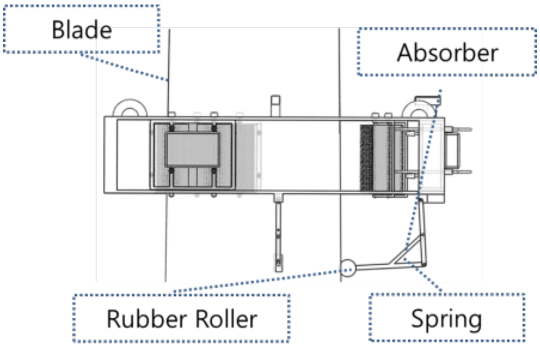
Roller shock absorber offsets the vibration which is caused when the robot moves vertically by the rope. It prevents the blade from any damage, which can be caused if the wind blows and the robot wobbles so frame crashes into the blade. Shock absorber weighs from 440kg to 145,000kg. Absorber and spring are attached right down the leading edge brush frame and side brush frame so that it can move vertically, maintaining certain space between itself and the blade figure. Furthermore it uses rubber roller to prevent any damage to the blade when moving up and down.

*2.2 Brush- Water Jet Module*

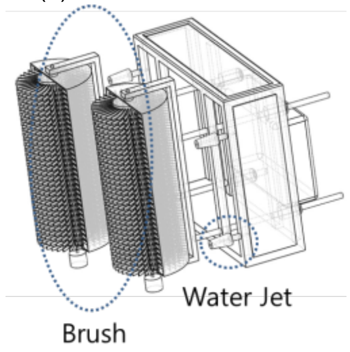
There are all 3 brush-water jet module, 1 module at each leading edge brush frame and side brush frame. There are 2 brushes and 4 water jet nozzle at brush-water jet module. Injection pressure of the water jet can be regulated from 0 to 145bar and make it possible to clean certain contaminated areas intensively at the secondary cleaning procedure. When at the middle of the secondary cleaning procedure, only 1 out of 4 water jets is used. Brush is made up of nylon, which don't damage the blade surface. DC motor, rotating 120RPM drives the brush. Razor sensor makes it possible to maintain certain space between the module and the blade so that the robot can clean all part equally.

*2.3 Frame Moving of Brush*

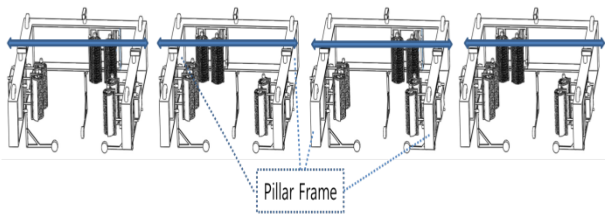
Show the brush-water jet module moving the frame horizontally. Use distance measuring sensor and motor to make each brush-water jet module to go back and forth the frame 3 times a minute, taking 4 pillar frames as the standard. The robot can cover the whole surface of the blade because the robot moves vertically and brush-water jet module moves horizontally.



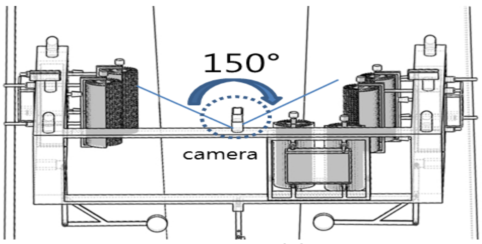

(a) Roller Shock Absorber



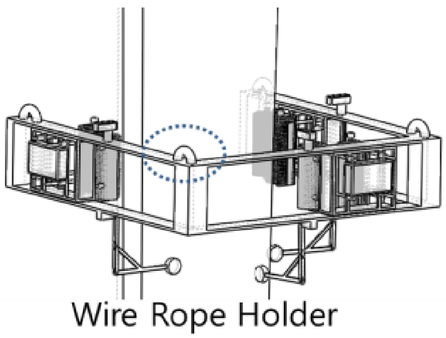

(b) Brush- Water Jet Module




(c)Frame Moving of Brush




(d) View Angle of Camera




(f) Wire Rope Holder

*Fig.6. Part Concept Design*

*2.4 Camera*

Of all the 3 cameras, show the camera which is located upside of the leading edge brush frame [Fig.6-(d)]. It checks the condition of the blade surface real-time during moving 150 angle. Control Director using the unaided eye is check the vision data that is send by camera. and he send the interrupt signal about any crack or portions that need extra cleaning. If it detects any crack or portions that need extra cleaning , it marks the location using the number of the hoist rotation and length of the rope. This makes the procedure more effective in time as it remembers the region that needs extra care. There don't need to vision algorithm because of using unaided eye.

*2.5 Rope Holder*

Connect the rope to the rope holder and make it possible that the robot moves vertically through the crane. When pulling the rope to the hoist, measure the rotation of the hoist and check the length change of the rope thus marking the robot's location. The robot weighs almost 1.5t, including water tank, frames, and other components. Wire rope is designed as to endure about 6 ton because of applying quadruple safety factor. Wire rope should be designed 10mm in diameter[9].

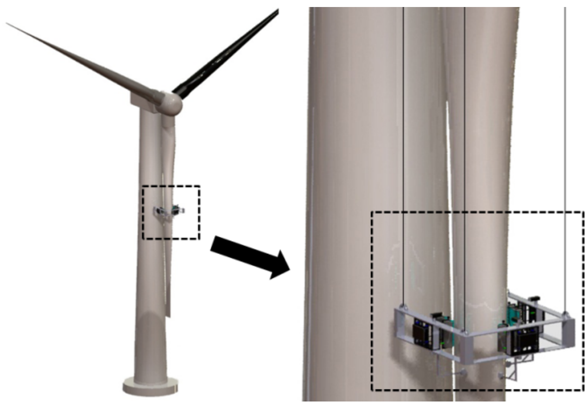


*Fig. 7. General Application Figure*

**CONTROLLER**

Blade cleaning robot needs 19 motors[Fig 8]. 6 brush rotating motors, 3 brush vertical movement motors, 3 water jet turning angle regulating motor, 4 hoist motion motors. Vertical movement of the blade uses 4 motors in the nacelle and lift up 4 wire ropes simultaneously. All 9 sensors are needed, and razor sensor and distance measuring sensor are used. Razor sensor is used to maintain the distance between brush and the blade surface. Distance measuring sensor is used to measure the distance between brush-water jet module and pillar frame, preventing any crashes between them. Control of the integration motor is done by 1 PLC controller and uses 3 microcontrollers, 1 controller at each frame. Microcontroller takes charge of the rotation of brush, movement of the camera, operation of the water jet. It also takes charge of the movement of the module by reading the numbers on the distance measuring sensor. PLC controller synchronizes 3 microcontrollers, and control hoist of the nacelle to control vertical movement. It saves the crack detection interrupt of Control Director with the hoist encoder data. CAN (Controller Area Network) is used between the PLC controller and the microcontroller.

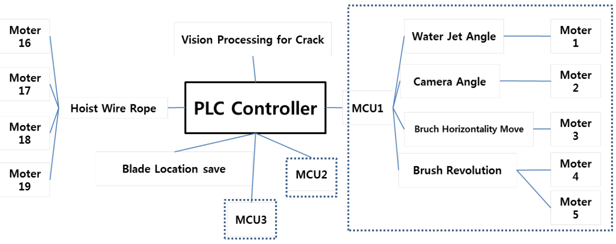



*Fig. 8. PLC Control Diagram*

## Conclusion

If the blade cleaning robot becomes commercialized, no more man power could be needed. The robot will also reduce the time of the cleaning and improve the safety as well. Furthermore, aerodynamic performance will be improved so the overall amount and efficiency of the electricity generation would be advanced.

If a method that minimizes the amount of the water used at the water jet and the brush and at the same time eliminate the dirt efficiently is developed, it could be possible to downsize the water tank and reduce the weight of the robot.

Extra inspection methods, like ultrasound scanning, can be added to more precisely check cracked areas of the blade. Develop packages of 1 cleaning & maintaining robot to every wind power generator and secure some space down the pillar to keep the robot, inspection and cleaning could be done more often and the time needed to install and move the robot could be reduced.

## Acknowledgement

This research was supported by a grant (code #10041091) from the Industrial Strategic Technology Development Program that was funded by the Ministry of Knowledge Economy of The Korean government.

## References

1. Global Wind Energy Council, "Offshore wind power developments", *Global Wind Statistics 2010*, 2011.
2. Norbert, E., "Robot for Rotor Blade Inspection", 2010 1st International Conference on Applied Robotics for the Power Industry, 2010.
3. Soltani, M., "Effect of surface contamination on the performance of a section of a wind turbine blade", Scientia Iranica, pp. 349–357, 2011.
4. BladeCleaning, FLYING INSCTS, http://www.bladecleaning.com/problematica_EN.htm, 2012.
5. Gustave, P., "Insects Cause Double Stall", *EWEC2001*, CopenHagen, 2001.
6. Tschirhart, B., "(A PANE IN THE GLASS) The Drag Effect", True North Curling Inc., Vol.1(24)
7. "BladeCleaning", Working principles, http://www.bladecleaning.com/bladecleaning_EN.htm, 2012.
8. "EXTREME Wind Service", gallery, http://www.eahire.co.uk/Portfolio.html, 2012.
9. Feyrer, K., "Wire Ropes (Tension, Endurance, Reliability)", Springer, pp. 5, 2007.
10. Corten, G.P., "Insects can halve wind-turbine power", *Nature*, Vol. 412, pp. 42-43, 2001.