Development of Rotational Smart Lighting Control System for Plant Factory

Won-Sub Lee, Sung-Gaun Kim*

Abstract**—**Rotational Smart Lighting Control System can supply the quantity of lighting which is required to run plants by rotating few LED and Fluorescent instead of that are used in the existing plant factories.The initial installation of the existing plants factory is expensive, so in order to solve the problem with smart lighting control system was developed.

The beam required intensity for the growth of crops, Photosynthetic Photon Flux Density(PPFD)is calculated; and the number of LED, are installed on the blades, set; using the Lighting Simulation Program.Relux, it is able to confirm that the difference of the beam intensity between the center and the outer of lighting system when the lighting device is rotating.

Keywords**—**Plant Factory, Lighting Control System, Rotational Lighting System, Lighting Equipment

I. Introduction

THE plant factory is defined as ‘it controls environmental condition artificially regardless of the Season and Location under the control of lighting, temperature, humidity, carbon dioxide concentration, culture fluid, and so on for crops’. In short, it is a facility that is able to control the temperature and humidity and produce crops stably with artificial light source for the whole year regardless of weather or season[1]. In addition, it actualizes the value-added agriculture, for example raising functional crops, which is hard to raise, and dramatically increases productivity through all the year-round cultivation. In this way, it can be used as the base of the food station and the plant factory can be the alternative for the future agriculture[2].

Rotational Smart Lighting Control System for the plant factory relative to the central axis of the building is equipped with a blade.Blade height is adjustable as crops grow.Blade is rotated depending on roughness values measured in ambient light sensor. Light required for plate located in planting crops that supply system.Current plant factory lighting system has a problem. The problem is initial installation costs caused by many lights installation at the top of planting board.In this paper, the cost of installation has been improvedto solve the problem by usingRotational Smart Lighting Control Systemand verified the validity of simulation.

Won-SubLee, Division of Mechanical and Automotive Engineering, Kongju National University, Republic of Korea, (e-mail: Leews@kongju.ac.kr)

Sung-Gaun Kim*, Division of Mechanical and Automotive Engineering, Kongju National University, Republic of Korea, (e-mail: kimsg@kongju.ac.kr)

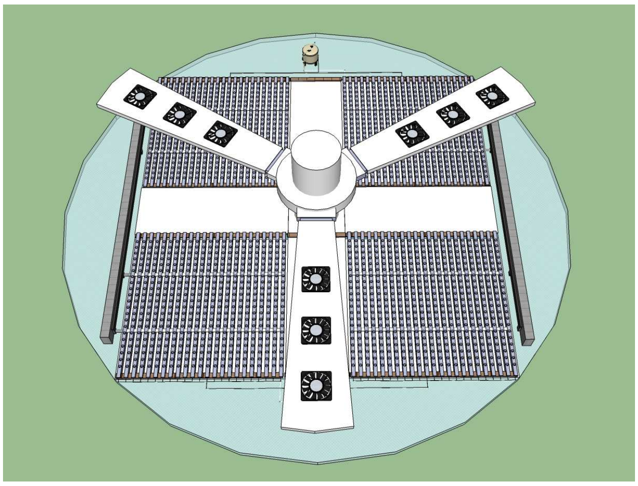

Fig. 1 Rotational Smart Lighting Control System conceptual

‘Relux’ was used for the lighting simulation program.Assuming that the blade at the program. type of lamp and angle between lamp and lamp set to a variable and each simulation run and got the result value.In addition, reducing the light angle from 90degrees to 30degrees, 15degrees, and 10degrees was simulated.Because the dynamic light rotating is impossible in the ‘Relux’ program, moving the angle by 5degrees was performed in the simulation.

II. Model Design And Simulation Process

A. Model Design

Table Ishows that Light saturation and the light compensation point of various plants based on fluorescent lamps.Light saturation point is the light intensity, which do not increase the rate of plants’ photosynthesis[3].

TABLE I
LIGHT SATURATION POINT AND THE LIGHT COMPENSATION POINT OF VARIOUS PLANTS (BASED ON FLUORESCENT LAMPS)

Crops	Light Saturation Point, lx (PPFD)	Light Compensation Point, lx (PPFD)
Tomato, Watermelon	70,000 (847)	3,000 (36)
Cucumber	55,000 (665)	2,000 (24)
Peas	40,000 (484)	2,000 (24)
Lettuce, Green peppers	25,000 (302)	1,500 (18)
Grapes	40,000 (484)	400 (5)
Saintpaulia	5,000 (60)	500 (6)
Ginseng	12,000 (145)	500 (6)

Light compensation point is achieved when the plant’s absorption and emission of carbon dioxide are equal. Andit is the point when the substantial amount of carbon dioxide which plant absorbs becomes zero.Therefore, light supplied to plants must be equal or exceed the light compensation point, and equal or less than the light saturation point.For example, the maximum 302μmol/m²s, and the minimum of 18μmol/m²sPhotosynthetic Photon Flux Density (PPFD) is required to cultivate lettuce.

Plants use a photon which is in a light for photosynthesis. Photosynthetic Photon Flux Density(PPFD) is a way of representing a light intensity which is used by plants in this case [4].

$$1\,\mathrm{lx} = 1\,\mathrm{lm/m}^2$$

The equation above is about the illuminanceunits (lx) and the luminous units (lm).When there is a light with intensity of 1lumen in one square meter, it is called 1lux.

TABLE II
THE RELATION BETWEEN 1μmol/m²s AND lx

Light Source	lx
Light of the sun	54
Incandescent light	50
Fluorescent light	74
RED LED (660nm)	9.94
BLUE LED (450nm)	11.9
WHITE LED (Warm white)	68.2

Table II shows relationship between 1μmol/m²sand lx. In the case of fluorescent light 1μmol/m²sis equivalent to 74lx.When Photosynthetic Photon Flux Density(PPFD) is sat to 200μmol/m²s, the value of illuminance can be calculated as 14,800lx.Also, when the light supply is 0.2m above the plant, the area will be 0.04m². Therefore, the luminous flux is calculated as 592lm.In the case, P42180 (RED) LED of Seoul Semiconductor was chosen as an example.For this product, when luminous flux is measured 48lm, Photosynthetic Photon Flux Density (PPFD) is measured as 5μmol/m²s.Therefore, when the light with 200μmol/m²s is above the 0.2m of the crop, 40 LED is needed.

Plants penetrate light which wave length is greater than 670nm, and reflect shorter than 610nm. In this case, a blue light, which have wave length 450nm, is used in photosynthesis.Therefore, plants are known to be grown well between red light (660nm) and blue light (450nm).

Figure 2 and Figure 3 shows concept of Rotational Smart Lighting Control System and Configuration of Rotational Smart Lighting Control System.LED and fluorescent light (light blade) are installed around central axis.And, light blade isconceptually designed by red LED, blue LED and fluorescent light which are efficient for photosynthesis.

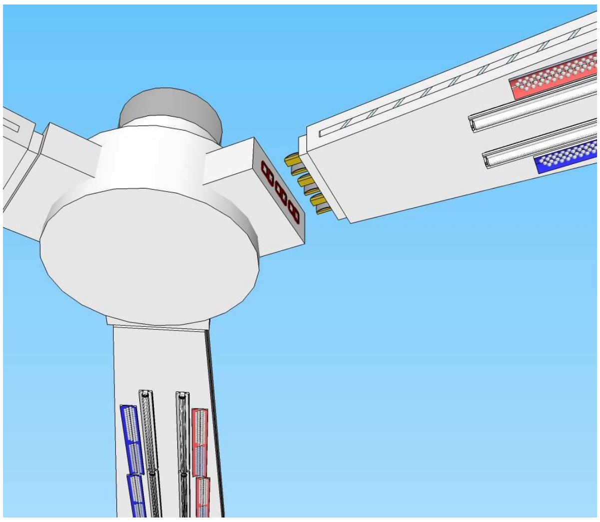

Fig. 2 Concept of Rotational Smart Lighting Control System

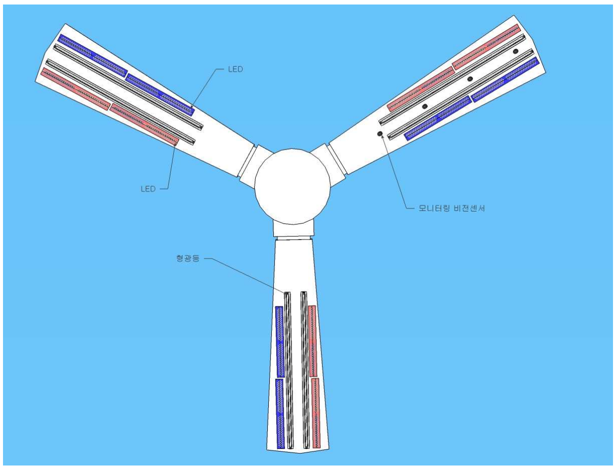

Fig. 3 Configuration of Rotational Smart Lighting Control System

B. Simulation process

Simulation was executed by using light simulation program 'Relux'. Assuming the angle of blade is different (10degree, 15degree, 30degree, and 90degree), simulation was done by using constant and variable light.

Figure 4 is simulation area set by 'Relux', and TableⅢ is exterior parameter of simulation area.4 modules were assumed as one light, and three measurement points for light intensity are set from point 1(inside) to point 3(outside).

TABLE III
APPEARANCE PARAMETER SETTING

Separation	Dimension
Radius	1,000mm
Height	700mm

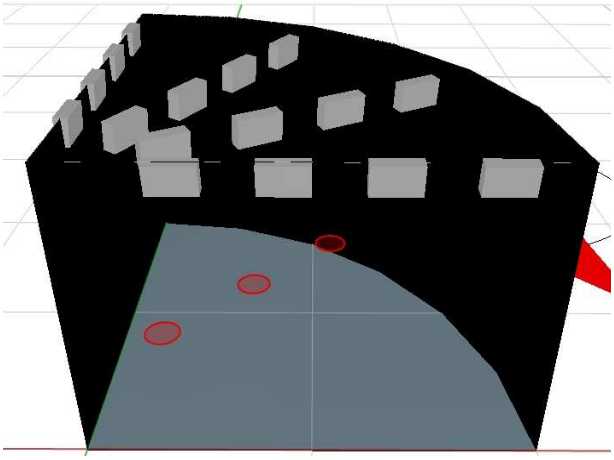

Fig. 4 Set the simulation area

Figure 5 is parameter setting for LED light when module's LED of Lamp Power 2W is sated by five. Figure 6 is type of LED lighting used in the simulation.

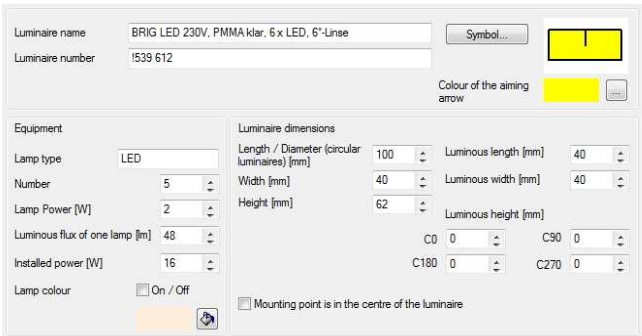

Fig. 5 LED Light parameter setting

Fig. 6 LED Light type

When angle between each light is 90degree, three LED light that are shown in Figure 6 are mixed for simulation. And the cases for angle 30degree 15degree and 10degree simulation were executed by LED light sated as Figure 5.

III. Simulation Results

Figure 7 is graph of luminous energy during simulation when two blades are locating together by 90degree, and rotating light by 5degree. Graph is indicating luminous data (lx) measured in from each measurement point during the rotation.Table Ⅳ is luminous energy measured from 0degree to 90degree by 5degree gap at the measurement point.

Figure 8 is graph of luminous energy (lx) measured at the measurement point when there was 30degree gap between rotating two blades and moving light by 5degree.

TABLE Ⅳ
THE TOTAL LIGHT INTENSITY AT THE MEASURING POINT

Light Source	lx
Point 1	15839
Point 2	15615.4
Point 3	15135.8

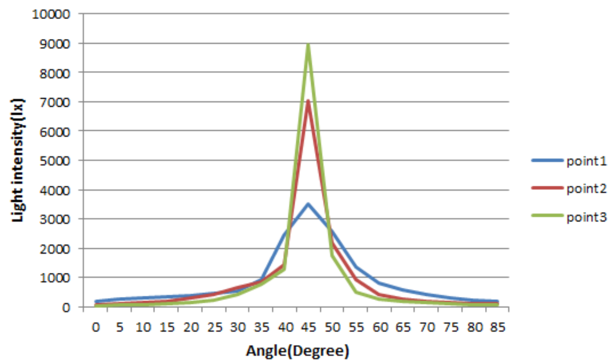

Fig. 7 The simulation results from each measurement point (90degrees)

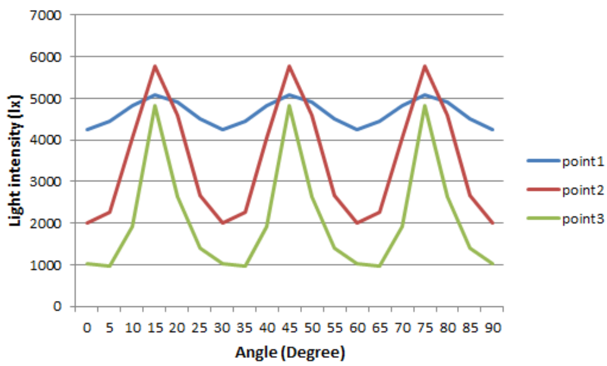

Fig. 8 The simulation results from each measurement point (30degrees)

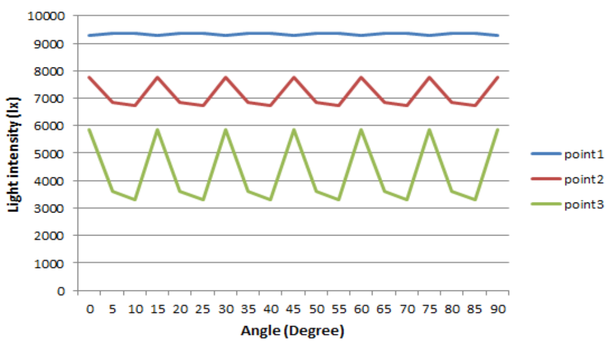

Fig. 9 The simulation results from each measurement point (15degrees)

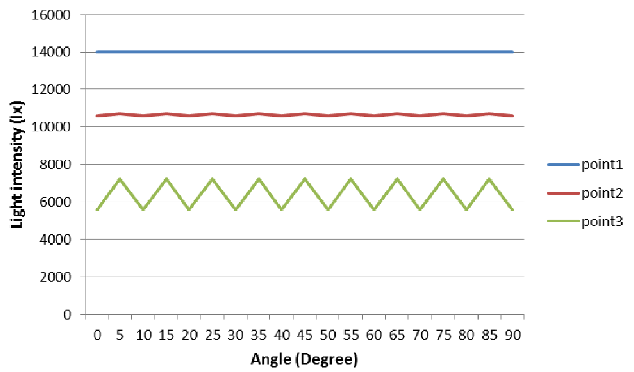

Fig. 10 The simulation results from each measurement point (10degrees)

Figure 9 is graph of luminous energy (lx) measured at the measurement point when blades are rotating with 15degree gap and moving light by 5degree. And figure 10 is graph of luminous energy (lx) measured at the measurement point when blades are rotating with 10degree gap and moving light by 5degree.

IV. Conclusions

It is concluded that, as we assumed, the smaller the angle of two blades, the faster the rotation speed of blades. And lighting simulation program using ‘Relux’ set the lighting according to the angle between the blades and run the simulation and the lighting fixtures is rotated as the light of the differences resulting were analyzed.

Lighting fixtures inside of the blade (point 1) in the outer (point 3), which is measured in terms of each measure to the increasing amount of low intensity were measured, the smaller the angle between each blade, the more light that is measured to know that the constant observation could be.

Acknowledgment

This work was supported by the Grant of the Korean Ministry of Education, Science and Technology"(The Regional Core Research Program/Zero Energy Green Village Technology Research Center)

References

[1] J.H Kim, “Trends and prospects of plant factory”, KREI a research paper, Vol. 61, October, 2009.
[2] J.E Son,“Plant Factory – A Prospective Urban Agriculture”, The Korean Society for Bio-Environment Control, Vol. 2, No. 1, pp. 69~76, 1993.
[3] S.W Lee, “Plant Factory and plant cultivation using the LED artificial light”, Optical science and technology, Vol. 14, No. 3, pp. 12~19, July, 2010.
[4] Y.H Kim, "Plants associated with the production of light in physics terms and concepts", Journal of the Korean Society for Agricultural Machinery, Vol. 22, No. 4, pp. 503-512, 1997