Advanced Science and Technology Letters
Vol.120 (GST 2015), pp.550-553
http://dx.doi.org/10.14257/astl.2015.120.110

CFD Based Internal Fan Control Simulation for Improvement of Cultivation Environment in Plant Factory

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Abstract. A vertical plant factory has problems of either producing the uneven quality crops due to the temperature deviation between the upper and lower beds or increasing energy consumption after prolonged cultivation. The conventional heating methods wherein an air conditioning device and external circulation fans are simultaneously operated are effective in maintaining the cultivation environment in the entire area. However, this method has a limit in improving the air flow locally stagnant inside the cultivation beds. In this study, a CFD-based internal fan control simulation is proposed in order to improve the cultivation environment inside a plant factory. The changes in the temperature and air flow of the entire area in the facility as well as in each growing bed were analyzed with a simulation. Based on the simulation, the improvement in the cultivation environment by the internal fans was verified. The analysis results showed that the method with the additional internal fans was effective in maintaining the uniform cultivation environment by improving the air flow locally stagnant in the entire facility and inside the growing beds.

Keywords: CFD Simulation, Internal Fan, Plant Factory, Cultivation Environment

1 Introduction

A vertical type plant factory, in spite of a high efficiency in the crop growing area, has problems of uneven crop growth due to the temperature deviation between the upper and lower areas and increases in the energy after prolonged cultivation. In the existing researches, a method wherein multiple numbers of external fans were installed and operated simultaneously with an air conditioning facility was used [1].

This method is effective in maintaining a crop cultivation environment in the entire area of the facility. However, it has a limit in improving the air flow locally stagnant inside of the each growing bed. Therefore, it needs to additionally install and operate internal fans in order to maintain the temperature distribution in each growing bed and to form an adequate air flow suited to crop growth. It is known that by operating

ISSN: 2287-1233 ASTL

internal fans installed above the plant population not only the air flow stagnant near the leaves is increased but also the factors that hinder the crop growth are removed by reducing the resistance from the boundary layers of the leaf surface [2]. However, an experimental method to validate the effect of internal fans incurs a considerable time and cost in establishing experimental environment and securing a reliability of measured data, a simulation method to predict the results needs to be introduced [3].

Computational Fluid Dynamics (CFD) not only can artificially control various environments and conditions but also are suitable to provide an efficient operation by finding out optimum values such as structure, shape, and operational plan through a numerical analysis [4]. Therefore, this study aims to investigate effects of operating the additional fans on the improvement of cultivation environment inside a plant factory by using a CFD based internal fan control simulation technique.

2 Materials and Methods

In this study, a vertical plant factory (3.47m×4.35m ×2.97m) located in the basement was used as a subject space for the simulation.

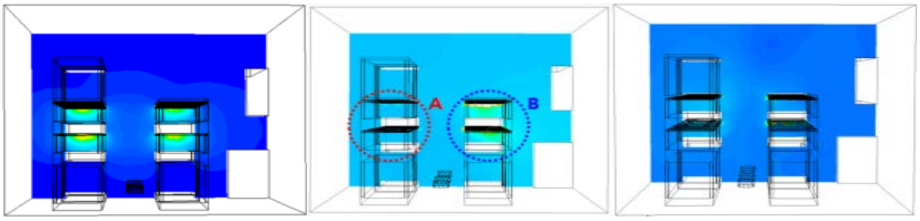
Table 1 presents the experimental conditions classified into a total three cases according to operation methods of air conditioning and internal fans. Case A is the basic environment wherein air flow device was not operated. Case B is the condition wherein only internal fans were operated. Case C is the condition wherein both the air conditioning and internal fans were operated. Among the total 48 internal fans installed on the four sets of plant cultivators having two layers and one row, only 24 internal fans having the same specifications attached on the two sets of plant cultivators were adopted for the analysis for the Case B and Case C wherein the internal fans were operated.

Table 1. Simulation Conditions

Case	Air conditioning	Internal Fan
Case A	Off	Off
Case B	Off	On
Case C	On	On

A modeling was performed in this study for the structural shape inside the facility using a Gambit (Ver. 2.4). Numerical analysis was also carried out using a commercial CFD code Fluent (Ver. 6.3). The number of total mesh was around 730,000 and the most universally used k-ε turbulent model was adopted as a model for the air flow analysis. The actually measured data were used as the input values for the boundary conditions during CFD analysis. That is, the temperature of air conditioning and outlet of the internal fans used as the input data for the analysis were 23℃ and 26℃, the average air flow rates were 5m/s and 0.9m/s, respectively. Further, analysis was carried out as an unsteady state so that the temperature and air flow distribution could be checked as time was elapsed during the experiment. The initial temperature in the area was set as 24℃ which was within a temperature range suited to the growth of the leafy vegetables. The heat loss within the area towards outside was not considered.

3 Results

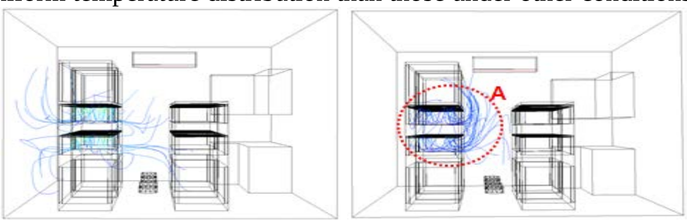


Case A **Case B** **Case C**

Fig. 1. Temperature distribution according to control conditions

Figure 1 shows the graph for the temperature distribution which was kept on changing according to the each control condition. Case A showed that the average temperature inside the facility was around 27.6℃ which was higher by around 3.6℃ than that of the target temperature. It was because of the environmental characteristic of the sealed structure and the air conditioning device for the air circulation was not operated. Moreover, the inner temperature at the growing bed was further greatly increased locally due to the heating of the LED lightings attached at each growing bed.

The analysis results for Case B showed an average temperature of 27.0℃ which was lower than that of the Case A. Still, the temperature was higher by around 3.0℃ than the target temperature. At the point (A) where only the internal fans were operated, the temperatures at the outside as well as inside of the growing beds were uniform as shown in Figure 1. While, at the point (B) where the internal fans were not operated, the temperature inside the growing bed was higher than outside. The average temperature under the Case C condition wherein both the air conditioning and internal fan were operated was the nearest to the target temperature with an average temperature of 24.6℃. The temperature distribution of the entire space under the Case C condition was matching around 83% with the target temperature of 24℃, showed the most uniform temperature distribution than those under other conditions.



Case B **Case C**

Fig. 2. Air flow distribution according to control conditions

Figure 2 shows the air flow characteristics that were changed according to each control condition. The sky blue colored region in each graph indicates a high temperature or strong air flow, while the blue colored region indicates a low temperature or weak air flow. Further, the arrows display the direction, size, and overall air flow at the each point. Under the Case B condition, the air was discharged only to the growing bed showing that the air flow was not smooth due to the fan installation location. While, the average air flow was further promoted by the air conditioning in the Case C wherein the air conditioning device and internal fans were simultaneously operated, thereby it was the most effective in improving the air flow stagnant inside the growing bed (See the point A).

4 Discussion

In this study, the changes in the temperature and air flow were analyzed by the internal fan control simulation based on the CFD in order to improve the cultivation environment inside a plant factory. The simulation results showed that the Case C condition wherein the air conditioning and internal fans were simultaneously operated was matching with the target temperature of 24℃ with an average temperature of 24.6℃. Further, it was the most effective in improving the air flow locally stagnant inside the growing beds. In the future, the proposed system would be validated by comparing and analyzing the cultivation environment, changes in the crop growth, and energy consumption by way of the actual measurement and cultivation experiment based on the simulation results.

Acknowledgement. This research was supported by the Functional Districts of the Science Belt support program, Ministry of Science, ICT and Future Planning(2015K000281). This work was supported by the Korea Foundation for the Advancement of Science & Creativity (KOFAC), and funded by the Korean Government (MOE)

References

1. Kim, D.E., Chang, Y.S., Kim, J.G., Kim, H.H., Lee, D.H., Chang, J.T.: Environmental Control of Plant Production Factory Using Programmable Logic Controller and Computer. J. Bio-Environment Control. 15, 1—7 (2006)
2. Yu. I.H., Cho, M.W., Lee, S.J., Chun, H., Lee, I.B.: Effects of Circulation Fans on Uniformity of Meteorological Factors in Warm Air Heated Greenhouse. J. Bio-Environment Control. 16, 291--296 (2007)
3. Kim, H.J., Yim, K.J., Lee, S.L., Park, K.S.: CFD Analysis on the Flow Uniformity of a CO_2 Enrichment System. J. Protected Horticulture and Plant Factory. 22, 123--130 (2013)
4. Park, D.Y., Jang, S.T., Chang, S.J.: Numerical Study on the Thermal Environment of a Natural Light Based Multi-layered Plant Factory. J. Korea Institute of Ecological Architecture and Environment. 13, 43--50 (2013)

