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Optimum Configuration of Gutters for Glasshouses Using ANSYS and ADAMS

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ANSYS/ADAMS를 이용한 유리온실 최적의 Gutter 형태 설계

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Abstract A gutter is generally a fixed beneath the edge of a roof to carry off rainwater, or a narrow trough that collects rainwater from the roof of a building to diverts it from the structure, typically into a drain. Reasonable designs reduce the mass of the gutters (~ 16.9%), make it faster and easier to assemble, and gives it consistent strength and integrity (about 10%). New gutter systems are presented according to the results of structural analyses performed by ANSYS and ADAMS/Durability Hot Spots. In addition, the CATIA program can improve the precision of the 3D system simulations. The design of a gutter system installations also needs to comply with the specific rainfall intensities and adequate overflow provisions needs to be provided to prevent water from sides of the roofs during heavy rainfall periods. The principle outcome of this work is a computational design tool that can be used to improve the gutter performance considering a variety of factors (gutter geometry, drainage and rainfall intensity). A good gutter design must satisfy many criteria, including durability, low cost, and ease of repair and cleaning.

요 약 일반적으로 유리온실의 거터는 빗물이나 결로를 온실 밖으로 배출시키는 역할을 하는 구조물이다. 본 논문에서는 기존 거터를 개량하여 질량을 줄이고 온실의 온도차이로 발생하는 결로를 많이 담을 수 있는 새로운 거터를 설계한다. 개발할 거터는 CATIA로 설계한 후 ANSYS 구조해석과 ADAMS/Durability를 이용하여 Hot Spot해석을 수행한 결과를 바탕으로 설계하였으며, 거터의 성능을 개선하기 위해 거터의 형상, 결로의 배수, 강도 등을 고려하였다. 그리고, 개발할 거터는 설치 방법이 쉬운 결로받이 일체형 거터이며, 기존 거터보다 질량이 약 16.9% 감소하였으며 내구성도 약 10% 상향되었다.

Key Words : Gutter, Durabilti, Configuration, CATIA and ANSYS, ADAMS/Durability

1. Introduction

A glasshouse (also called a “greenhouse”) is a building in which plants are grown. These structures range in size from small sheds to industrial-sized buildings. Commercial glass greenhouses are often high-tech cultivation facilities for vegetables or flowers. They are filled with equipment such as screening installations and heating, cooling, and lighting devices that are automatically controlled with a computer. Glasshouses are also structural buildings with different types of covering materials such as glass or plastic [2, 8].

This paper develops a gutter configuration for

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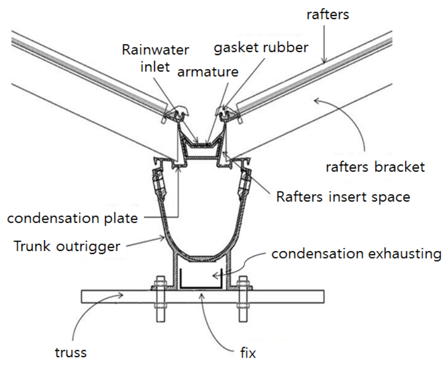
glasshouses. Not only the gutter design is of great economic importance, but also the choice of the rainwater system, which often comes down to three criteria: whether it is for domestic or commercial purposes, its aesthetics, and its long life prediction ability. Gutters are essential but relatively low-cost parts of roof-water harvesting systems [3]. It is possible to collect roofwater without using glides or ground-level troughs, and some general house geometries concentrate the run-off from adjacent roofs into gulleys/valleys (Gould & Nissen-Petersen, 1999; and Qiang & Fuxue, 1995) [1]. In this paper, the optimum gutter weight and fixing trajectory are explored and recommended. This study was motivated by the field observation of evidently oversized gutters and the absence of any published 'informed' guidance on sizing. Durability is one of the most important points to consider in designing gutters [4, 8].

Ideally, a gutter system should be economical to produce, efficient in capturing runoff water, easy to align and install, resistant to damage, and (if not completely self-cleaning) simple to clean. The main objective of this paper is to produce a new structural design for gutters that will enable them to resist the force between their upper part and each side of the roof to reduce their damage. This paper also considers the loads of glasshouses that act on gutters and investigates the common location of deformation in gutters [6, 8].

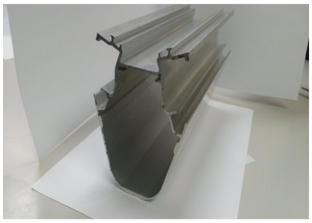
2. Gutter material and methods

2.1 Experiment description

In this section, we consider the shape of the existing gutter by conveying water from its entry point into the gutter to the runoff. The flow in the gutter is affected by the shape of the gutter. The extra water coming from the roof and the loads from both sides of the roof are considered. The glasshouse structures were made of glass, and the gutter system had an aluminum component.



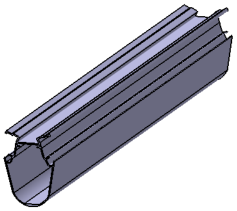
[Fig. 1] Gutter of separated condensation tray



[Fig. 2] Existing range gutter

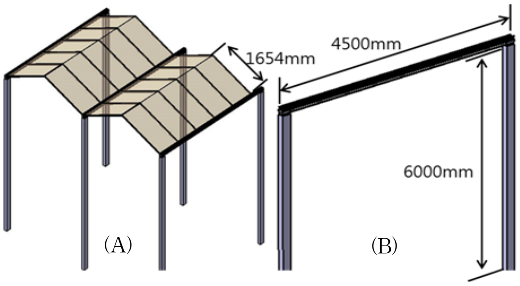
In the existing range gutter of glasshouses, a condensation tray must be installed and removed, as shown in Fig. 1. The existing gutter needs to separate the condensation tray from the axle trusses and the gutter, as shown in Fig. 1. The condensation tray of the gutter is difficult to align and install, unresistant to damage, and difficult to maintain. Fig. 1 shows the separated condensation tray gutter related to the application for the patent name Boal Beheer B.V. with the application number EU/EP [19920202566] [8].

2.2 CATIA modeling



[Fig. 3] CATIA model of existing range

Glasshouses (also called "greenhouses") can be generally divided into glasshouses and plastic greenhouses. They can also be divided into three types: white-span, Venlo-type, and energy-saving and energy-economizing type.



[Fig. 4] CATIA modeling of glasshouse

In this session, we show how to design a Venlo-type glasshouse system for examination, as shown in Fig. 4. The Venlo-type glasshouse is a mini-glasshouse. It is designed to be packed with plants tended from the outside [7]. The development of CATIA automates the construction of glasshouses and simulates their 3D model. In addition, ANSYS and ADAMS/Durability are applied to an integrated systems analysis [8].

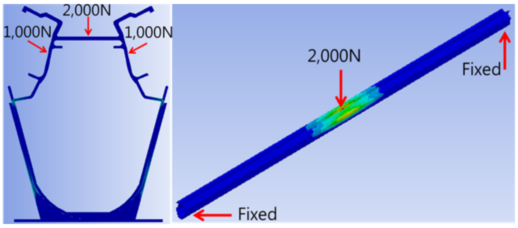
- The glasshouse is installed under general condition using CATIA, as shown in Fig. 4.
- The gutter design is 4,500 mm long, and the spaces between the pillars are 4,500 mm wide and between the beams, 4,500 mm.
- The exiting gutter had a 13.734 kg of mass and was made of aluminum.

2.3 ANSYS structural analysis

Boundary conditions

Step 1: Fig. 5 shows the existing range gutter that was analyzed with ANSYS. We estimated the weight of the person who went over the gutter as about 200 kg at the center of the gutter. The load of the gutter from the roof reached 100 kg.

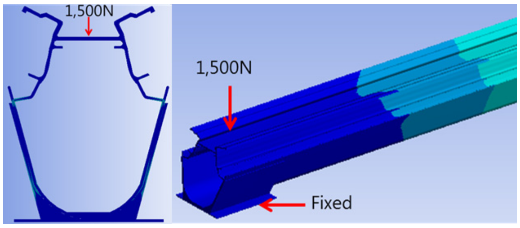
Step 2: Fig. 6 shows that a 150 kg concentrated load was applied at the end of the existing gutter (over the pillars).



[Fig. 5] ANSYS analysis of exiting range gutter (Step 1)

[Table 1.A] Data analysis (Step 1)

Model	Mass [kg]	Deformation [m]	Strain [m/m]	Stress [Pa]
(A)	13.734	6.9668e-3	8.1421e-3	2.5584e8



[Fig. 6] ANSYS analysis of exiting range gutter (Step 2)

[Table 1.B] Data analysis (Step 2)

Model	Mass [kg]	Deformation [m]	Strain [m/m]	Stress [Pa]
(A)	13.734	2.5329e-4	8.7699e-3	2.8274e8

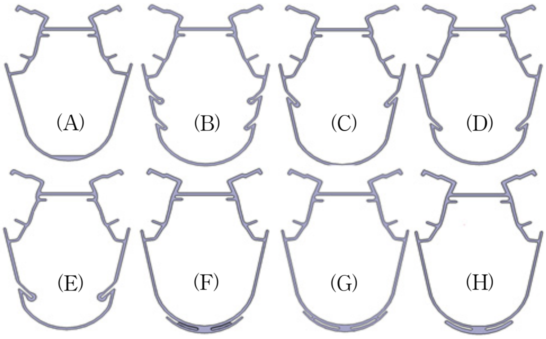
Table 1. (A and B). Description data

The existing gutter had an aluminum mass of 13.734 kg. Its total deformation was 6.9668e3 m; maximum elastic strain, 8.1421e-3 m/m; and maximum stress, 2.5584e-8 Pa. We provided concentrated loads of 2,000 N at the center of the gutter and 1,000 N on both sides of the rafter. Table 1.A, show that the gutter received the load by bending by 6.9668 mm, and that the maximum stress was 2.5584e8 Pa.

The total deformation was 2.5329e-4 m; maximum strain, 8.7699e-3 m/m; and maximum stress, 2.8274e-8 Pa. In Fig. 6, the point cycle shows the maximum stress, but we assumed that the shape of the gutter remained the same. The result of the bending was only 0.28274 mm.

3. New gutter experiment description

As part of our continued product development initiatives, we regularly introduce new products and update our existing ranges. Therefore, we have designed new products. These seven systems have various profiles. A comprehensive range of fittings provides the installer a complete roof drainage solution [2, 3].

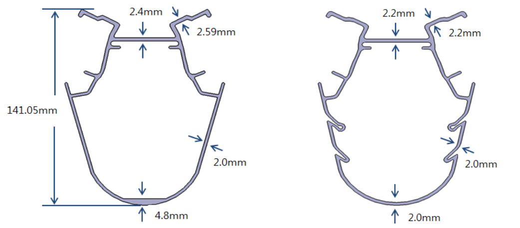


[Fig. 7] CATIA modeling design

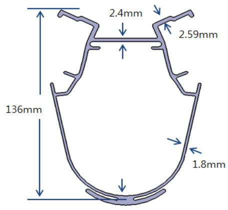
In this process, the drainage is built into the newly developed gutter. The drainage inlet locations are often established through the long gutter geometries. The drainage location intends to reduce the spread of water over the plants in the glasshouse. All the drainage water should be isolated from the ground to avoid contamination, and stored in tanks for use in the system.

3.1 Difference between the exiting gutter and the new product:

The Boundary Element Method (BEM) is an accurate and precise model that has been tested and verified in several studies. It is used to calculate the performance of designed gutters. Fig. 8 shows the differences between the existing range gutter and the newly designed gutters. The new products look thinner and weigh less than the existing gutter. Rigid gutters are divided into two groups, all of which were compared with a simple common gutter (the existing range gutter). The first group consists of simple gutters but with different inner shapes and thicknesses [Models B, C, D, and E]. The second group consists of gutters with similar widths but greater depths, as shown in Models F, G, and H.



(a) Exiting gutter (b) Newly developed gutter (Group I)



(c) Newly developed gutter (Group II)

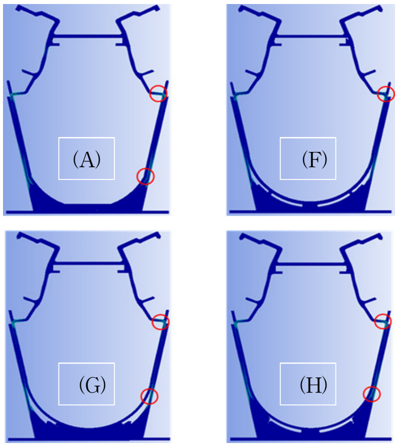
[Fig. 8] Difference between exiting gutter and new product

3.2 ANSYS structural analysis

This structures and the boundary conditions of the existing gutter and the newly developed gutters were analyzed, compared, and integrated under the same conditions. The material of the gutters was aluminum alloy. The supporter of the gutter was set as the fixing point, as shown in Fig. 5 and 6. The total deformation in Model H was much lower than that in Model A.

Different configurations of the gutter were tested to improve their performance. Such improvement can be furthered using various treatments such as interception and conveyance of the water flow. The supporter of the gutter was set as the nodal point, the length of the gutter was 4,500 mm, and the concentrated force at the end of each point was 1,500 N, as shown in Fig. 5. According to Table 2.B, the gutters in Models F, G, and

H performed better. They all belong to the second group of gutters that we designed. Model A performed better, however, for a reason.



[Fig. 9] Result of gutter modeling using ANSYS (Step 1)

In all the tested Models, the bending force was deformed according to the gutter shape and size in the area immediately below the gutter surface. Model H was stronger and more durable.

[Table 2. A] Comparison analyzed data (step 1)

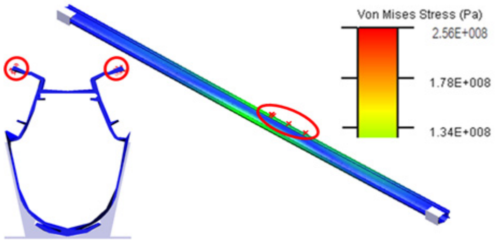
Model	Mass [kg]	Deformation [m]	Strain [m/m]	Stress [Pa]
(A)	13.734	6.9668e-3	8.1421e-3	2.5584e8
(B)	13.988	8.3335e-3	6.8103e-3	3.2121e8
(C)	13.014	8.2930e-3	7.0886e-3	2.0896e8
(D)	13.363	8.2929e-3	3.9325e-3	4.8020e8
(E)	13.740	7.9322e-3	4.6471e-3	2.0253e8
(F)	14.363	6.6403e-3	7.0014e-3	2.9195e8
(G)	14.954	6.0980e-3	8.0311e-3	2.6026e8
(H)	14.411	6.4043e-3	8.5162e-3	2.7020e8

[Table 2. B] Comparison analyzed data (step 2)

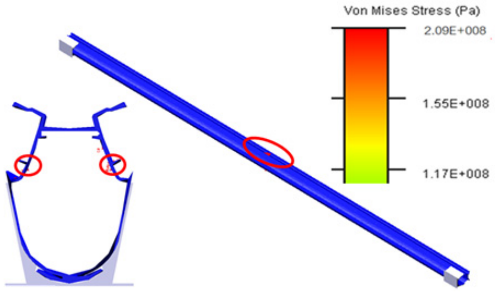
Model	Mass [kg]	Deformation [m]	Strain [m/m]	Stress [Pa]
(A)	13.734	2.5329e-4	8.7699e-3	2.8274e8
(B)	13.988	2.5100e-4	6.2943e-3	2.9719e8
(C)	13.014	3.0363e-4	7.9019e-3	2.4845e8
(D)	13.363	2.5627e-4	5.2749e-3	2.1739e8
(E)	13.740	3.3633e-4	4.7573e-3	2.1178e8
(F)	14.363	2.9466e-4	4.2416e-3	1.8065e8
(G)	14.954	2.5358e-4	5.0440e-3	2.2261e8
(H)	14.411	2.7400e-4	5.4420e-3	2.3635e8

4. Discussion

This study predicted the durability and efficiency of various gutters using CATIA 3D-designed modeling and simulation analysis using ANSYS and ADAMS/Durability. We considered the total deformation, equivalent elastic strain, and equivalent (von-Mises) stress of the gutters, which also increased the stress and deformation, by designing new shapes. We found that Models F and H were more efficient. The mass of Model A was much better than that of Models F and H, but a dew (exhausting) condenser must be installed in it. Nevertheless, its mass was increased more significantly than that of the other models, as shown in Fig. 1. In this analysis, the effects of the existing range gutter were compared with those of the designed models, and the results indicated that the degree of improvement was increased by enhancing the overall inside surface area of the gutters [3]. Interestingly, Model H had the best positive efficiency and reducible mass. The maximum stresses by location that were shown using ANSYS in Steps 1 and 2 were 2.7020e8 Pa and 2.3635e8 Pa [2, 3, 8].



[Fig 10. A] ADAMS/Durability Hot Spots (step 1)



[Fig 10. B] ADAMS/Durability Hot Spots (step 2)

ADAMS/Durability was also carried out. The results revealed that the maximum stress on the gutter was at the Hot Spots, as seen in Fig. 10 (A) and (B). The results of the analysis using ANSYS and ADAMS/Durability were almost the same, so they were both applied to the integrated gutter system analysis module [8].

5. Conclusion

The fabrication of gutters with the correct shapes can help enhance their durability and life. In this study, the flow profile inside the gutter was measured at varying gutter cross-sections. A good match was found between the measured and predicted profiles in Model H. Further efforts are being made to investigate this matter, which will be subject of future papers [1, 5].

[Table 4] Recommended gutter model

Model	Mass [kg]	Deformation [m]	Strain [m/m]	Stress [Pa]
	14.411	6.4043e-3	8.5162e-3	2.7020e8
		2.7400e-4	5.4420e-3	2.3635e8

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