

Finite Element Analysis of the Drying Chamber of Freeze-drying Equipment

Du Hang

School of Mechanical and Electrical Engineering
Xi'an Technological University
Xi'an, 710021, China
E-mail: 1228939146@qq.com

Yang Zhao

School of Mechanical and Electrical Engineering
Xi'an Technological University
Xi'an, 710021, China
E-mail: 94546666@qq.com

Peng Runling*

School of Mechanical and Electrical Engineering
Xi'an Technological University
Xi'an, 710021, China
E-mail: pengrunling@163.com

Yang Zhuoyu

School of Mechanical and Electrical Engineering
Xi'an Technological University
Xi'an, 710021, China
E-mail: 284699065@qq.com

Abstract—In this paper, the finite element analysis of the drying chamber of the freeze-drying equipment with a shelf area of 75 m² is carried out, and its structure is optimized. Firstly, the structural design of the drying chamber of ZLG-75 freeze-drying equipment was determined. Then use Solid works to carry out three-dimensional modeling of the drying chamber body. And using ANSYS software to analyze the strength and stiffness of the drying chamber body. Comparing the degree of deformation in the drying chambers with different wall thicknesses and different number of reinforcing ribs. Optimized design for the entire structure, It was finally determined that the wall thickness of the drying chamber was 8 mm and the spacing of the reinforcing bars was 410 mm.

Keywords-Freeze Drying Equipment; Drying Room; Optimization; Finite Element Analysis

I. INTRODUCTION

In food freeze-drying equipment, the Danes designed and manufactured the freeze-drying equipment for food use in 1943[1]. In 1950, people invested a lot of energy in food freeze-drying and began systematic research. The specifications of foreign freeze-dried equipment are more than domestic, supporting equipment, the energy-saving structure is also more sophisticated, continuous lyophilization equipment has a large production capacity[2-5]. Due to some reasons, China's food freeze-drying equipment has already had a big gap with others. At the end of 1960, experimental food freeze-drying equipment was completed. Some freeze-drying equipment was established by the introduction of Japanese freeze-drying technology around 1970, but it was eventually stopped due to efficiency problems. Around 1980, China finally paid attention to the market of freeze-dried foods and began to develop rapidly.[6] The freeze-drying equipment not only introduced Japanese equipment, but also introduced the equipment produced by the Danish company Atlas[7].

In the following years, domestic freeze-drying equipment and processes developed rapidly, and the gap with foreign countries is slowly narrowing. However, the wall thickness and the number of reinforcing ribs of the drying chamber of

the current freeze-drying equipment are all selected according to the empirical formula, and the safety factor is relatively large, which not only has high material cost, but also increases the manufacturing process difficulty and cost of the box[8]. In this study, the finite element is used to simulate the structure of the drying chamber.

II. DETERMINATION OF THE STRUCTURE OF THE DRYING CHAMBER OF THE FREEZE-DRYING EQUIPMENT

The drying chamber of the lyophilization equipment is a vacuum container, which has a spherical shape, a cylindrical shape and a box shape. The spherical and cylindrical shapes have good strength rigidity, but the effective space utilization rate is low[9-10]. The design shelf area is 75 m², and the drying box is large in volume. Therefore, the box type box is selected, and the structure of the box type drying chamber designed by the empirical formula is shown in Fig. 1. For the box type box, when the volume is large, the strength of the load is insufficient. I will solve the strength problem by adding ribs around the box.

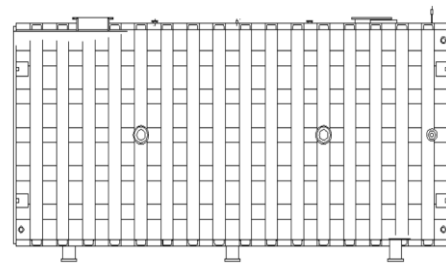


Figure 1. Assembly diagram of rectangular box-shaped drying chamber

III. THREE-DIMENSIONAL MODELING AND FINITE ELEMENT ANALYSIS OF DRYING CHAMBER

The drying chambers with wall thicknesses of 4mm, 8mm and 15mm are respectively modeled, and in the modeling corresponding to the wall thickness: there are no ribs, plus ribs with a lateral spacing of 150mm, and

reinforced ribs with a lateral spacing of 410mm. A total of nine modeling schemes were performed.

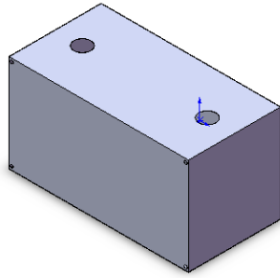


Figure 2. Drying chamber with a wall thickness of 4 mm

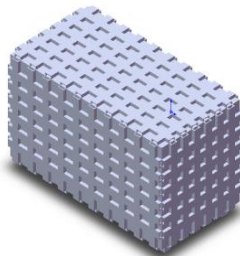


Figure 3. Drying chamber with a wall thickness of 4 mm and a rib spacing of 150 mm

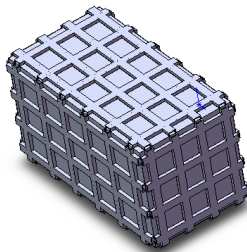


Figure 4. Drying chamber with a wall thickness of 4 mm and a rib spacing of 410 mm

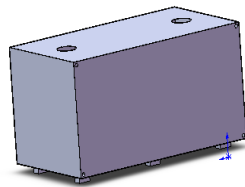


Figure 5. Drying chamber with a wall thickness of 8 mm

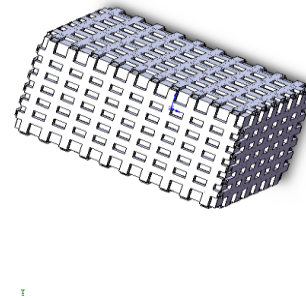


Figure 6. Drying chamber with a wall thickness of 8 mm and a rib spacing of 150 mm



Figure 7. Drying chamber with a wall thickness of 8 mm and a rib spacing of 410 mm

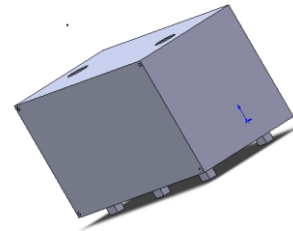


Figure 8. Drying chamber with a wall thickness of 15 mm

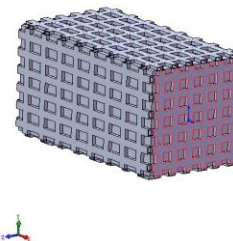


Figure 9. Drying chamber with a wall thickness of 15 mm and a rib spacing of 410 mm



Figure 10. Drying chamber with a wall thickness of 15 mm and a rib spacing of 410 mm

Use ANSYS to analyze the drying chamber and select the equivalent stress, equivalent strain, and total deformation options in the Solution option.

1) Firstly analyze the modeling results of the drying chamber without stiffeners, as shown in the following figure.

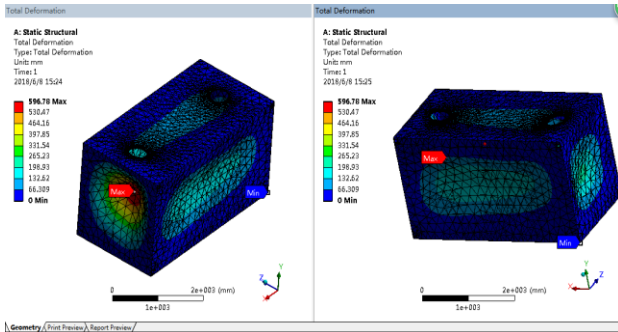


Figure 11. Total deformation of the drying chamber with a wall thickness of 4mm

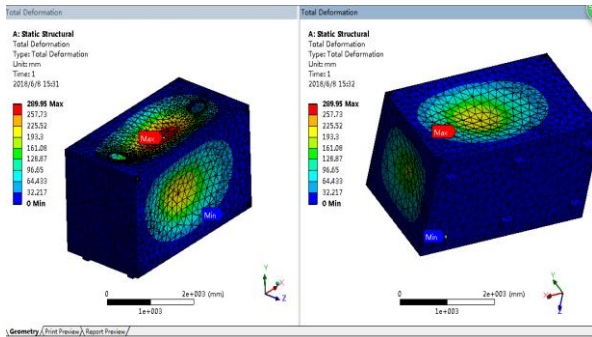


Figure 12. Total deformation of the drying chamber with a wall thickness of 8mm

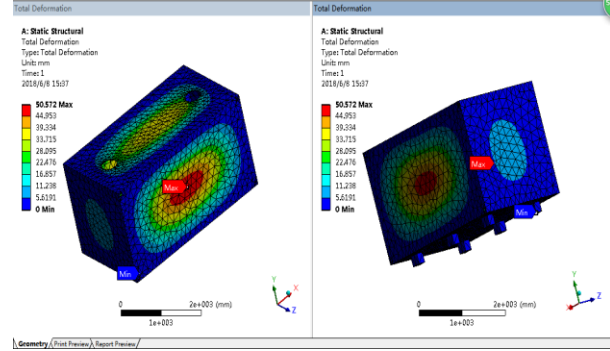


Figure 13. Total deformation of the drying chamber with a wall thickness of 15 mm

If the ribs are not added, the strength and rigidity of the drying chamber body will not meet the design requirements. Even in a drying chamber with a wall thickness of 15 mm, the front surface will have a deformation amount of 50 mm, and the wall thickness is 4 mm, and the deformation amount of 8 mm is larger, which is not satisfactory.

2) After adding the ribs with a pitch of 150 mm on the dry outdoor wall, analyze the results as shown below.

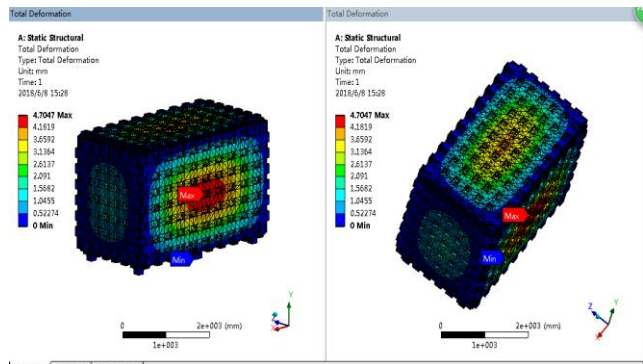


Figure 14. Total deformation cloud diagram of a drying chamber with a wall thickness of 4 mm and a rib spacing of 150 mm

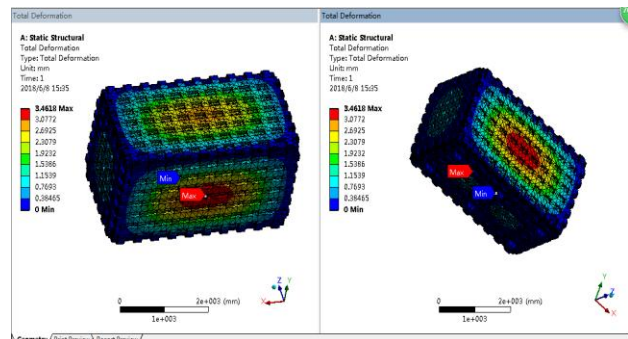


Figure 15. Total deformation cloud diagram of drying chamber with wall thickness of 8mm and rib spacing of 150mm

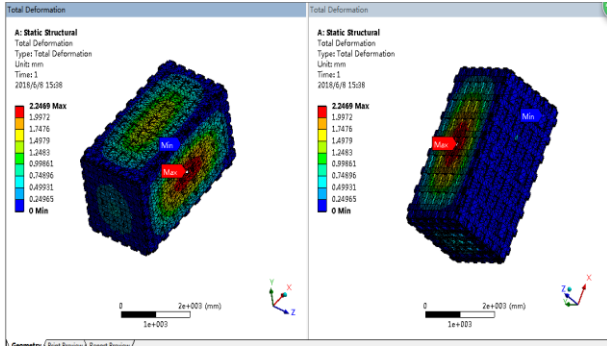


Figure 16. Total deformation cloud diagram of a drying chamber with a wall thickness of 15 mm and a rib spacing of 150 mm

After adding the reinforcing ribs to the drying chambers with different wall thicknesses, the strength and rigidity of the drying chamber are significantly improved. However, the greater the number of reinforcing ribs, the higher the manufacturing cost.

3) In order to reduce the manufacturing cost, the rib spacing is gradually increased and analyzed. When the spacing of the ribs is increased to 410 mm, the analysis results are as follows:

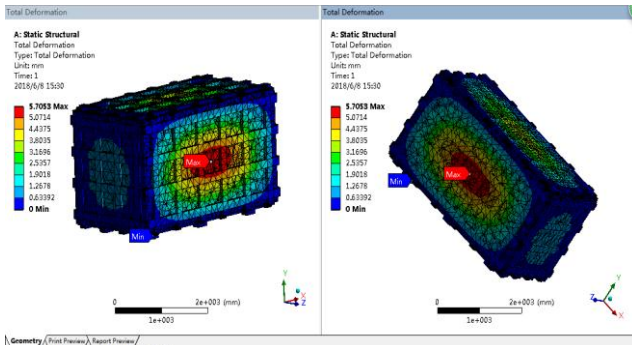


Figure 17. Total deformation cloud diagram of a drying chamber with a wall thickness of 4 mm and a lateral spacing of the ribs of 410 mm

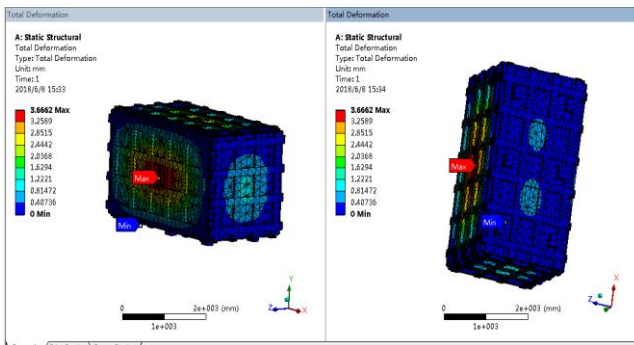


Figure 18. Total deformation cloud diagram of a drying chamber with a wall thickness of 8 mm and a lateral spacing of the ribs of 410 mm

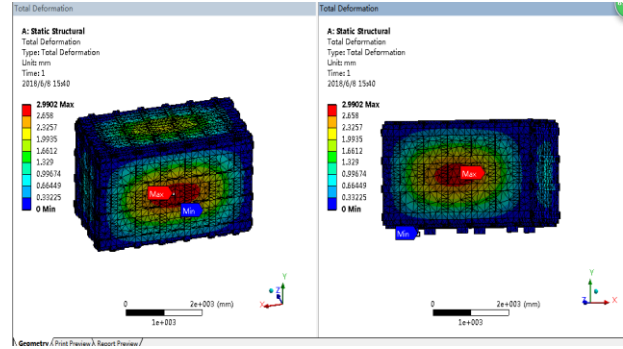


Figure 19. Total deformation cloud diagram of a drying chamber with a wall thickness of 15 mm and a lateral spacing of 410 mm

It can be seen from the figure that when the spacing of the reinforcing ribs is 410 mm, although the strength and rigidity of the drying chamber body are changed, the strength and rigidity satisfy the design requirements. From the point of view of total deformation, the deformation of the drying chamber corresponding to each wall thickness is only about 1 mm.

In summary, after ANSYS analysis, we can clearly see from the deformation cloud diagram that without reinforcement, the strength and stiffness required by the design can not be met, and the reinforcement can meet the design requirements. However, in the initial stage of design, the rib spacing calculated by the empirical formula satisfies the required strength and rigidity, but the spacing of the ribs is small, resulting in a large number of ribs. When the distance between the ribs is increased to 410 mm, the number of ribs is reduced by half, and the body strength and rigidity of the drying chamber are not greatly affected, and the amount of deformation is in the design range and the like. Therefore, the final choice is 8mm wall thickness and 410mm rib spacing. As shown in Figure 20.

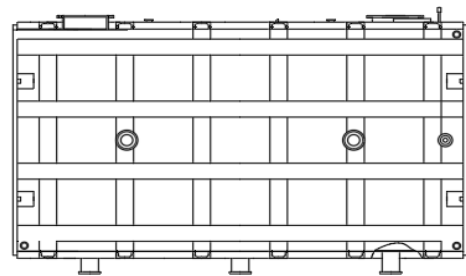


Figure 20. Optimization of the rectangular box-shaped drying chamber assembly diagram

IV. CONCLUSION

Through this study of the strength and stiffness of the drying chamber, the following conclusions are obtained:

- It is unscientific to increase the strength and rigidity of the box by increasing the wall thickness in the box type drying chamber of the large-scale freeze-drying

equipment. It is necessary to appropriately add the reinforcing ribs to greatly reduce the wall thickness.

- For the problem of insufficient strength and rigidity of the 75 m² box type drying box, the problem is solved by adding reinforcing ribs to the outer wall; finally, the outer wall structure with the spacing of the reinforcing ribs of 410mm and the wall thickness of 8mm is determined.

This design solves the problem of low effective space utilization in the drying chamber, but the drying chamber energy consumption is still not improved, so the structure of the drying chamber needs to be further optimized.

ACKNOWLEDGMENT

This paper was supported by the Key Laboratory Research Program of Education Department of Shaanxi Province (18JK0392).

REFERENCES

- [1] Xu Chong, Chen Jie, Chen Liyuan et al. Application of vacuum freezing technology in the processing of edible fungi, *Journal of Microbiology*, 2015, 35(6): 98~99

- [2] Shi Weiqin. The latest progress in food vacuum freeze drying at home and abroad, *Shanghai Far East Pharmaceutical Machinery General Factory*, 2012: 190~192
- [3] Xu Chenghai, Zhang Zhijun, Zhang Shiwei et al. Analysis of current status and development trend of vacuum drying, *drying technology and equipment*, 2009, 7(5): 209~213
- [4] Li Wei, Chen Min. Design and calculation of small laboratory vacuum freeze dryer for vegetables, *Journal of Xi'an Highway and Transportation University*, 1996, 16(3): 97~101
- [5] Zhou Yongan. *Design, Packaging and Food Machinery for Food Vacuum Freeze Dryer*, 1996, 14(3): 18~20
- [6] JohnM.Walker, *Cryopreservation and Freeze-Drying Protocols, METHODS IN MOLECULAR BIOLOGY*,368
- [7] Yan Ma,Xingzhuang Wu,Qi zhang. Key composition optimization of meat processed protein source by vacuum freeze-drying technology,*Saudi Journal of Biological Sciences*,1~8
- [8] Hong-Ping Cheng, Shian-Min Tsai, Chin-Chi Cheng. Analisis of Heat Transfer Mechanism for Shelf Vacuum Freeze-Drying Equipment, *Advances in Materials Science and Engineering*,2014,1~7.
- [9] Liu Jun, Runling Peng, Xie Yuanhua. *Freeze Vacuum Drying*, Beijing, Chemical Industry Press. 2015.9
- [10] Hu Xinzhuo. Ray125 vacuum freeze dryer design, master's thesis, Shanghai, East China University of Science and Technology, 2017