Finite Element Dynamic and Static Analysis of Agaricus bisporus Picking Robot Mobile Platform

Hao Chen¹, Tao Yu² and jianfei Chai¹*

¹Shanghai University, School of Mechatronic Engineering and Automation, China
²Shanghai Polytechnic University College of Engineering, China
¹*Information Technology office, School of Mechatronic, Engineering and Automation, Shanghai University, Shanghai, China
*Corresponding author’s e-mail: jfchai@shu.edu.cn

Abstract. In response to the design needs of the spore mushroom picking robot mobile platform, SolidWorks software was used to build the model and ANSYS software as the analysis tool. The static and modal analysis of the mobile platform of the Agaricus bisporus picking robot was carried out, and the stress cloud diagram, displacement cloud diagram and vibration mode diagram were obtained. The resulting stress from the stress diagram is less than the yield stress of the material, but the stress concentration is large. After the improvement of the connection method of the mobile platform parts, the stress concentration of the mobile platform becomes significantly smaller, which is more in line with the design requirements. This is of great significance to the researchers of picking robot mobile platforms.

1. Introduction

The Agaricus bisporus picking robot mobile platform is one of the important structural components of the Agaricus bisporus picking robot, and the structural characteristics have a great influence on the performance of the Agaricus bisporus picking robot, mainly reflected in the strength, seismic performance and service life of the mobile platform [1]. Therefore, the mobile platform is the most critical force-bearing component in the spore mushroom picking robot. Its strength and rigidity will directly affect the accuracy and life of the picking robot. Due to the complex shape of the mobile platform structure, it is difficult or even impossible to calculate the static and dynamic characteristics by the general method [2]. Therefore, this article will use ANSYS software to conduct static analysis and modal analysis on the structure of the mobile platform, study the impact of its static and dynamic performance, understand the stress, strain and deformation of the mobile platform, and provide the necessary for the design of the bisporus mushroom picking robot in the future.

2. Establishment of the finite element model of the mobile platform model

2.1. The establishment of three-dimensional model of the spore mushroom picking robot mobile platform

SolidWorks is used to build a three-dimensional model of the spore mushroom picking robot mobile platform, as shown in Figure 1. The large-scale finite element analysis software ANSYS is used to do the finite element analysis of the spore mushroom picking robot mobile platform, because SolidWorks and ANSYS have a complete interface [3], so that the established 3D model can be accurately imported into the finite element analysis software ANSYS, Thereby avoiding the errors that may be generated.
when using other common formats for conversion [4–6]. It should be noted that the default unit of ANSYS needs to be consistent with the default unit of SolidWorks.

Figure 1. Three-dimensional model of the mobile platform of Agaricus bisporus

2.2. Finite element meshing of the mobile platform of Agaricus bisporus picking robot

The solid45 unit is used to define the mobile platform of the spore mushroom picking robot, and the column material is 7075 aluminum alloy, and its performance parameters are shown in Table 1 [7]. When meshing, due to the complex structure of the mobile platform, there are cross beams inside and outside, and some of the beam wall panels are perforated, which makes the surface shape of the mobile platform complex, and it is difficult to use mapping grid. The grid division in this subject adopts the free grid division form. And adopt Smart Sizing control (Smart Sizing), ANSYS divides the grid precision into 10 levels in the smart splitting control, in which the default precision is 6, where 1 is the finest grid, and 10 is the coarsest grid [8–9]. Considering that the mobile platform is a large-sized structure, in order to reduce the number of units and increase the analysis speed, the accuracy of the meshing can be appropriately reduced. In this topic, the grid division accuracy is 7 levels. In the selection of elements, considering the large manual intervention of the 10-node 4-hedron element, this article uses the 10-node 4-hedron element SOLID45, first of all to control the size of the loading part, and then select the seven-level precision pair in the meshing tool dialog box. The model is divided into free grids. After the division, there are 167545 nodes and 88323 units respectively. The division result is ideal. The grid division is shown in Figure 2.

Figure 2. Grid division of Agaricus bisporus picking robot mobile platform

Table 1. 7075 aluminum alloy material performance parameters

| density (kg/cm³) | Poisson’s ratio | Elastic Modulus (MPa) | tensile strength (MPa) | Yield Strength (MPa) |
|----------------|----------------|-----------------------|-----------------------|---------------------|
| 2.81           | 0.33           | 7.1×10⁵               | 524                   | 455                 |

3. Static analysis of the mobile platform of Agaricus bisporus picking robot

The static analysis of the Agaricus bisporus picking robot mobile platform is to calculate the response of the robot mobile platform structure under a fixed load. That is, the stress distribution and deformation of the frame under various working conditions, the maximum stress value and the maximum displacement value are obtained, and the dangerous points of stress and strain are determined. Improve the frame structure according to the danger points to ensure that the robot is safe and stable during the picking process, while also reducing its production costs.
3.1. Load and boundary condition setting of the mobile platform of the spore mushroom picking robot

The load carried by the mobile platform mainly includes: the mobile platform's own weight $q_1=450N$, expressed by the acceleration of gravity; the load $q_2=430N$ in the picking area, distributed on the mobile platform through the uniform load; the load $q_3=330N$ in the auxiliary area, through the static force The principle of equivalence is distributed on the placement of the mobile platform; the load $q_4=100N$ in the visual area is applied to the corresponding unit area according to the principle of equivalent load; the load distribution of the mobile platform of the spore mushroom picking robot is shown in Figure 3.

![Figure 3. Load distribution of the mobile platform of Agaricus bisporus picking robot](image)

This article mainly studies the stress distribution and deformation of the mobile platform under working and start-stop conditions. Among them, the dynamic load coefficient of the mobile platform when working is taken as 1.3, and the dynamic load coefficient when starting and stopping is taken as 2. Since the mobile platform of the Agaricus bisporus picking robot has always been in the Y direction of forward and backward movement directions, the two degrees of freedom in both X and Z directions need to be constrained.

3.2. Static analysis results of the mobile platform of Agaricus bisporus picking robot

After the load and boundary constraints are applied to the model, the static structural module in ANSYS Workbench is used to solve the calculation. The node equivalent stress distribution and displacement distribution cloud map of the Agaricus bisporus picking robot mobile platform are shown in Figure 4 and Figure 5.

![Figure 4. Equivalent stress cloud of the mobile platform of Agaricus bisporus picking robot](image)

Figure 4 is an equivalent stress cloud diagram. It can be seen that the stress is mainly concentrated near the connection part of the left and right wall panels of the mobile platform of the Agaricus bisporus picking robot, that is, there will be stress concentration at this point, where the maximum stress reaches 158Mpa (material yielding The stress is 455MPa). The stress of this connection structure is large. The deformation of the mobile platform under the action of multiple forces is shown in Figure 5. It can be seen that the maximum deformation is 41.228mm under the action of multiple forces, and the maximum deformation occurs at the connection between the wall plates on the left and right sides of the mobile platform and the beam.
3.3. Comparison of the optimization results of the spore mushroom picking robot mobile platform

According to the analysis of the previous analysis results, in order to meet the use requirements of the mobile platform, it is necessary to change the force situation here, concentrate and disperse the force of the object, balance the force points of the mobile platform, and prevent fracture and deformation. According to the principle of reducing stress concentration, the simplest method besides increasing the beam is to change the connection method of the beam. Under the premise of ensuring the normal operation of the mobile platform, you can choose to change the connection hole between the beam and the wall panel from the original circular hole to an elliptical hole. In order to enhance the reliability of the connection between parts. As shown in Figure 6. Re-establish the model of the optimized mobile platform, analyze and calculate the results as shown in Figure 7, Figure 8 and Table 3.
According to the analysis results of ANSYS, it can be seen that after optimizing the connection method of the wall panel and the beam, the stress distribution of the optimized mobile platform is more uniform, and the phenomenon of stress concentration is significantly improved. The maximum stress value is reduced from 158Mpa to 39.897Mpa, which is much smaller than the yield stress value of the material (the yield stress of 7075 aluminum alloy is 455Mpa). Therefore, the optimized mobile platform is more in line with the conditions of use.

4. Modal analysis of agile mushroom picking robot mobile platform

In structural dynamics analysis, modal analysis plays an important role, it is mainly used to calculate the two basic parameters of the model's natural modal: natural frequency and vibration mode. They show the characteristics of the free vibration of the system. For a given system, the ratio of the system mode vector and the natural frequency are determined by the physical parameters of the system and are inherent to the system. If the natural frequency of the structure is known, the natural frequency of the structure can be avoided from its external excitation frequency during use during design and improvement, thus providing the necessary basis for the dynamic optimization design of the frame.

The modal analysis of the mobile platform of the Agaricus bisporus picking robot is an undamped mode, and the motion equation of the dynamic problem is:

\[ [M] \ddot{\mathbf{x}} + [K] \mathbf{x} = \mathbf{0} \]

Where: \( M \) is the structural mass matrix; \( K \) is the structural stiffness matrix; \( \ddot{\mathbf{x}} \) is the nodal acceleration vector; \( \mathbf{x} \) is the nodal displacement vector.

The vibration of the mobile platform structure is generally a simple resonance, and its displacement vibration law is generally in the form of a sine function \( \mathbf{x} = \mathbf{x}_0 \sin \omega t \), where \( \omega \) is the free vibration frequency. Bring the above formula to get:

\[ ([K] - \omega^2[M]) \mathbf{x} = \mathbf{0} \]

Modes are the natural vibration characteristics of a structure. Each mode has a specific natural frequency, damping ratio, and vibration mode. Since the analysis structure of constrained modal analysis is more in line with the actual working conditions, this article also uses the constrained modal analysis method. Use ANSYS Workbench to analyze the constrained modal of the mobile platform. The mode of taking the first 6 orders is shown in Fig. 6. The first 6 natural frequencies and vibration modes of the mobile platform are shown in Table 2.

| Amount of change         | Before optimization | Optimized  | The amount of change |
|--------------------------|---------------------|------------|----------------------|
| Maximum stress (MPa)     | 158                 | 39.897     | -118.103             |
| Maximum displacement (mm)| 41.228              | 4.3312     | -36.8968             |

Table 2. Comparison of data before and after optimization of mobile platform connection
Figure 9. The first six vibration modes of the mobile platform of Agaricus bisporus picking robot

Table 3 Frequency and deformation modes of mobile platforms

| Order | Natural frequency (Hz) | Maximum deformation (mm) |
|-------|------------------------|--------------------------|
| 1     | 33.966                 | 23.417                   |
| 2     | 39.341                 | 23.289                   |
| 3     | 44.790                 | 31.234                   |
| 4     | 45.439                 | 32.979                   |
| 5     | 46.325                 | 28.500                   |
| 6     | 46.816                 | 33.016                   |

Figure 6 shows the vibration modes of the mobile platform in the 1st to 6th order. Among them, compared with other vibration modes, the maximum deformation under the fourth and sixth vibration modes is the largest, respectively 32.979mm and 33.016mm, and they are located on the two connecting shafts of the mobile platform. Table 3 shows the first 6 natural frequencies of the mobile platform. It can be seen that the natural frequency of the mobile platform of the Agaricus bisporus picking robot is not continuous in the low frequency range, the distribution is relatively uniform, and the variation range is small, which does not affect normal use.

5. Conclusion
(1) The static analysis results of the mobile platform under working conditions show that the maximum deformation of the mobile platform is 41.228 mm, and the maximum stress on the mobile platform is 158 Mpa. After the optimized connection mode, the maximum deformation of the mobile platform is 4.3312mm, and the maximum stress is 39.897 Mpa. The stress on the optimized mobile platform is more dispersed, which is much lower than the yield stress of the material.

(2) Carry out constrained modal analysis on the mobile platform. The lowest natural frequency of the first 6 modes of the mobile platform is 33.966 Hz. The highest natural frequency is 46.816Hz. The range of frequency change is small and will not cause resonance of the mobile platform.

The analysis results show that the finite element analysis of the mobile platform of the Agaricus bisporus picking robot based on ANSYS Workbench improves the design efficiency of the mobile platform, and has certain reference significance for the further improvement and optimization of the mobile platform.

Acknowledgments
This work was supported by Shanghai Agriculture Applied Technology Development Program, China(Grant No.2019-02-08-00-10-F01123) and the Project of Key Discipline of Shanghai Polytechnic University (No. XXKZD1603).

References
[1] Mao Jian. Dynamic and static analysis and optimization of the main structure of high-grade CNC honing machine [D]. Lanzhou University of Technology, 2012.
[2] Huang Hui. Finite element analysis and optimized design of torpedo tanker [D]. Shijiazhuang Railway University, 2013.
[3] Mao Jian, Xin Zhou. Finite element static and dynamic analysis of the column of 2MK2250 + 150
high-end CNC honing machine [J]. Machinery and Electronics, 2011 (11): 36-38.

[4] Wang Ren. Structural design and analysis of the mechanical arm of the agricultural picking robot [D]. Hunan Agricultural University, 2010.

[5] Sun Jinxia. Static analysis of fuel cell vehicle frame based on finite element technology [J]. SAIC Motor, 2006 (06): 36-38.

[6] Lv Jiangtao. Static and dynamic finite element analysis and structural improvement of SX360 dump truck frame [D]. Xi’an University of Technology, 2000.

[7] Liao Yixiang. Update to the MUSIG model in ANSYS CFX for reliable modelling of bubble coalescence and breakup [J]. Elsevier, 2020,81 (C).

[8] Liu Yan. Finite element analysis and optimized design of tunnel car frame [D]. Shijiazhuang Railway University, 2017.

[9] Liu Lijuan, Wang Zhanying, Liang Jianming, Liu Chundong, Wang Shaolei, Geng Mingchao. Static finite element analysis of the front frame of ZL30 loader [J]. Electronic Testing, 2017 (07): 34-35.