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Silkworm Frame Stacking System Based on Two axis Motion Platform

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Abstract: *Since ancient times, China has been a major country in sericulture. Although China has a long history of planting mulberry and raising silkworms, the stacking and handling of silkworm frames has always been manual, which is not only time-consuming and laborious, but also requires a large number of workers, and the handling efficiency is low. To solve this problem, this paper designs a silkworm frame stacking system based on a two axis mobile platform according to the handling and movement of the big silkworm frame in the silkworm breeding industry, which is used to solve the mechanical handling problem of the big silkworm frame in the silkworm breeding industry, and realize the handling and placement process of the big silkworm frame. The three-dimensional modeling of the mobile platform is conducted using UG, and the ANSYS Workbench finite element modal analysis of the gear shaft is conducted. Through modal analysis, the natural first-order frequencies of the two gear shafts are respectively 9545.8Hz and 7892.4Hz, which are greater than the frequency of the two gear shafts, that is, the natural speed is greater than the speed of the gear shaft. Therefore, the gear shaft design meets the requirements. Finally, the overall design meets the requirements for smooth handling of the big silkworm frame.*

Keywords: *Mobile Platform, Modal analysis, ANSYS Workbench, UG 3d modeling*

1. Introduction

As an intelligent logistics transfer and handling system that integrates multiple functions, mobile platforms provide a highly flexible and automated transportation method for modern equipment manufacturing, logistics and other industries[1]. In agriculture, mobile platforms can be used as mobile robots. In the past, the level of mechanization in the silkworm industry was low, and the handling of silkworm frames was generally done manually, which was time-consuming, laborious, and inefficient. With the continuous development of emerging technologies, new agricultural production models have emerged, and the intelligence of agricultural machinery is currently the development direction of agricultural machinery[2]. Agricultural robots are the product of the transformation of agriculture from artificial to intelligent and automated[3]. Agricultural mobile platforms have experienced rapid development in recent decades[4].Applying mobile platforms to automatic stacking of silkworm frames has also become a current research hotspot. With the further research and development of mobile platforms, the characteristics of high transportation efficiency and not wasting a lot of human labor will lead to an increasing demand for mobile platforms in the silkworm industry market. Therefore, it is necessary to design, improve and optimize mobile platforms, and launch an efficient and economical silkworm frame stacking system.

2. Main institutional design

This article designs a small two axis moving platform based on the handling and movement of large silkworm frames in the sericulture industry, which is used to solve the mechanical handling problem of large silkworm frames in the sericulture industry and achieve the handling and placement process of large silkworm frames. The small two axis mobile platform is expected to have the following characteristics: low manufacturing cost, relatively small size, simple structure, simple operation, high handling efficiency, and the ability to smoothly transport large silkworm frames. This device mainly includes a driving motor device, an x-axis transmission mechanism, a z-axis transmission mechanism, a

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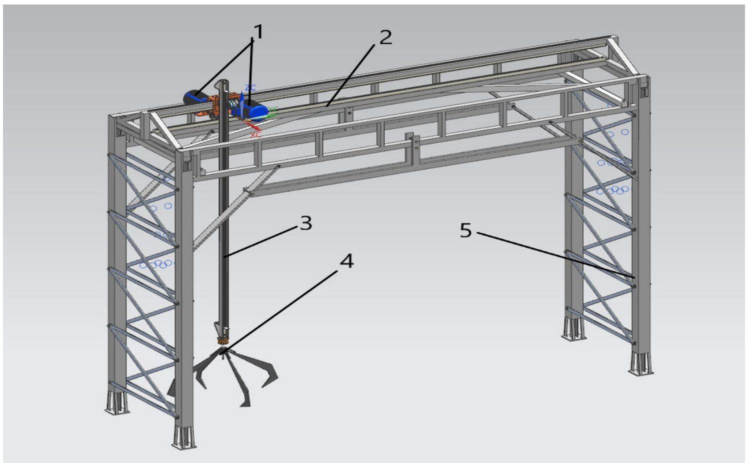
silkworm frame grabbing mechanism (the grabbing structure is not designed in this article), and a mobile platform main body mechanism,as shown in Figures 1 .

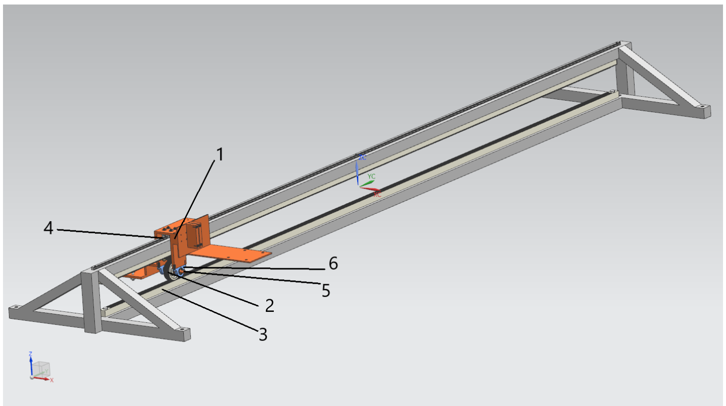


1. Drive motor; 2. X-axis gear rack transmission; 3. Z-axis gear rack transmission; 4. Capture mechanism; 5. Mobile platform entity

Figure 1 Main mechanism of two axis mobile platform

3. X-axis transmission mechanism

For this design, based on the advantages of high efficiency, compact structure, reliable operation, long service life, and stable transmission of gear transmission, a gear set transmission system with external gear meshing and rack and pinion meshing was selected for mechanical transmission, as shown in Figures 2 . Install the electric motor on the driving wheel 1, and the driving wheel 1 drives the driven wheel 2 to move back and forth on the meshing racks, so that the Z-axis of the moving platform can move left and right under the driving wheel.



1. Carrying platform; 2. Gear set; 3. Spur gear set; 4. Slide guide rail; 5. Gear shaft; 6. Bearing seat

Figure 2 X-axis transmission system

4. Z-axis transmission mechanism

The transmission system of the Z-axis moves vertically. In order to connect the Z-axis moving rod with the X-axis moving rod, a slider and guide rail are selected to be assembled and connected to the gear shaft on the X-axis gear transmission through the loading platform. This allows the vertical moving rod to perform auxiliary movement on the slider guide rail under the drive of the gear. Then, a slider is installed vertically on the loading platform, connected to the guide rail on the Z-axis transmission device, and driven by the Z-axis transmission device, allowing the vertical moving rod to move up and down. As shown in Figure 3, comparing several transmission systems, it was found that bevel gears are suitable for vertical transmission. The Z-axis transmission system was selected as a combination transmission of bevel gears and spur gear teeth. By calculation, it is reasonable to choose a Z-axis length of 2500mm.The calculation shows that a motor with a minimum power of 0.258kw is required to meet the design

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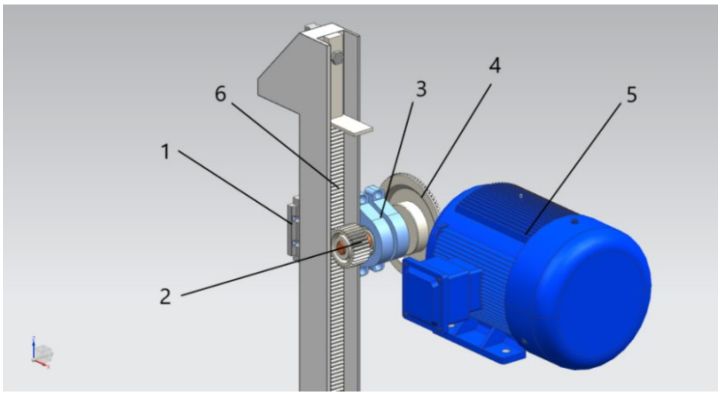
requirements.To choose a motor with a higher power, which is 0.55kw, the Y series Y80M1-4 motor is chosen.



1. Slide guide rail; 2. Straight tooth gears; 3. Bearing seat; 4. Bevel gear set; 5. Electric motor; 6. Rack and pinion

Figure 3 Z-axis transmission system

5. Design of Mobile Platform Main Body

Silkworm tools are all the tools needed in the process of raising silkworms, and the large silkworm frame is an important tool used to raise silkworms in the sericulture industry. According to the design requirements, when the end grabbing mechanism of the Z-axis grabs the large silkworm frame, the height between the large silkworm frame and the grabbing mechanism is 500mm. The height of stacking the large silkworm frames into a group is 2000mm, and the bracket should leave a certain distance for the Z-axis to move up and down,so the height of the bracket H>2000+500=2500mm.Therefore, the height of the bracket, as shown in Figure 4, is 3000mm.

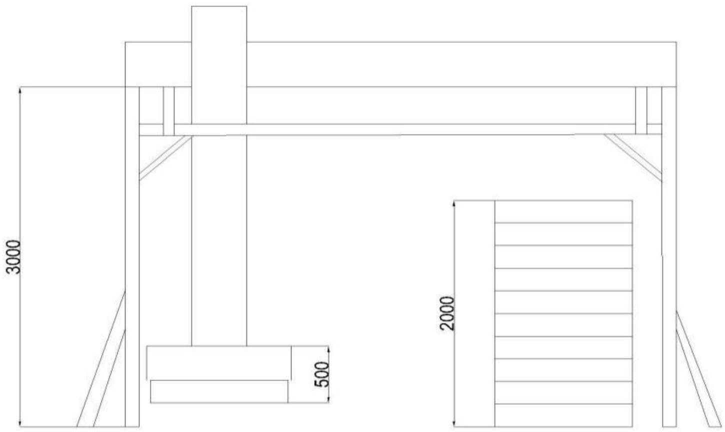


Figure 4 Support height

Select channel steel as the material for the bracket,according to the design requirements, it is calculated that in order to ensure the stability of the support structure and prevent damage, the mass of the selected crossbeam should be less than 457kg. In addition, the transmission system and drive system of the two axes, as well as the large frame, have their own mass, which must be borne by the bracket and meet the design requirements of small size. Therefore, the mass of the crossbeam in the X-axis direction is 20kg, and the mass of the crossbeam in the Y-axis direction is 10kg. Therefore, the material of the crossbeam is commonly chosen Q235 steel.

The specification of the large silkworm frame is 1000 × 1500mm, and the width of the large silkworm frame is 1000mm. The distance during the horizontal movement in the middle of the Z-axis is the distance moved in the X-axis direction, and the horizontal movement length is required to be greater than or equal to 1500mm. Therefore, the horizontal movement distance L of the Z-axis moving rod is:

$$L \geq 1000+1500+1000=3500mm$$

According to the requirements and sufficient space to be reserved for the Z-axis for lateral movement, the length of the crossbeam is selected as 4000mm, as shown in Figure 5. The width of the crossbeam is selected as 57mm, and the height of the crossbeam is also selected as 50mm.

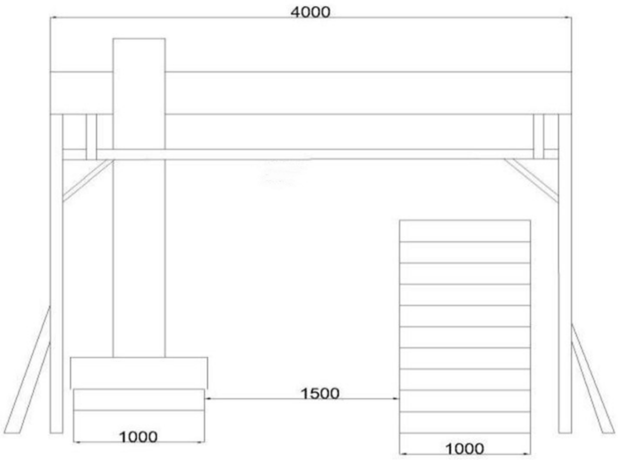


Figure 5 Cross beam length

6. ANSYS Workbench Dynamic Analysis

6.1 Modal analysis of spur gear shaft

Select the stepped shaft as the gear shaft on the Z-axis, use 45 steel as the material for the shaft, and calculate the basic structure of the shaft according to the Mechanical Design and Mechanical Parts Design Manual, as shown in the following Figure 6:

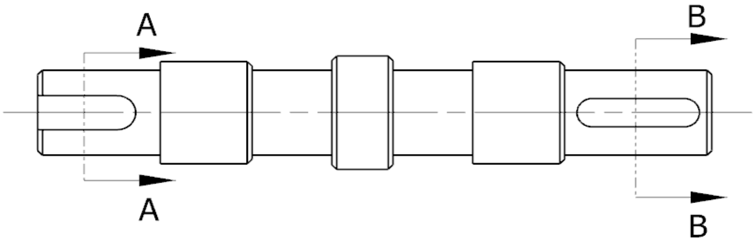


Figure 6 Spur gear shaft

Check the strength of the shaft according to the combined stress of bending and torsion: When checking,take $\alpha = 0.6$ .The calculated stress of the axis is

$$\sigma_{ca} = \frac{\sqrt{M + (\alpha T_1)^2}}{W}$$

In the formula: σ_{ca} is the calculated stress of the axis, M is the bending moment acting on the axis, T is the torque acting on the shaft,the bending section coefficient with W as the axis, α is the conversion coefficient.

Derived from design,the torque of the shaft is $T_1 = 1.5 \times 10^4 N \cdot mm$,the speed of the shaft is $n_1 = 463.3 r/\min$,and the diameter of the indexing circle for the large gear is $d_2 = 126mm$,from the structural diagram of the axis,it can be seen that section A-A is a dangerous section.So, based on the force calculation at the cross-section, it can be concluded that $M = 10929 N \cdot mm$, $W = 337.5mm^3$,the calculated stress of the shaft is:

$$\sigma_{ca} = \frac{\sqrt{17790^2 + (0.6 \times 1.5 \times 10^4)^2}}{337.5} = 42MPa$$

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The material of the shaft is 45 steel,tempering treatment,Check "*Mechanical Design*"[5] get $[\sigma_{-1}] = 60MPa$,the calculated stress is $\sigma_{ca} < [\sigma_{-1}]$,meet the design strength requirements.

Perform finite element dynamic analysis on the spur gear shaft and bevel gear shaft of the mobile platform. Finite element ANSYS dynamic analysis is divided into modal analysis, harmonic response analysis, transient dynamic analysis, and spectral analysis[6].

Use NX UG10.0 to create a 3D model of the gear shaft, and then import it into ANSYS Workbench,the material selection for the shaft is 45 quenched and tempered steel.The material density is $\rho = 7.85g/cm^2$,elastic modulus is $E = 2.06 \times 10^{11} Pa$, Poisson's ratio is $\mu = 0.3$ .Perform modal analysis:

(1) Define the material parameters of the gear shaft, and then grid the shaft to obtain the results shown in the Figure 7:

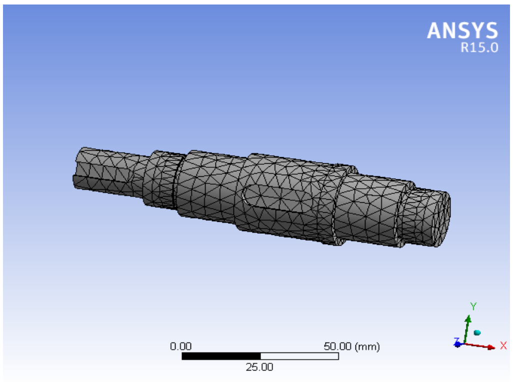


Figure 7 Grid division diagram of spur gear shaft

(2) Apply constraints

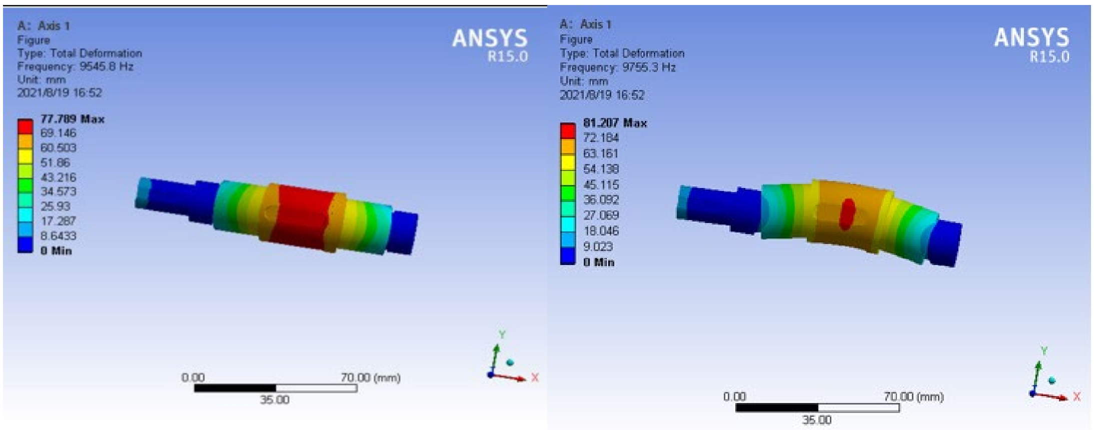
Apply cylindrical constraints to the two bearings of the gear shaft.

(3) Analyze

After completing the previous steps, the gear shaft was analyzed and the fourth mode was selected. The obtained vibration mode diagram and modal data are shown in the Figure 8 and Figure 9 below:

order	first order	second order	third-order	fourth-order
Frequency/Hz	9545.8	9755.3	12848	13308
Maximum vibration displacement/mm	77.789	81.207	106.99	347

Figure 8 Modal Data Table



(a) first order (b) second order

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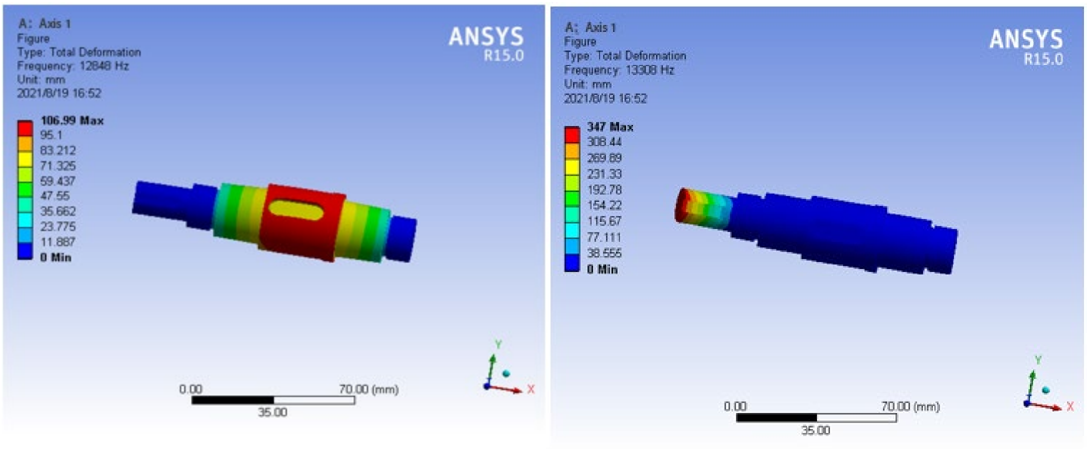

(c) third-order (d) fourth-order

Figure 9 Modal vibration mode diagram of spur gear shaft

From the above figures, it can be seen that the maximum displacement of the gear shaft vibration is mainly at the gear installation section. From the verification of the shaft above, it can be concluded that this section meets the strength requirements of the design. By solving, the first natural frequency is 9545.8Hz, and the first rotational speed is $n_1 = 572748r/\min$ .The speed of the gear shaft is much smaller than the rotational speed of the natural frequency, so the gear shaft meets the design requirements.

6.2 Modal analysis of bevel gear shaft

Use NX UG10.0 software to model the bevel gear shaft, and then import it into the workbench for modal analysis.The material of the gear shaft is selected as 45 steel,material density is $\rho = 7.85g/cm^3$,elastic modulus is $E = 2.06 \times 10^{11} Pa$,Poisson's ratio is $\mu = 0.3$.

(1) Define the material parameters of the gear shaft in the workbench, then divide the grid to obtain the image shown in the Figure 10:

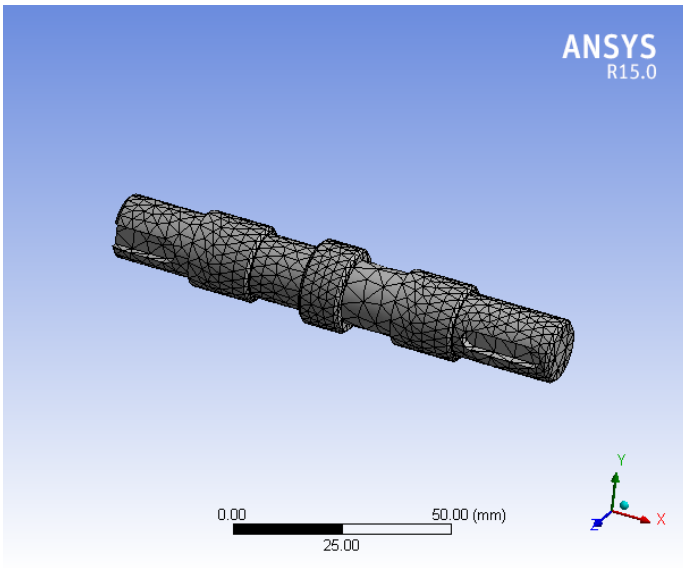

Figure 10 Grid division diagram of bevel gear shaft

(2) Apply constraints

Apply a cylindrical constraint to the bearing of the bevel gear shaft.

(3) Analyze

After dividing the gear shaft into grids and applying constraints, the gear shaft was solved. In modal analysis, the fourth mode was selected, and the data in Figure 11 and modal shape diagram (Figure 12)

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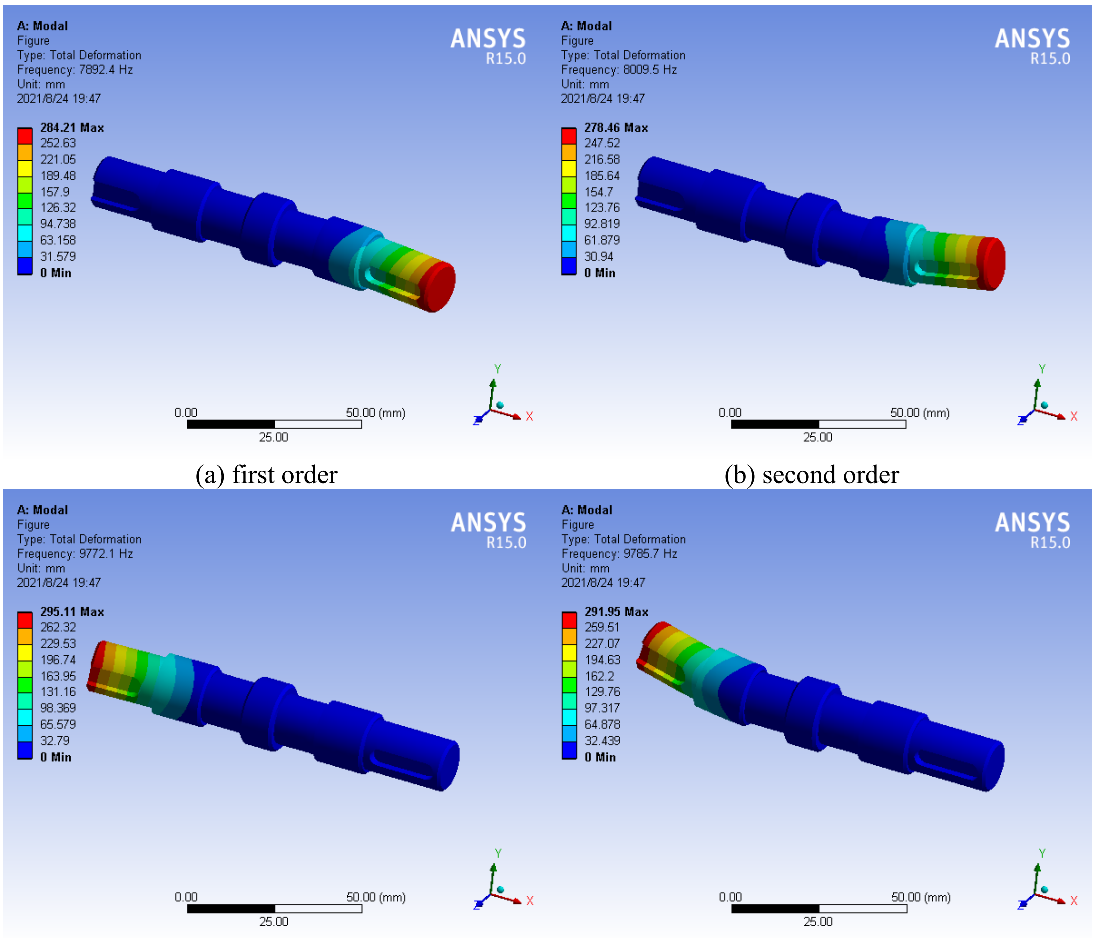
were obtained as follows:

order	first order	second order	third-order	fourth-order
Frequency/Hz	7892.4	8009.5	9772.1	9785.7
maximum displacement/mm	284.21	278.46	295.11	291.95

Figure 11 Modal Data Table



(a) first order (b) second order

(c) third-order (d) fourth-order

Figure 12 Modal vibration mode diagram of bevel gear shaft

Based on the above data, the first-order natural frequency can be obtained as 7892.4Hz, and the calculated rotational speed of the first-order mode is $n_1 = 473544 r / \min$,and the speed of the gear shaft is $n = 463.3 r / \min$ .Meeting the design requirements.

7. Conclusion

The design of a small two axis mobile platform is to facilitate the gripping and handling of goods by small farms or factories.The strength of the main bracket was calculated, and the maximum bearing capacity that the bracket can withstand was 4480N. Other components were selected within the bearing range.Calculate the minimum output frequency of the required motor according to the design requirements and complete the motor selection. By designing the two axis movement mode of the mobile platform and selecting the most suitable gear rack transmission scheme, the mobile platform can move flexibly in the X and Z axis directions.Design and verify the gear shaft to meet the design strength requirements, and finally conduct finite element dynamic analysis on the gear shaft to meet the design requirements. The design of a small two axis mobile platform can to some extent meet the needs of small farms and individual breeders for transporting silkworm frames, and the price is cheap, reducing labor consumption, improving work efficiency, and to some extent solving the transportation problem of silkworm frame stacking in mulberry farming.

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