Design and optimization of the frame of the air-driven electrostatic spray locomotive

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Abstract. Aiming at the problem of excessive vertical bending and deformation of the frame due to the excessive weight of the air-driven electrostatic sprayer when fully loaded, and the crossbeam of the frame is prone to deformation. In this paper, the design and research of the frame are based on the mechanical principle, the Solidworks software is used to model the frame, and the ANSYS software is used to perform static analysis on the frame of the air-driven electrostatic sprayer when fully loaded, so as to obtain the stress and displacement of the frame. Verify the rationality and correctness of the finite element analysis. Finally, with the maximum deformation as the constraint, the lightweight design of the frame structure is carried out to complete the structural optimization of the frame.

1. Introduction

With the development of agricultural modernization, agricultural production has developed from extensive, low-tech to refined and high-tech [1]. At present, there are relatively few domestic researches on the frame of air-driven electrostatic sprayers, and domestic production The main components of the air-driven electrostatic sprayer frame are produced by imported and foreign-funded enterprises, which has caused the problem of high cost of the sprayer [2,3]. The frame is an important component of the air-driven electrostatic sprayer. It is the installation carrier of each system. It bears various vibrations and shocks generated by the sprayer when it is working. Therefore, the weight of the frame and its distribution position directly affect the air-driven electrostatic The driving stability of the sprayer, so reasonable frame structure and dimensional parameters are very important to the frame [4,6].

At present, Tong Shuiguang and others use the finite element method to analyze the static and dynamic characteristics of the internal combustion vehicle frame. Calculate the force of the frame under critical conditions, perform modal analysis, and perform harmonic analysis on the frame based on the results of the modal analysis. Response analysis shows that the safety of the frame is relatively high, and the vibration performance of the front panel is significantly improved after the addition of M2052 high-damping alloy gaskets [7]. Ren Zhili and others analyzed the dynamics and statics of the newly designed tobacco seedling transplanting machine frame through finite element analysis. Obtain the static equivalent stress, equivalent strain cloud diagram and the maximum stress and strain values, obtain the dynamic six-order modal analysis results, and test the performance of the frame [8]. According to the
static analysis results of the pure electric passenger car frame, Sheng Jian and others analyzed the weak links of the frame, took the wall thickness of the main beam of the frame as the input parameter, optimized the parameters of the frame, obtained the corresponding frame optimization model, and performed it under typical working conditions. The statics analysis, comparing the analysis results with the force of the frame before optimization, provides a theoretical basis for the improvement and optimization of the frame structure of pure electric passenger cars [9].

Use the finite element analysis software ANSYS to perform static analysis on the frame, calculate the stress distribution and deformation of the frame under bending conditions, and optimize the frame structure and carry out lightweight design based on the finite element analysis results.

2. Frame structure design
The main frame of the frame uses hot-dip galvanized channel steel profiles. The main walking tires, auxiliary casters, traction devices, rear brackets, rear handles, and side guardrails are installed on the frame. The structure of the frame is shown in Figure 1. The basic parameters are shown in Table 1.

![Frame structure diagram]

Figure 1. The structure of the frame

| Material                  | S235JR steel                      |
|---------------------------|-----------------------------------|
| Surface treatment         | Hot dip galvanized               |
| Axle                      | Adjustable                        |
| Tractor connection method | Eye circle joint lever            |

3. Finite element analysis and structure optimization of frame
All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. As show in Fig. 1 and Table 1, three scheme comparing.

3.1. Simplification of the frame
A three-dimensional model of the frame of the air-driven electrostatic spray locomotive was established in Solidwork, and the frame was simplified. The frame material is Q235A (density is 7.85×103kg/m3, elastic modulus E is 2.11×105MPa, Poisson’s ratio is 0.26) welded. The simplified three-dimensional structure diagram of the frame is shown in Figure 2.
Figure 2. Three-dimensional structure drawing of the frame

3.2. Mesh division
Mesh division is an important part of finite element analysis, and its quality can directly affect the accuracy of the finite element analysis results. The model of the frame is divided into hexahedral grids, the grid size is set to 5 mm, and the whole frame is gridded by the intelligent grid division function of ansys workbench19.0. The grid division diagram of the frame is shown in Figure 3.

Figure 3. The grid division diagram of the frame

3.3. Load loading
The load on the sprayer frame includes concentrated load and uniform load. The uniform load is mainly the weight of the frame, and the concentrated load is mainly the weight of the cartridge (including the weight of the liquid when fully loaded), the total weight of the spray structure, and the weight of the transmission structure. The spray structure mainly includes a fan and a nozzle, and the force mainly acts on the base of the wind box at the rear, and the direction is vertical downward. The transmission mechanism mainly includes a diaphragm pump, a transmission shaft and a gear transmission, which are respectively installed on the front and rear bases, and the force direction is downward. The Weight and type of load are shown in Table 2.

| order | Name               | weight of the load | Type of load     |
|-------|--------------------|--------------------|------------------|
| 1     | Frame weight       | 1299.97            | Uniform load     |
| 2     | Cartridge          | 915N               | Concentrated load|
| 3     | Liquid medicine    | 9800N              | Concentrated load|
| 4     | Spray structure    | 390N               | Concentrated load|
| 5     | Transmission       | 756N               | Concentrated load|
The frame load distribution diagram is shown in Figure 4.

![Figure 4. The frame load distribution diagram](image)

3.4. Condition analysis

Sprayers usually run on roads and fields, and the road conditions are complex, which makes the working conditions of the sprayer quite complicated, usually with horizontal bending conditions, torsion conditions, acceleration conditions, turning conditions and braking conditions, but consider The sprayer is towed by the front tool vehicle, and the speed should not be too fast, and it acts on the farmland. Therefore, in order to better understand the force of the frame, this study analyzed the horizontal bending conditions.

The horizontal bending condition mainly simulates the situation when the sprayer is running at a constant speed under full load and filled with liquid medicine on a flat road, and observes the stress distribution and deformation of the frame. This condition mainly tests the rationality of the site model. Constraints: Constrain all degrees of freedom at the connection between the front and rear wheel devices and the ground. Constrain the translational freedom of the rear bracket in the Z direction. The stress distribution diagram of the frame is shown in Figure 5.

![Figure 5. Stress distribution of the frame](image)

The analysis shows that the maximum stress of the frame under bending conditions is 163.67 MPa, which appears at the junction of the longitudinal beams of the device hub and the cross beams on both sides of the ground. Because the cross beams on both sides above the longitudinal beam bear the full load of the cartridge, and this longitudinal beam The beam and the side beams on both sides are welded, so stress concentration occurs. The maximum displacement of the frame is 1.62mm, which appears at the top of the rear bracket at the tail. The safety factor $S=235/163.67=1.43$ (in this paper, the safety factor is 1.3). The frame has high strength and surplus, and the structure is reasonable. However, for the quality of the frame, the deformation size can still be optimized.
3.5. Structure optimization

On the premise of satisfying the structural strength and rigidity, in order to reduce the structural mass and reduce the deformation of the rear base, the following optimizations were carried out on the frame structure: (1) The outer surfaces of the steel frames on both sides are loaded with 10 straight notches with a center spacing of 70mm and a radius of 15 in a linear array. (2) In view of the problem of stress concentration in the base of the rear bellows, reinforcing ribs were added to the connection between the rear base and the structure on both sides of the fixed bellows.

The three-dimensional structure diagram of the frame after optimization is shown in Figure 6.

![Figure 6. Optimized frame structure diagram](image)

The stress distribution diagram of the frame after optimization is shown in Figure 7.

![Figure 7. The stress distribution diagram of the frame after optimization](image)

3.6. Optimization conclusion

After analysis and optimization, the mass of the frame is 121.26kg. The maximum stress of the chassis is 131.65Mpa, which appears at the junction of the windbox base and the cross beams on both sides. The maximum deformation is 1.52mm, and the safety factor $S=235/131.65=1.78$ is greater than 1.3 (the safety factor is selected as 1.3). Compared with the unoptimized frame, the maximum stress is reduced by 32.02Mpa, and the maximum deformation is reduced by 1mm. The overall mass of the frame is reduced by 11.39kg (the original frame mass is 132.65kg). The safety factor is greatly improved and the structure is good.

4. Conclusion

This article is aimed at the problem of excessive vertical bending deformation of the frame caused by the excessive weight of the air-driven electrostatic sprayer when fully loaded, and the crossbeam of the
frame is prone to deformation. Carry out design research on the frame, and perform static analysis after applying loads and constraints to the frame through finite element analysis software. Taking the maximum deformation of the frame as a constraint, the structure of the frame is changed, and the frame is designed to be lightweight, thereby completing the structural optimization of the frame. Finally, the optimized frame structure is statically analyzed. The optimized frame performance is improved, the weight is reduced, and the safety factor of the frame is relatively improved.

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