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Structural Design and Finite Element Analysis of Truss Canal Slope

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Abstract: The material and structure form of truss channel slope desilting machine are selected and designed, then the three-dimensional solid model is modelled by Solidworks software, and the model is meshed and loaded into the ANSYS workbench. Then the stress, strain change and frequency and mode of the first eight modes are obtained by using the static structure module and modal module.

1. Introduction

The key to the structure design of canal slope dredging machine is to meet the characteristics of lightweight, good environmental adaptability and robustness, high strength and small deformation. Therefore, according to the above characteristics, overall structure, static and modal analysis of the structure according to the size of applied load, obtain specific vibration frequency and deformation quantity through simulation results, and provide theoretical basis for structural optimization design of canal slope dredging machine.

2. Model establishment

The slope of the South - to - North Water Diversion channel is 1: 2 or 1: 1 [1] and the slope length is 7 - 8 m, so this requires the dredging equipment to meet the changes of different slopes, and the overall support structure should meet high support strength and stiffness, and can operate safely and reliably. Considering the above characteristics, consult the mechanical design manual, and select the angle iron with structural steel as the supporting structure for design [2 - 3]. Finally, angle iron of 50x50x4 and 50x32x4 are selected as the supporting structure design, including 50x50x4 angle iron as the main support structure, 50x32x4 model angle iron as the side support structure. The overall structure design is shown in Figure 1 below. The figure includes 8 m long truss along the canal slope, 1.5 m and 2 m vertical truss, 3 m long transverse truss and electric turntable.

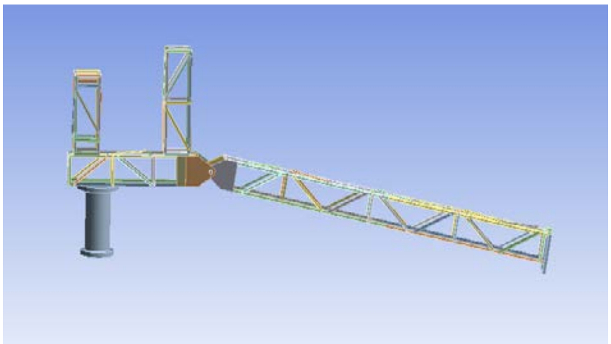


Figure 1: Structural diagram of truss of dredging machine

The canal slope truss support structure has two degrees of freedom in space and is constrained into ANSYS. The frame is fixed on the electric platform, limiting the degree of freedom on the three coordinate axes. There is friction connection at the bottom and the flange connection, and the friction coefficient is 0.2; the fixed connection between the turntable and the transverse truss and the truss, as shown in Figure 2.

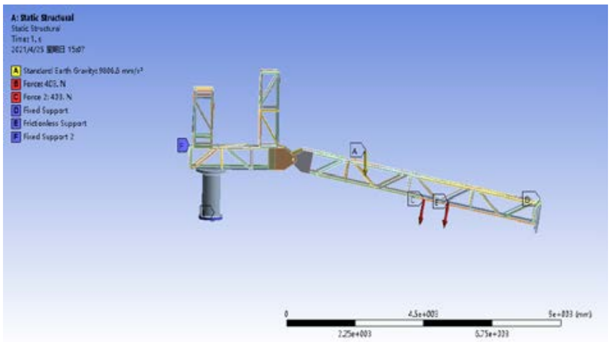


Figure 2: Apply Constraints and Loads

3. Static Analysis Theory

Statics is first used to analyze the structural layout response under the fixed load, regardless of the inertia and damping, the linear static problem is the most critical problem in static mechanics. Based on the classical mechanical theory, the kinetic equations of the system can be described by the formula (1):

$$M\ddot{X}+C\dot{X}+KX=F(t) \tag{1}$$

Among them, M is mass matrix, C is damping matrix, K is system stiffness matrix, F is external force, $\ddot{X}$, $\dot{X}$, X respectively represents the system velocity change rate, velocity and displacement.

According to the definition of linear static, the system speed and acceleration are 0 and constant load, so the physical equation can be expressed as the following formula (2)

$$KX=F \tag{2}$$

Three assumptions must be met in the linear hydrostatic analysis:

Small deformation, in the linear static analysis, the system deformation is very small relative to the overall size, the deformation does not affect the stiffness of the whole system.

Linear material, linear static problem studies the internal nature of the material in the elastic deformation phase, which satisfies the linear relationship between stress and strain.

Fixed load, linear static problem assumes that loading and constraints do not change over time, and the application of loading is a very slow process.

4. Mode Analysis Theory

Modal analysis is a method to study structural dynamics, including inherent frequency, damping and modal vibration, is the current mature technology, it is aimed at linear systems or approximate linear systems. Modal analysis is usually widely used in structural vibration, noise, fault diagnosis, and dynamic response [4,5].

Definition of modal analysis: transform the coordinate of the vibration differential equation of the linear system into the analysis problem under mode coordinates, thus decoupling the equations into the independent equation described by mode coordinates and mode parameters, and then find the mode parameters of the system, the coordinate change matrix is mode matrix, each of which is listed as mode vibration [6].

The equation of motion of the multi degree of freedom damped system in physical coordinates is shown in formula (3) below

$$[M]\ddot{x}+[C]\dot{x}+[K]x=F(t) \tag{3}$$

Among them $[M],[C],[K]$ are mass matrix, damping matrix, stiffness matrix respectively, $\ddot{x},\dot{x},x$ representing acceleration matrix, velocity matrix and displacement response quantity matrix, and F(t) represents the N dimensional shock force.

The equation of motion converting the coordinate change into modal coordinates is shown in formula (4)

$$\left(K-\omega^2 M+j\omega C\right)X(\omega)=F(\omega) \tag{4}$$

The response of any L point is a linear combination of the modal responses of each order:

$$x_l(\omega)=\varphi_{l1}q_1(\omega)+\varphi_{l2}q_2(\omega)+\cdots+\varphi_{lN}q_N(\omega) \tag{5}$$

The decoupled equations of motion are as shown in formula (6)

$$\left(K_{dia}-\omega^2 M_{dia}+j\omega C_{dia}\right)Q=F_{\varphi} \tag{6}$$

5. Analysis of simulation result

5.1. Results Analysis of Mechanical Analysis

From Figure. 3 and Figure 4, the maximum deformation of the truss is generated at the transverse truss and the upper half along the canal slope, the maximum deformation amount is between 5.93mm, equivalent stress is between 0.006-55.467MPa.

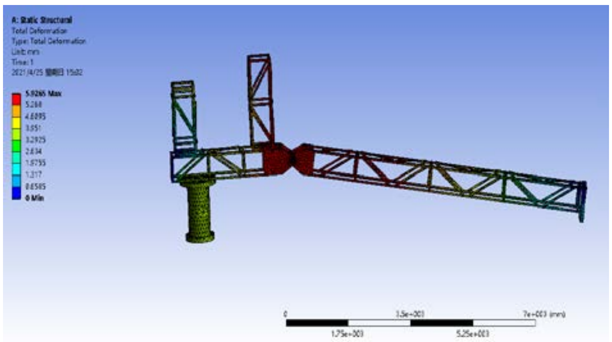


Figure 3: Cloud map of the truss displacement change

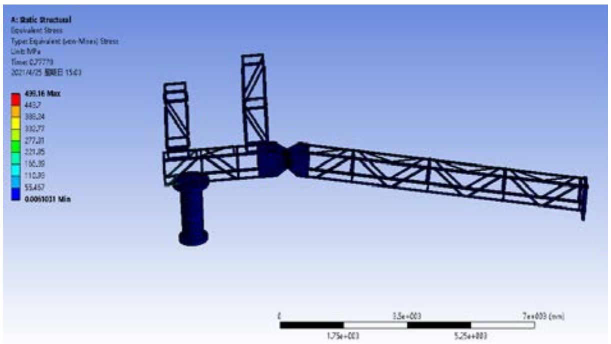


Figure 4: Cloud map of truss and equivalent effect force

Generally, the working environment of the truss is relatively bad, and the bad weather occurs from time to time, so it is necessary to check the strength and stiffness of the truss.

5.1.1 Strength analysis of the truss

According to the structural design of the truss, the calculation formula of the allowable stress [7] is as follows (7)

$$[\sigma]=\frac{\sigma_s}{K_n} \tag{7}$$

σ_s ------Yield limit stress of the material

K_n ------safety factor

The material used in the truss of the channel slope dredging machine is the structural steel, the yield stress of the structural steel is 235MPa, in which the safety factor can be found from the truss design specification, for the structural steel, the safety factor can be taken 1.5, the allowable stress of the available structural steel is:

$$[\sigma]=\frac{\sigma_s}{K_n}=\frac{235}{1.5}=156.7MPa \tag{8}$$

The strength of the overall structure of the dredging machine meets the requirements.

5.2.1 Analysis of truss

The calculation formula for the allowable deflection is obtained by consulting the Crane Design Specification Manual [8]:

$$[f]=\frac{l}{400} \tag{9}$$

The longest truss length in this structure is 8 m, the allowable deflection value is 20mm, the maximum deformation of 5.93mm shows that the stiffness of the truss also meets the design conditions.

5.2. Analysis of modal analysis

Natural frequency and vibration type of the canal slope dredging mechanism model are shown in Figure 5 and Table 1

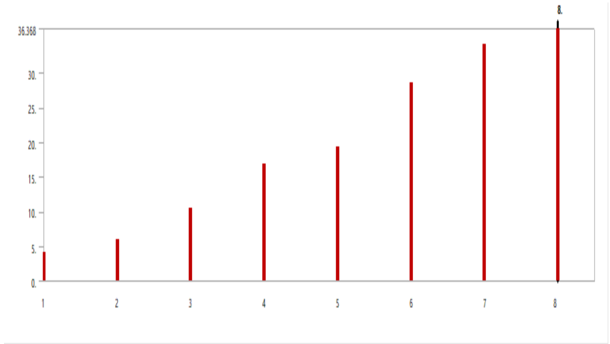
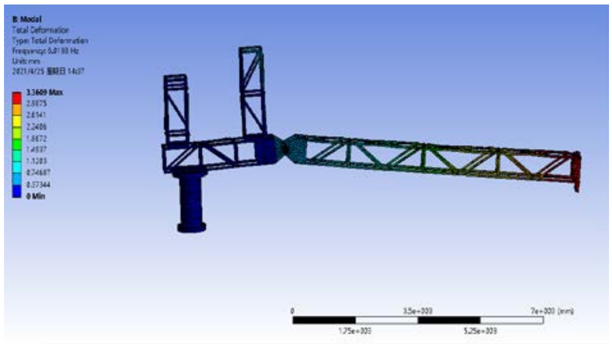


Figure 5: Natural Frequency Map of the Truss

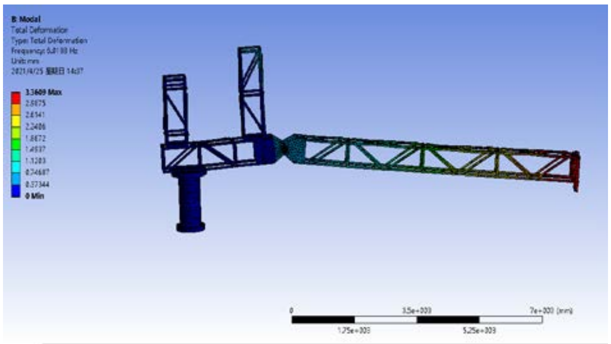
Table 1: Truss vibration type results

order	natural frequency (HZ)	maximum amplitude (mm)	Trend of vibration change
1	4.149	2.692	Left and right swing along the x axis
2	6.0188	3.3609	Swing it up along the z axis
3	10.418	2.4209	Move up and down along the z axis
4	16.858	1.9115	Swing along the y axis
5	19.3	3.588	Left and right swing along the x axis
6	28.613	4.7979	Left and right swing along the x axis
7	34.069	4.5857	Upper truss torsion movement
8	36.368	5.5003	Lower truss torsion

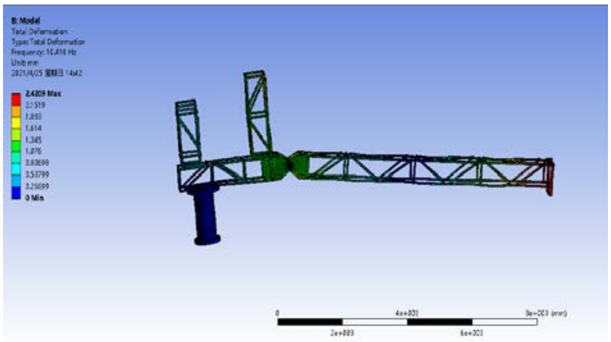
The front fourth-order mode vibration pattern of the truss is shown in Figure 6.



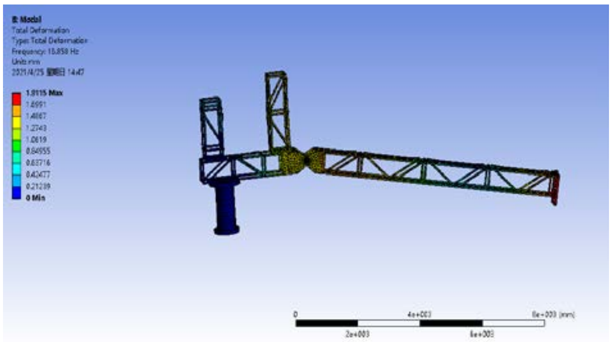
(a) First - order modal vibration type



(b) Second - order modal vibration type



(c) Third - order modal vibration type



(d) Fourth - order modal vibration type

Figure 6 Front 4th order vibration pattern of truss

6. Summary

3D entity modeling and finite element analysis via Solidworks and ANSYS, the overall deformation and equivalent force of canal slope dredging machine truss are obtained, the maximum deformation is 5.93mm,Equivalent stress is 55.467MPa,The allowable stress and allowable deflection of the truss is 156.7MPa,20mm., Maximum displacement deformation quantity and equal effect force all meet the requirements; then conducted the modal analysis of the whole truss, obtained the frequency and vibration type of the first eighth order modes, and the change form of each order, predicted the situation in the real situation, so as to have corresponding preventive measures and lay the foundation for the improvement and optimization of the dredging truss.

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