Statics and modal analysis for large vibrating screen

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Abstract: The 3D modeling software of Solidworks was used in the paper for the 3D modeling of large banana vibration shaker. And then the 3D model was imported into Ansys Workbench for finite element analysis. The overall stress and strain distribution of the shaker could be got under static loading. Secondly, the analysis of the dynamic characteristics of the entire shaker should be done, and the modal frequencies and mode shapes could be got through the analysis of the modal analysis results. Finally, the hammering test was done to verify the theoretical analysis. And it also provided a necessary theoretical basis for the design and improvement of the entire shaker.

Keywords: The stress and strain; Modal analysis; Hammering Method

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Theoretical analysis

Working principle. The banana type vibrating shaker consists of block eccentric vibration exciter, motor, screen box, sieve plate, spring and base. Its screen side plates were all riveted by the HUCK bolt articulated, and HUCK bolts were used in the connection of exciter beam and screen side panels. Therefore, it had a smoothing operating and a reliable working. The eccentric wheel was installed at both ends of the vibrator spindle girders, and it could be used to adjusted the weight of the eccentric block. Tccentric block in the vibration exciter was drove by motor through V-belt. A lot of centrifugal force were produced by the operation of eccentric block. And the screen box was stimulated to produce a amplitude circular motion. Spring was used to bear screen box and reduce the power passed to the basic foundation during the operation of the sieve[1,2].

Centrifugal force calculation. The eccentricity and the quality of the eccentric block were known by the exciter type. The exciting force P0(t) was 80 KN, and it could be calculated by the formula (1) (2):

$$P(t) = P_0 \sin(\omega t) \quad (1)$$

$$P_0(t) = me\omega^2 \quad (2)$$

was the rotation angular velocity of the exciter, was the quality of the eccentric block and was the eccentricity of eccentric block[3].

Finite Element Analysis

The establishment of Finite element model. The software of SolidWorks was used to model the vibrating shaker. First, in order to reduce the number of units for the finite element analysis and improve the whole efficiency of the computation, some of the characteristics of the solid model had been simplified. Second, the model was imported into the software of Ansys Workbench for the establishment of Finite element analysis model. The entire sieve was connected to the base through the spring, the base was fixed on the ground and bond processing was used for other connections [4]. The specific model was shown in Figure 1(a) .

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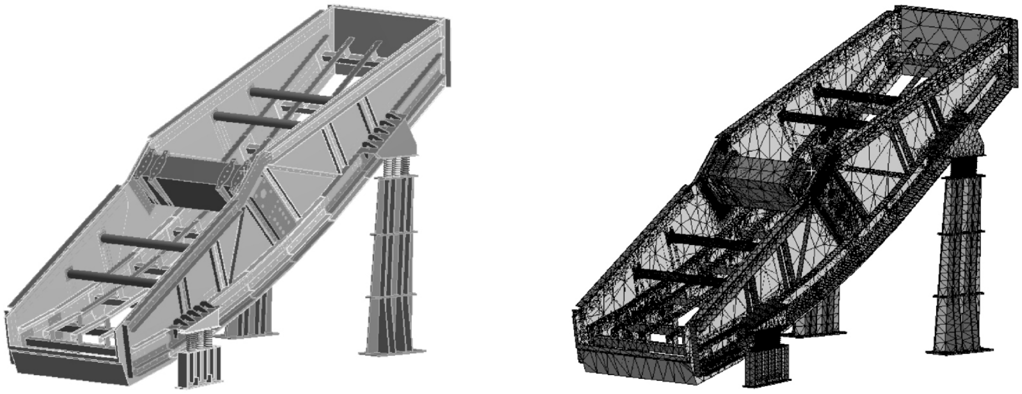


(a) (b)

Figure.1, The three-dimensional parametric model and finite element model of shaker

Material properties, meshing and the constant way. First, the material properties of various components of the vibrating shaker were got by the testing of spring stiffness in the damping system of the entire shaker. And the values were shown in Table 1. Second, the whole shaker model was imported into the software of ANSYS Workbench for automatic meshing. Different cell types and grid densities could be got according to the type of the contact surface between the components and the different parts of the structure. The specific meshing was shown in Figure 1 (b). Finally, the constraints between the various components under the sieve were set as the paste method. The entire sieve was connected to the four bracket through damping system, and the connection between the bracket and the ground was fixed constraints.

Table.1, Material properties

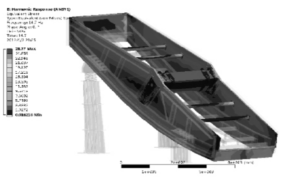
Material	components	Density ρ（g/cm^3）	Modulus of elasticity E(GP)	Poisson's ratio μ
Structural steel (steel 45)	Screen box body	7.85	210	210
Spring steel (60Si_2 Mn)	Spring	7.85	196	196
Gray pig iron	Support base	7.35	113	113

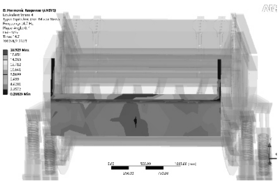
Static mechanical analysis. The phenomenon of structural damage appeared in the processing of long-term using. The causes of these structural damage were mostly the stress concentration due to fatigue failure [5]. Therefore, it is very necessary to find out the stress concentration location of the shaker and the major components. The stress distribution of the major components was shown in Figure 2 by the statics analysis of the shaker.

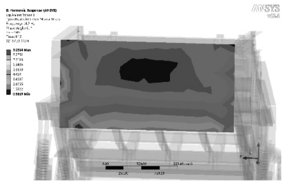
Modal analysis. The shaker excitation frequency was 14.1Hz, and it was calculated by speed of the motor and transmission of the shaker. Therefore, the first ten mode shapes were needed to be calculated. The modal frequencies and mode shapes were described in Table 3, and part of the vibration-type cloud images shown in Figure 3[6].

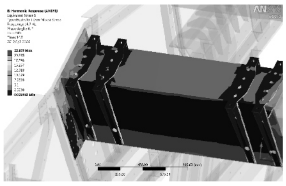
Table.2, Stress distribution table

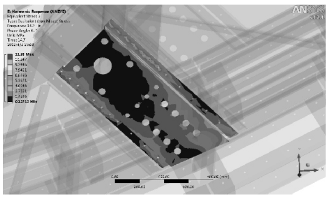
Parts name	Concentration position	Max stress (MPa)	Parts name	Concentration position	Max stress (MPa)
Vibrating screen	The front baffle of cabinet	26.77	Vibration beam	The upper fixing holes on both sides	22.875
Cabinet	The front baffle	26.77	The main boards	The top and the bottom corner position	11.85
The front baffle	The top edge	26.77	The front shock absorber bracket	The front angle	69.66
The rear baffle	The lower edge	9.238	The rear shock absorber bracket	The top of the first shock absorption	15.88

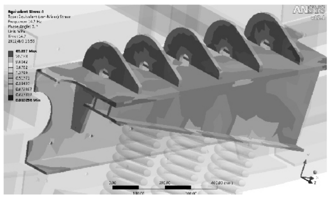

Overall stress contours


The front baffle


The rear baffle


Vibration beam


The main boards


The front shock absorber bracket

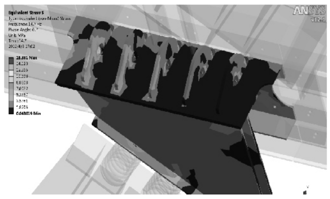
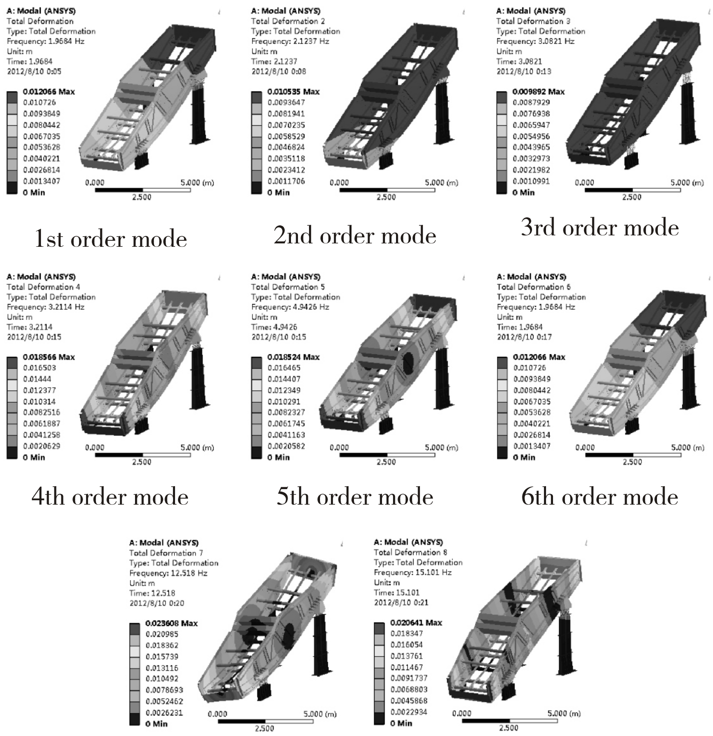

The rear shock absorber bracket

Figure.2, stress contours

Table.3, 1~10 natural frequency and mode of the whole machine

Order	Natural frequency(Hz)	Vibration mode
1	1.9684	Cabinet and the spring translational vibration in the Z-axis direction
2	2.1237	Cabinet and the spring translational vibration in the X-axis direction
3	3.0821	Cabinet and the spring translational vibration in the Y-axis direction
4	3.2114	Torsional vibration of the body and the spring around the center of body, Y
5	4.9626	Torsional vibration of the body and the spring around the center of body, Z
6	9.6332	Torsional vibration of the body and the spring around the center of body, X
7	12.518	The symmetric torsional vibration of left and right side of the whole screen and and rear panels along the longitudinal center of the box
8	15.101	The whole box around the third and the seventh root of the beam along the Z axis direction (horizontal) into the third-order torsional vibration
9	17.51	The upper end of the bracket drives the spring along the Z direction (horizontal) swing (two bracket vibration direction symmetrical)
10	17.547	two the upper end of the bracket drives the spring along the Z direction (horizontal) swing (two bracket vibration direction)



1st order mode 2nd order mode 3rd order mode

4th order mode 5th order mode 6th order mode

7th order mode 8th order mode

Figure.3,1~8th mode of the whole machine

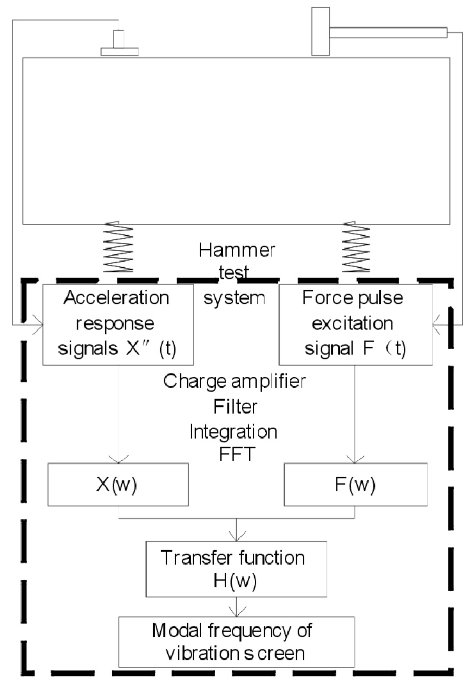


Figure.4, Hammer experiment flow chart

Experimental Analysis

The experimental principle. In the actual structure or model of the vibration testing, the selection of hammering method to measure the structure natural frequency is more economical, ideal for vibration measurement. It could realize the multi-support excitation, a single point of response and the real time display of the frequency response curve on the computer.

Experimental program. The manually hammering modal experimental flow chart was shown in Figure 4, the using of the WS-5924 series of hammering test system was developed by the Beijing spectrum Company for laboratory equipment.

Experimental analysis results. Impact force signal and acceleration response signal could be got by the hammer experiments of 15 measurement points of the shaker side panels. Combined with the hammer test software some of its modal frequency could be got. And it was shown in Table 4 [7,8].

Table.4, Analysis results of experimental

order	1	2	3	4
Frequency (Hz)	2.004	2.154	3.132	8.228

Conclusion

1) The established shaker finite element model was basically correct, the calculated finite element analysis results were relatively credible, and it was consistent with the experimental results.

2) Combined with the finite element static analysis results, some areas prone to larger stress of before and after the shaker plate were properly modified. The whole structure of before and after the board become more

reasonable could be got by increasing the ribs or appropriate strengthening of the thickness. 3) The 10 order modal shapes could be obtained by modal analysis of the shaker, and the amplitude of the various components of the system on 7-8 order modal frequency which was the closest to the operating frequency. It also provided a reference for subsequent harmonic response analysis.

4) According to the theory of vibration, the shaker system resonance was caused by natural frequency. Therefore, in order to avoid the shaker resonance, the operating frequency must be made away from the inherent frequency band (up and down not less than 10%). Compared the 8th order natural frequency with operating frequency, the difference was between the ranges of 7.1%. Therefore, it should appropriate improved the structure of the shaker to insure the difference was greater than or equal to 10%.

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大型振动筛静力学及模态分析

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摘　要：先用3D建模软件Solidworks对大型振动筛进行三维建模，然后将3D模型导入到ANSYS Workbench进行有限元分析，可以得到静载荷作用下的振动筛的整体应力及其分布。其次，根据整个振动筛的动态特性的分析结果，可以得到模态频率和振型的模态分析结果。最后，通过锤击试验验证了理论分析的结果，而且为整个振动筛的设计和改进提供了必要的理论基础。

关键词：应力和应变；模态分析；锤击法