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Modal Analysis of the Light Electric Sanitation Vehicle Frame

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Abstract

Aiming at the complex modal characteristic of the frame of the light electric sanitation vehicle under various working conditions, the finite element method is used to study the natural frequency and modal shape cloud diagram. Based on the frame model established in the three-dimensional software, the model characteristic is analyzed, the natural frequency and modal shape of the first five orders of mode are obtained, and their influences on vehicle travel are analyzed. The frame is improved, and the influence of the improved frame on the natural frequency and modal shape are analyzed. The results show that the bending and torsion resistance of the improved frame is ameliorated. Compared with the torsion resistance, the bending resistance of the frame is much ameliorated, which lays a foundation for the relative experiment, dynamics analysis and structural improvement of the frame.
Keywords- Electric Sanitation Vehicle, Modal Analysis, Frame, Finite Element Analysis

I. INTRODUCTION

The low-order elastic mode of the frame not only reflects the rigidity of the frame, but also is a key indicator of the conventional vibration characteristics of the vehicle. If the road excitation is the same as the natural frequency of the frame when the vehicle is running, it will cause resonance and reduce the steering stability, comfort and service life of the related components [1-3]. In order to improve the performance of the frame, many scholars have studied the modality of the frame. Wang H Y et al. used ANSYS to study the mode of light truck frame [4,5]. Li W F et al conducted modal analysis on the sub-frame of a SUV sedan [6,7]. Ouyang T C et al. used the finite element analysis software ANSYS to establish a parametric finite element analysis model for a heavy truck frame [8]. Yin Andong used Hyper Works software to perform modal analysis on the frame under full load bending and torsion conditions [9]. The above-mentioned frame modal research laid the foundation for the relevant tests, dynamic analysis and structural improvement of the frame.

In order to solve the above problems, this study is aimed at the modal analysis of a light electric sanitation vehicle frame. Specifically, the frame model is built in the three-dimensional software, and the frame model is simplified. The simplified frame model is introduced into the finite element analysis software ANSYS Workbench to establish a finite element model, and modal analysis of the frame is carried out. The frame is improved based on the analysis results and related requirements. The modal analysis of the improved frame is carried out, and the influence of the improved part on the natural frequency and modal shape of the frame is analyzed.

II. ESTABLISHMENT OF GEOMETRY MODEL AND FINITE ELEMENT MODEL

The three-dimensional model of the whole vehicle without the cab is shown in Fig. 1. As shown in Fig. 1(a), the vehicle consists of a cab, a lifter, a garbage box, a frame, a chassis, a battery, a lifting lug, a leaf spring and a leaf spring base. The three-dimensional model of the frame is shown in Fig. 1(b). For the smooth progress of the analysis, the frame model is reasonably simplified. Because the frame is welded from proximate materials and sheet materials, the frame is modeled as a whole body.

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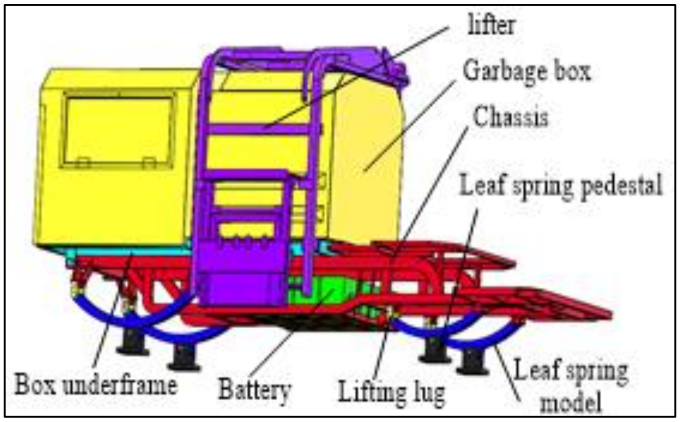

Fig. 1 (a): Whole Vehicle Model Without the Cab

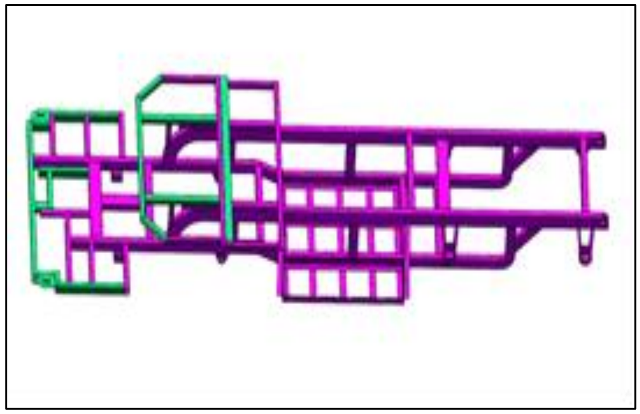

Fig. 2 (b): Frame Model

Fig. 1: Establishment and simplification of three-dimensional model

The simplified three-dimensional frame model is introduced into the finite element analysis software ANSYS Workbench. The material parameters are defined for the frame model. The frame material is 20# steel, the yield limit of 20# steel is 275 MPa, Poisson's ratio is 0.3, the modulus of elasticity is 206 GPa, and the density is 7850kg/m^3. Because this study aims at free modal analysis of the frame, the frame is not constrained.

Meshing is an important step in finite element analysis. The quality of the mesh directly affects the accuracy of the final result, and the number of meshes directly affects the scale of the calculation. Therefore, it is necessary to pay attention to the balance of the quality and quantity of the mesh in establishing the meshing model. In addition to the line unit and the point unit, a unit quality factor is calculated based on the ratio of the given unit volume to the side length, and a comprehensive quality metric is provided and the range is 0-1.The 1 represents a perfect cube or square, and the 0 represents a unit volume of zero or negative. The mean value of the grid quality in this study is guaranteed to be above 0.7.

III. MODAL ANALYSIS OF THE FRAME

For the analysis of the frame, the free mode is analyzed and the natural frequency of the frame and the corresponding modal shape are calculated. Because the first 6 orders are rigid body motions, the 7th-order mode is recorded as the first-order mode, and then sorted sequentially. The first five orders of mode and the corresponding modal shapes are shown in Fig. 2.

As shown in Fig. 2 and Table 1, the first-order mode of the frame is a torsional mode with the frequency of 28.165 Hz. When the vibration frequency of the frame is near this frequency, torsional vibrations occur in the frame. The torsional mode mainly reflects the ability of the frame to resist torsion, and there should not be more excessive torsional stresses on the frame.

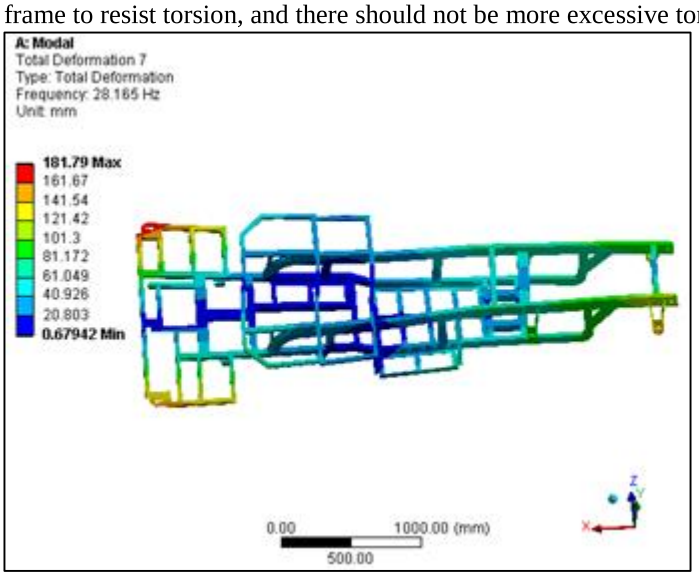

Fig. 2 (a): 1st Order Mode

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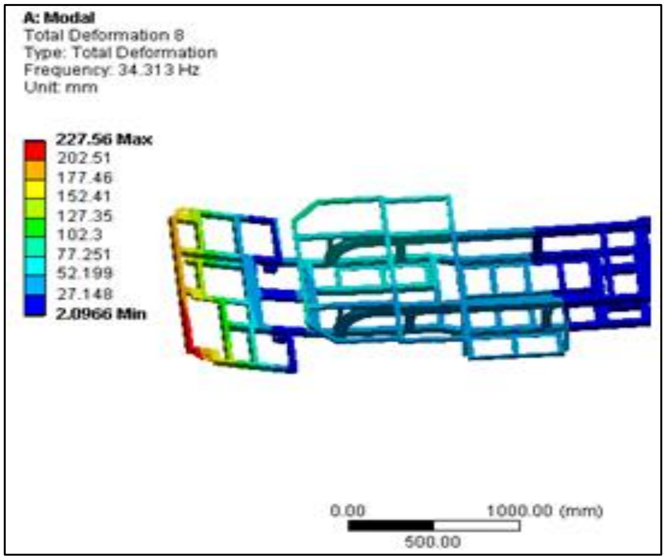

Fig. 2 (b): 2nd order mode

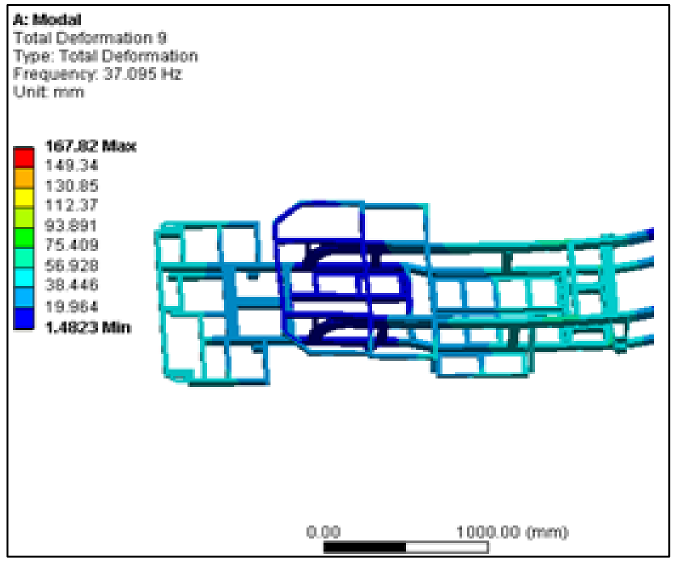

Fig. 2 (c): 3rd order mode

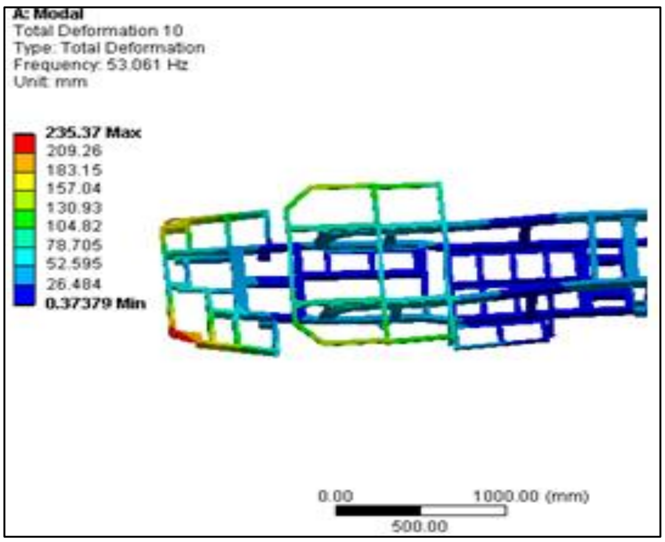

Fig. 2 (d): 4th order mode

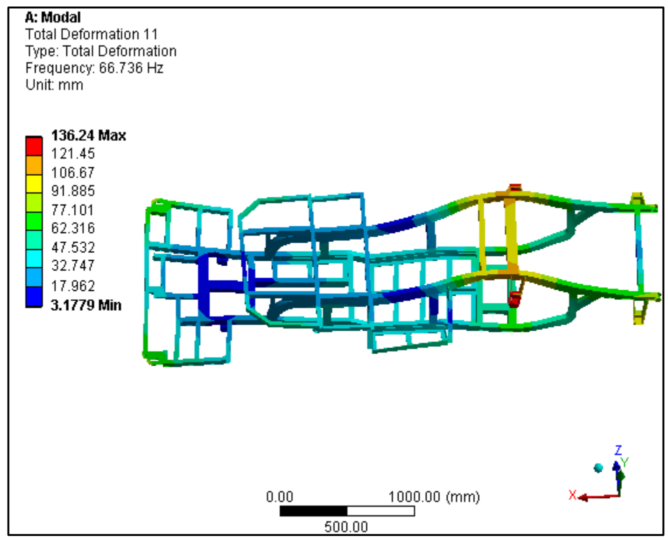

Fig. 2 (e): 5th order mode

Fig. 2: First five orders of mode

Table 1: First five orders of natural frequencies for the free frame mode

Order	*1*	*2*	*3*	*4*	*5*
Frequency(Hz)	*28.165*	*34.313*	*37.095*	*53.061*	*66.736*

The second-order mode of the frame is a vertical bending mode with a frequency of 34.313 Hz, which indicate that the bending vibration of the frame occurs in the vertical direction when the frame is at this frequency. This mode mainly reflects the performance of the frame against vertical bending. It can be seen from the vibration cloud diagram that the vertical bending vibration amplitude of the front part of the frame is the largest, which indicates that the rigidity of the frame front part is relatively small in the vertical direction; the third-order mode of the frame is a transverse bending mode with a mode of 37.095 Hz, which indicates that the bending vibration of the frame occurs in the lateral direction when the frame is at this frequency. This mode mainly reflects the performance of the frame against lateral bending. It can be seen from the vibration cloud diagram that the amplitude of the lateral vibration of the frame rear part is the largest, which indicates that the lateral rigidity of the frame rear part is small.

The fourth-order mode of the frame is a second-order torsional mode with a frequency of 53.061 Hz, which indicates that the torsional vibration occurs when the frame is at this frequency. The second-order torsional mode of the frame has an important influence on the steering stability of the vehicle and the second-order torsional frequency has a greater effect on the swinging head problem of the vehicle; the 5th-order mode of the frame is a combined mode of torsion and lateral bending, which indicates that the frame is subject to a combined vibration of torsion and lateral bending at this frequency. It can be seen from the above vibration cloud diagram that the displacement of the front and rear portions of the frame is large, and the strength of the front portion of the frame are minimal.

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IV. IMPROVEMENT OF THE FRAME

The frame is improved based on the analysis results and related requirements, two of the four batteries on the left side of the frame are longitudinally mounted in the right front position of the frame, and the other two batteries are longitudinally installed in the middle of the left side of the frame. The improved frame is shown in Fig. 3. The addition of the beam 3 not only increases the rigidity of the battery frame, but also solves the problem of insufficient strength of the front part of the frame obtained by modal analysis. For other related requirements, an angle iron is added there to increase the strength and increase the thickness of the two vertical boards at the joint. The thickness of the added angle iron is 3 mm, and the thickness of the two vertical boards at the joint is increased from 8 mm to 10 mm.

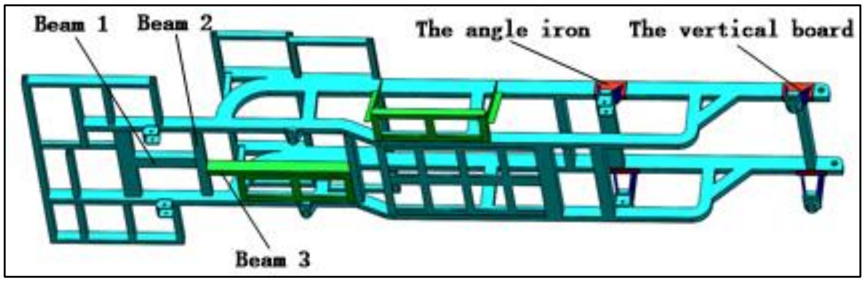

Fig. 3: Improved Frame

V. MODEL ANALYSIS OF IMPROVE FRAME

The free modal analysis is analyzed on the improved frame. The natural frequencies and modal shapes of the first five orders are shown in Table 2. After improvement, the various modal shapes are increased, which shows that the improved frame's ability to resist bending and torsion is enhanced. As can be seen from Table 1 and Table 2,, the natural frequency variation of the improved frame torsional mode is smaller than the natural frequency of the bending mode, which indicates that the frame improvement is more obvious for the improvement of the bending performance.

Table 2: First five orders natural frequencies and modal shapes of the improved frame

Modal order	Natural frequency (Hz)	Modal shape
1	28.808	Twisting in the vertical direction
2	40.717	Bending in the horizontal direction
3	44.927	Bending in the horizontal direction
4	59.574	Twisting in the vertical direction
5	75.645	Twisting in the vertical direction and bending in the horizontal direction

VI. CONCLUSIONS

By analyzing the free mode of the frame, the natural frequency and corresponding vibration mode of the first five orders of the frame are obtained, and the influence of the natural frequency of the first five orders is obtained on the vehicle travel. The analysis results show that the minimum free mode is relatively large, so the frame is not prone to resonance. The frame is improved based on the analysis results and related requirements. The modal analysis of the improved frame is carried out, and the analysis results are compared with the mode of the improved front frame, and the influence of the improved part on the modal natural frequency and the frame performance is obtained. The results show that the improved part has an impact on the bending and torsion resistance of the frame. The performance of the bending and torsion resistance of the improved frame has been ameliorated. The performance of the improved frame bending resistance has much amelioration compared with the torsional resistance. Through the analysis and research on the modality of the improved frame and the original frame, the foundation for the design, design and improvement of the similar frame is laid.

REFERENCES

[1] Feng Jinzhi, Deng JiangBo, Zheng SongLin, Li Yuan. Design method of car subframe based on material replacement. Automotive Engineering, 2016, 38(6): 778-782.
[2] Li Weifeng, Zhu Maotao, Lu Feng, Chen Yazhou. Case study on modal analysis of subframe of a SUV car. Noise and Vibration Control, 2013, 33(3): 124-127.
[3] Li Guojun. Analysis of dump truck frame finite element modal. Equipment Manufacturing Technology, 2014, 12: 118-119.
[4] Wang Huiyun, Lv baozhan, Zhu Sihong. Modal analysis of Light-truck frame based on ANSYS. Coal Mine Machinery, 2007, 28(3): 59-61.
[5] Wu Haibo, Li Jin, Shi Leilei.Finite element modeling and modal analysis of light truck frame. High & Automotive Applications, 2012, 51(4): 17-19.
[6] Li Weifeng, Zhu Maotao, Lu Feng, Chen Yazhou. Case study on modal analysis of the subframe of a SUV car. Noise and Vibration Control, 2013, 33(3): 124-127.

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[7] Zhao Jianzhong, Zhang Ruikun, Song Yangyiong, Chen Yong. Structure intensity and modal analysis of a SUV rear sub-frame. Mechanical Engineering & Automation, 2016(4): 48-50.
[8] Ouyang Tiancheng, Wei Qifeng, Huang Jincheng. The modal analysis and optimization on heavy truck frame. Equipment Manufacturing Technology, 2012(4):19-21.
[9] Yin Andong, Gong Laizhi, Wang Huan, Xu Junbo. Finite element analysis of electric vehicle frame based on HyperWorks. Journal of hefei University of Technology, 2014, 37(1):6-9+77

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