Theoretical Basis of Lightweight Study of Dumper Carriage

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Abstract

This paper mainly introduces the finite element theoretical analysis basis of the study on lightweight of dump truck.The stress and deformation of the carriage were analyzed by finite element static analysis;The natural frequency and formation of carriage are obtained by modal analysis;On the basis of modal analysis, the harmonic response of the carriage is analyzed to verify its response under sine load.

Keywords

Lightweight;Static analysis;Modal analysis;Harmonic response analysis.

1. Introduction

Automobile lightweight has become one of the main means to improve the competitiveness of automobile products and promote the energy saving and emission reduction of automobile industry.Lightweight car body has also been the focus of domestic and foreign automobile enterprises.

Implementation of the new technical conditions for the safety of motor vehicles （GB1598-2012）,There is a strict requirement for the quality of the car, and the client is constantly asking for the best of the car, and the greater the better, the greater the quality of the car. Some studies show that the car industry is now in the forefront of attention to the lightweight and safety performance of the car body. About 75% of the fuel consumption in the course of the journey has to do with the quality of the car, which is a 10% drop in the car, an 8% drop in fuel consumption, and a 4% drop in emissions. America's transit vehicles in Europe experiments show that meet the standards of the IV conditions, every hundred kilometers fuel consumption and weight meet Y: Y 0.003%+3.3434.

2. Research and Development of Light Weight of Dump Truck

Shuxun C[1] finite element analysis methods, such as the arm type compression garbage truck carriage structure optimized design, reduces the carriage structure stress, and the weight loss of 31%. Yuhua G[2] applied the finite element method to analyze the strength and mode of the bus body frame, and carried out the lightweight design, the body frame weight reduction by 5%. Qiguang W [3]analyzed the rigidity, strength and mode of the frame of the wingspan box truck, and carried out the lightweight design, reducing the weight by 95.8kg. Lingyu S[4]was studied with the method of theoretical derivation of the thin-walled beam section size and wall thickness, etc. The influence of geometric parameters on the quality of stiffness ratio, is proposed to obtain high rigidity body lightweighting design principle of the typical thin-walled beam. Qinghao] Y[5] application of computer aided design and finite element meshing technique and method to establish the mine car boxcar finite element three-dimensional entity unit model, effectively solve the problem of the structure and size large cargo van, strength analysis of mine car cargo van. Jiangwei C and Xiaohe L[6] analyzed the mechanical characteristics of the model, rigidity, strength and other mechanical characteristics of the mine dump truck, and adopted the BlockLanczos method to extract the first ten order model of the car, compared the low-order model of the car with the road excitation and the engine excitation, and found that the frequency of the car in no-load is close to the excitation frequency of the road, which is prone to fatigue damage. Qiguang W and Yonggen W [7] analyzed the bending, bending, torsion, braking and turning of the car by using the finite element method to

solve the problems of the wingspan car, and made a lightweight design for the car by using the APDL parameter of the optimization module provided by ANSYS.

Since the beginning of the last century, the development direction of foreign dump trucks has been divided into heavy duty and light duty. Heavy duty mine dump trucks are mainly used in mining areas. Light dump trucks are commonly used in various construction sites in and around the city, mainly transporting construction materials and garbage, etc. In the foreign dump car market, Europe and the United States lead the world in the design and manufacture of special vehicles, and the design and manufacture of dump vehicles also lead the world. High strength steel, aluminum alloy and engineering plastics are increasingly used in the manufacture of dump trucks. Liangsheng W and ProdoytK B [8] on the body structure optimization design, using the two methods of optimization, topology optimization and size optimization of automobile body is optimized, results show that the size optimization than the topology optimization is more suitable for the lightweight car body. In 2012, Gundolf Kopp[9] et al. studied the application of lightweight materials in car cars. By redesigning important parts of car body structure with lightweight materials, they discussed the future prospect of vehicle structure modularization.At the same time, the safety problems caused by the application of new materials in vehicles are also studied. Sonia Calvel and Marcel Mongeau [10] through the setting of the design region, the lightest of the overall mass, and the distribution of the spare parts, and the design of the lightweight car parts of the French Renault corporation.

3. Finite Element Analysis Type of Carriage

The theoretical basis of statics analysis

In structural analysis,The general differential equation is:

$$M\ddot{x} + C\dot{x} + Kx = F(t)$$

Type in the: M ——mass matrix; $F(t)$ ——load vector; x ——the displacement vector; C ——the damping matrix; K ——Stiffness matrix.

The linear problem is that the load does not change with time, so the velocity vector and acceleration vector can be ignored, and the equation is obtained:

$$Kx = F$$

The results of stress and deformation can be obtained by calculation, the stress results of each node are equal to the numerical average of the stress of multiple units connected to it. In the process of structure statics analysis, through the analysis of the unit stiffness matrix and the static equilibrium equation of the finite element model can obtain the node displacement, stress and strain, etc., using post-processing software can easily view the deformation and stress state of the model.

Loading conditions of dump truck:

Bending condition: Apply all plumb loads to constrain the corresponding steel spring.

Working condition of reverse: Follow the left front wheel and hover.

Working condition of turning:Turning radius of 8.5 m, turning speed 2.3 m/s, in baffle on the corresponding centrifugal force on the side of the crate, boundary conditions and bending condition.

Braking condition:The brake deceleration is 0.35 m/s^2, and in the case of the crate and the front panel, the power is applied at 2:5, and the boundary conditions are consistent with the bending conditions.

Lifting condition:At the beginning of lifting, the boundary condition is consistent with the bending condition.

Fundamentals of modal analysis

Modal analysis is a method to determine the system modal parameters as the ultimate goal. The mode is the natural vibration characteristic of mechanical structure, each mode has its own natural

frequency, mode and damping ratio. The output results of modal analysis include natural frequencies and corresponding modes of vibration.

The motion equation of an elastic system with finite degrees of freedom can be derived by applying the principle of dynamic load virtual work. The moment matrix equation is:

$$[M]\{\ddot{\delta}\}+[C]\{\dot{\delta}\}+[K]\{\delta\}=\{P\}$$

Type in the: $[M]$ ——Total structure mass matrix; $[C]$ ——Structural damping matrix; $[K]$——Total stiffness matrix; $\{\ddot{\delta}\}, \{\dot{\delta}\}, \{\delta\}$——Node displacement, velocity, and acceleration matrix; $\{P\}$——Structural load matrix.

In structural dynamics, the natural frequency and the natural mode of vibration of structures are the basis for the analysis of structural dynamic response and other dynamic characteristics. In the modality analysis, the effect of the structural damping is small, and the natural frequency and the vibrational affect is very small, so it's often overlooked. In this case, the natural frequencies and modes of the structure are transformed into eigenvalue and eigenvector problems.

Basis of harmonic response analysis

Harmonic response analysis is used to determine the structure of the known frequency and amplitude of the sine steady-state response under load.

The analytical load of harmonic response is a simple harmonic load varying sine of time. This type of load can be described by frequency and amplitude.Harmonic response analysis can be acceleration, or force load can be applied to the specified node or foundation (nodes) all constraints, multiple incentive load and at the same time can have different frequency and phase.

According to the classical mechanics theory, the general dynamic equation of an object is:

$$[M]\{x''\}+[C]\{x'\}+[K]\{x\}=\{F(t)\}$$

Type in the: $[M]$ ——Mass matrix; $[C]$ ——Damping matrix; $[K]$ ——Stiffness matrix; $\{x\}$ ——Displacement vector; $\{F(t)\}$ ——Force vector; $\{x'\}$ —— velocity vector; $\{x''\}$——Acceleration vector;

$$F = F_0 COS(\omega t)$$

4. Conclusion

The working environment of the dump truck is complex, the working conditions are bad, and the reliability and safety requirements are high. As a direct and main load bearing structure of dump truck, the carriage should have sufficient strength, rigidity and impact resistance, and avoid resonance in the carriage. The static analysis and dynamic characteristics of the carriage were studied by means of finite element analysis. According to the operating conditions of the dump truck, the stress and deformation of the carriage under four typical operating conditions were analyzed, and the strength and rigidity of the carriage were checked. The dynamic analysis of the carriage is carried out. First, the modal analysis is carried out to obtain the natural frequency and formation of the carriage;On the basis of modal analysis, the harmonic response of the carriage is analyzed to verify its response under sine load;Because of the dump truck driving condition is relatively complex, car under the influence of various random load for a long time, are prone to fatigue damage, choose a different road condition random vibration analysis was carried out on the car, get the stress and deformation of random vibration.On the premise of ensuring the strength and rigidity of the carriage, the lightweight design can be realized by optimizing the structure of the carriage, reducing the total weight of the body, saving energy and reducing fuel consumption.

References

[1] The State Counci Development Research Center, De-partment of Industrial Economy, and China SAE, The Volkswagen Group (China). Annual Report on Automotive Industry in China, 2011 [M]. Beijing: Social Sciences Academic Press, 2011. (in Chinese).
[2] Shuxun C, Haibo W.The finite element analysis and optimal design of the finite element analysis and optimal design of the structural arm of a garbage truck with the arm form compressive garbage truck [J].Equipment manufacturing technology, 2008, 4: 47-49.
[3] Yuhua G,Huxiang L.Hybrid finite element model and lightweight study of bus body frame plate girder [J].Journal of agricultural machinery, 2007, 38 (9): 46-50.
[4] Qiguang W, Yonggen W.Analysis of skeleton strength and modal of wing span van [J].Agricultural equipment and vehicle engineering,2007, 193 (8): 8-12.
[5] Lingyu S.Theoretical research on lightweight design of thin - wall beam structure[J].Journal of Beijing university of aeronautics and astronautics, 2004, 30 (12): 1163-1167.
[6] Qinghao Y,Yali F,Wenming Z.Analysis on the strength of shijinpeng mining car cargo compartment[J].Coal mine machinery, 2007, 3: 7-9
[7] Qiguang W.Finite element analysis and lightweight design of wingspan carriage [D] .Yantai university, 2007.
[8] Hongfeng M.Structural design and analysis of a type of mine dump truck [J].Design and calculation of engineering machinery,2012, 43 (8): 1-4 .
[9] Gundolf K, Elmar B, Roland S. New Lightweight Structures for Advanced Automotive Vehicle-Safe and Modular[J]. Social and Behavioral Sciences, 2012, 48: 350-362.
[10] Sonia C, Marcel M. Black-box structural optimization of a mechanical component [J]. Computers and Industrial Engineering, 2007, 53: 514-530.