Ride Performance Analysis of Electric Vehicle Based on Battery Pack Position

Yu-hang SUN and Lei ZHANG
Tianjin University of Technology and Education the School, China

Keywords: Ride comfort, Installation position of battery, Electric vehicle, Rigid-flexible coupling model.

Abstract: The installation position of battery pack in the design of electric vehicle has a great influence on the ride comfort of the vehicle. Based on the electric vehicle model of Aion S the multi-rigid-body theory, finite element analysis and modal analysis were used to establish a rigid-flexible coupling vehicle model with flexible steering tie rod. Simulation data of rigid-flexible coupling vehicle models with three different battery pack installation positions were compared. The results show that, in this model, the installation position front of the battery pack can make the vehicle more smooth.

Introduction

With the rapid development of social economy, electric vehicle gains it popularity. Electric vehicle, which could conserve energy and reduce emissions at the same time we hope it could ride comfortably. In order to make sure that passengers could feel free and the loaded goods remain intact. Domestic and foreign scholars have done a lot of research on improving vehicle performance by changing the position of key components. Li Xingchang\cite{1} modal analysis was carried out on the truck frame, through the frequency response analysis, calculate the frame of the modal order, which tends to cause resonance by the engine incentive, by moving the installation position of engine, optimize the vertical vibration amplitude of cab, improved the cab ride comfort; In the study of high-speed locomotive, Hou Jianwen\cite{2} removed the transverse shock absorber and arranged the anti-yaw damper horizontally on the end beam of the frame, making it play the role of anti-yaw damper and transverse shock absorber at the same time, simplifying the structure of the bogie and further optimizing the dynamic performance of the locomotive; Zhou Kaiyue\cite{3} carried out topological optimization and position optimization design for the installation seat of intercity emu. On the premise of meeting the requirements of corresponding static strength, so that the new structure could meet the static strength and fatigue strength while the installation position was more reasonable and the overall structure was more compact; Li Shuyang\cite{4} came up with the side touch sensor installation location structure dynamic stiffness and the performance evaluation of the resonance frequency response analysis method, the design of the installation location structure was improved, effectively improve the efficiency of the sensor installation points of structure design and accuracy, and improve the safety of vehicle ride. According to the current research results, the original performance can be improved by optimizing the location of components. In this paper, dynamics simulation software ADAMS/Car is used to establish the rigid-flexible coupling complete vehicle model. Based on the vertical acceleration of the centroid and the dynamic travel of the suspension, the ride comfort of the electric vehicle is analyzed and the influence of front, middle and rear battery pack installation position on vehicle ride was analyzed and compared.

Ride Comfort Test Standard and Evaluation Index

Ride comfort refers to the ability of the vehicle to ensure the comfort of the driver and the passenger from the vibration and impact of the road during the normal driving process of the vehicle\cite{5}. In order to evaluate the ride comfort of vehicles more accurately, the country has formulated the evaluation standard and test method of the ride comfort of vehicles, and evaluated the ride comfort of vehicles by means of quantitative test results.
Considering the vibration in three directions, the weighted root mean square value of acceleration can be obtained according to equation (1):

\[ a_w = \sqrt{\left(1.4a_{wx}\right)^2 + \left(1.4a_{wy}\right)^2 + a_{wz}^2} \]  

(1)

\(a_{wx}\)—the weighted root mean square value of acceleration in the front and rear directions, \(a_{wy}\)—the weighted root mean square of acceleration in the left and right directions, \(a_{wz}\)—the weighted root mean square value of the vertical acceleration.

By the 02631-1:1997 (E). When the peak coefficient of the vibration waveform is less than 9. In this case, we generally evaluate it by measuring the weighted root-mean-square value of acceleration in three directions at a specific position. In this paper, the ride comfort of electric vehicle model is analyzed by random input test.

**The Establishment of Rigid-flexible Coupling Model**

The design method of vehicle suspension based on rigid body cannot meet the needs of current research, by introducing a flexible body into the suspension and designing the front suspension steering tie rod as a flexible body, the established model can be more accurate. More importantly, the simulation results can be closer to reality.

When an electric vehicle is turning, the steering tie rod section of McPherson's suspension will bear a lot of force, the steering tie rod is easy to produce large elastic deformation in the process of turning, thus affecting the ride comfort of the vehicle. In order to study and improve the ride comfort of vehicles, a subsystem of rigid-flexible coupling model of McPherson's suspension with the steering tie rod as the flexible body was established, other subsystems include the pinion - rack steering system, Multi-link suspension, Pacejka 89 tire model, Power battery packs and other parts are treated as rigid bodies.

**Establishment of Flexible Body Model**

The front suspension of the vehicle adopts McPherson's suspension, in which the steering tie rod part is built into a flexible model. The 3d parametric solid modeling software CATIA is used to draw the 3d figure of the steering tie rod, then finite element software ANASYS was used to conduct gridding and finite element processing on the steering tie rod, and then imported into the dynamics simulation software ADAMS/Car to apply appropriate load and corresponding constraints, and the rigid-flexible coupling vehicle model was established by combining with other rigid body subsystems.

**Establishment of Battery Model**

In order to better simulate the physical prototype, three-dimensional parametric solid modeling software CATIA was used to build a lithium battery model. The power battery package has a mass of 421kg and an external dimension of 900mm×600mm×200mm, which is arranged under the bottom plate.

**Battery Pack Installation Position Setting**

The installation position of battery pack in rigid-flexible coupling vehicle model is divided into front, middle and rear. The center-of-mass coordinate of the front-mounted battery are (1000,0,200). The center-of-mass coordinate of the middle-mounted battery are (1600,0,200). The center-of-mass coordinate of the rear-mounted battery are (2200,0,200), as is shown in the figure 1.
Random Road Construction

ADMAS/Ride module is used to build a B-class random road surface, which based on Sayers empirical digital formula and has left and right wheel rut road contour parameters, there are many different road measurement parameters to be chosen from. The power spectral density of the road contour $G_d(n)$ and spatial frequency $n$ are as shown in equation (3)

$$G_d(n) = G_e + \frac{G_s}{(2\pi n)^2} + \frac{G_a}{(2\pi n)^4}$$

(3)

$G_e$—the amplitude of spatial power spectral density of noise; $G_s$—the velocity power spectral density amplitude of noise; $G_a$—the acceleration power spectral density amplitude of noise.

The road surface established in this paper is rough cement road surface, $G_e = 0.1$, $G_s = 20$, $G_a = 0.1$.

Simulation Analysis of Ride Comfort

According to GB/T4970 -- 2009 <<simulation experiment method of automobile ride comfort>> requirements. ADAMS/Car, a multi-rigid-body dynamics simulation software, was used to simulate the vehicle ride performance of the battery front-mounted vehicle model, battery middle-mounted vehicle model, battery rear-mounted vehicle model. When the vehicle turns 90 degrees at a speed of 80km/h on the b-class random road surface, modal analysis is carried out on the flexible part of the rigid-flexible coupling vehicle model, the vertical acceleration of the body centroid and the dynamic travel of the suspension of the rigid-flexible coupling vehicle model were analyzed, and the simulation data of three different battery positions were compared.

Modal Analysis of Steering Tie Rod

A three-dimensional model of steering tie rod is built in CATIA. According to the mechanical properties and geometric properties of the steering tie rod, the finite element model is obtained by simplifying the steering tie rod. The first 8 modes of the steering tie rod are calculated, as is shown in the table 1.

| order | frequency (Hz) | modal characteristics |
|-------|----------------|-----------------------|
| 1     | $-4.31 \times 10^{-3}$ | reverse |
| 2     | $-1.21 \times 10^{-3}$ | reverse |
| 3     | $-7.33 \times 10^{-4}$ | reverse |
| 4     | $1.88 \times 10^{-4}$ | warping |
| 5     | $6.83 \times 10^{-4}$ | bending |
| 6     | $1.37 \times 10^{-3}$ | warping |
| 7     | 3441.31 | bending+reverse |
| 8     | 3700.25 | bending+reverse |
Vertical Acceleration of the Centroid

Figure 2 is the comparison diagram of the vertical acceleration spectrum of the centroid of the whole vehicle model with rigid-flexible coupling at different installation positions of the battery pack. Three curves tend to be similar, The peak frequency of the rigid-flexible coupling model of the front, middle and rear battery installation positions is respectively 0.1855; 0.1876; 0.1949. The peak frequency of the front-mounted battery rigid-flexible coupling vehicle model is 2% and 5% lower than that of the other two vehicle models, It can be seen that the electric vehicle battery pack installed in the vehicle has better ride comfort.

![Figure 2. Vertical acceleration spectra of centroid.](image)

Dynamic Travel of the Suspension

Figure 3 is the comparison diagram of the dynamic travel of the suspension of the centroid of the whole vehicle model with rigid-flexible coupling at different installation positions of the battery pack. Three curves tend to be similar, According to the simulation results, the change range of suspension longitudinal motion stroke can be obtained: The dynamic travel of the suspension of the rigid-flexible coupling model of the front, middle and rear battery installation positions is respectively -2.68~+3.24mm; -2.36~+2.81mm; -2.11~+2.69mm. When the vehicle turns 90 degrees at a speed of 80km/h on the b-class random road surface, the dynamic travel of the suspension of front-mounted battery rigid-flexible coupling vehicle model is 14% and 23% higher than that of the other two models It can be concluded that the design of the battery pack for the electric vehicle as a front position increases the vertical working range of the suspension in the process of turning, and also improves the elasticity of the suspension.

![Figure 3. Dynamic travel of the suspension.](image)

Conclusion

According to the simulation results of the vertical acceleration at the center of mass of the whole vehicle model of the front, middle and rear battery pack mounting positions, it is feasible to analyze the influence of the battery pack mounting positions on the ride comfort of the vehicle. In the design, the battery pack of the electric vehicle is designed at the front, which can achieve better ride comfort when turning at medium and high speed. The analysis and comparison of the influence of three battery pack locations on the ride comfort of electric vehicles provides a new experience for the study of ride comfort of electric vehicles, It provides a theoretical basis for the optimization of the overall structure and layout of electric vehicles, thus shortening the time of product development, saving cost and improving product quality.
References

[1] Li Xingchang, Deng Minya, Yang Yunjie. Vibration reduction optimization of truck frame based on engine installation position [J]. Enterprise technology development, 2018, 37 (12):65-68.

[2] Hou Jianwen. Analysis of the influence of installation position and parameters of anti-snake shock absorber on locomotive dynamic performance [D]. Chengdu: Southwest Jiaotong University, 2014.

[3] Zhou Kaiyue. Study on optimization design of welding frame installation seat for intercity emu [D]. Dalian: Dalian Jiaotong University, 2017.

[4] Li Shuyang, Chang Guangbao, Liang Jingqiang, et al. Structural optimization design of side impact sensor installation points based on frequency response analysis [J]. Research and Development, 2017 (7):15-18.

[5] Yu Zhisheng. Automobile theory [M]. Beijing: China machine press, 2006.