Simulation Analysis on Ride Comfort of Hybrid Heavy Truck Based on ADAMS

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Abstract. In traditional heavy truck design process, a large number of real vehicle tests are required to evaluate the ride comfort of the heavy truck. This not only increases the R&D costs but also prolongs the R&D cycle, which brings great inconvenience. This paper establishes a three-dimensional digital model in Adams/car based on the relevant parameters of a hybrid heavy truck. The ride comfort with different speeds was tested on B-level random roads and A-level impulsive roads, and the maximum body vibration acceleration of the heavy truck when driving on A-level impulse roads, weighted root mean square value of acceleration of driving seat vibration when driving on a B-level random road are obtained with different speeds. These values reflect the impact on human comfort and health when driving, provide a theoretical basis for the subsequent optimization design and greatly save manpower and material resources.

Keywords. Hybrid Heavy Truck, Virtual Prototyping, Ride Comfort, Pulse Road, Random Road

1. Introduction

Trucks work mainly on roads, which are not an absolutely flat surface and have many ups and downs, these uneven roads are the main source of body vibration [1]. In addition, the vibration generated by the engine or motor during operation, caused by the aging and deformation of vehicle parts and so on [2-3] will be transmitted to the driver through the tires, suspension, and seat, damage the vehicle structure at the same time, even cause serious traffic accidents [4-5]. This paper assumes that the driving seat is rigid not elastic when modeling the truck. Although the weighted root mean square of the acceleration obtained has a certain deviation, it does not affect the evaluation results of the ride comfort of the heavy truck and will not change the variation trend of vehicle ride comfort with speeds [6].

Traditional ride comfort research is based on data obtained from a large number of real vehicle tests [7-8], which prolongs the R&D cycle and increases the investment of personnel and funds. The use of virtual prototype technology can solve these problems well [9-10]. This paper establishes a three-dimensional model of a hybrid heavy truck using the car module of the mechanical system dynamic simulation software Adams, and simulates the ride comfort on the A-level impulse road and the B-level random road with the established three-dimensional digital model, provides a theoretical reference for the subsequent design and optimization of the hybrid heavy truck.
2. Vehicle modeling

In Adams/car, first, the lower-level system and the upper-level system are established; Then, the template is established, the template is the lowest-level system in all Adams systems. The subsystems of each part of the target vehicle can be established on the basis of the template; Finally, the subsystems are assembled to form a vehicle model [11-12]. For example, the sequence of modeling the front suspension steering group file is shown in Fig. 1.

When modeling the entire vehicle, the hybrid heavy truck needs to be simplified [13-14]. The geometry of each part is established with the local hard point through the relevant structure of the target vehicle model. The constraints between the geometry are added to the corresponding position of the model, such a subsystem is established. The Adams/car communicator is used to connect different subsystems to establish the target vehicle model, and input the required parameters, the vehicle can be simulated. A total of 9 subsystems have been established in this paper, namely: Front suspension subsystem, rear suspension subsystem, steering subsystem, cab subsystem, body subsystem, front wheel subsystem, rear wheel subsystem, power subsystem and brake subsystem. The vehicle model is shown in Fig. 2. The main parameters of the vehicle model used in the ride comfort simulation are shown in Table 1.

![Fig. 1 Front suspension steering group file](image1)

![Fig. 2 Vehicle model](image2)

**Table 1. Main parameters**

| Name                  | Parameter         |
|-----------------------|-------------------|
| Vehicle curb weight   | 10600KG           |
| Front Track           | 2065mm            |
| Rear Track            | 1860mm            |
| Wheelbase             | 5800mm            |
| Minimum ground clearance | 270mm          |
| King pin inclination  | 7°                |
| Caster angle          | 3°                |
| Camber                | 1°                |
| Toe angle             | 2°                |
| Front spring stiffness| 170.96N/mm        |
| Rear spring stiffness | 134.5N/mm         |
| Maximum speed         | 85Km/h            |
3. Ride comfort simulation

3.1. Impulse road simulation

According to the national standard, the impulsive road surface in ride comfort test should use triangular or rectangular bosses. This paper uses a triangular boss with a height of 60mm and a width of 400mm. The length of the triangular boss can be determined depends on actual needs, but must be greater than the wheel width of the test vehicle.

In this paper, the ride comfort analysis speeds of the hybrid heavy truck in the pulse road are 10km/h, 20km/h, 30km/h, 40km/h, 50km/h and 60km/h. The simulation step is 0.05s. The vehicle body vertical vibration acceleration obtained by simulation at different vehicle speeds are showed from Fig. 3 to Fig. 8.

![Fig. 3 Acceleration at 10km/h](image1)
![Fig. 4 Acceleration at 20km/h](image2)
![Fig. 5 Acceleration at 30km/h](image3)
![Fig. 6 Acceleration at 40km/h](image4)
![Fig. 7 Acceleration at 50km/h](image5)
![Fig. 8 Acceleration 60km/h](image6)
It can be seen from Table 2, in the speed range of 10km/h-60km/h, as the vehicle speed increases, the maximum vertical vibration acceleration increases. In actual operation, as long as the maximum acceleration of the truck in the vertical direction is not higher than 31.44m/s², it will not affect the health of the driver and passengers. Therefore, the result shows that when driving on impulse roads, the maximum acceleration of the research truck will not affect the health of the driver.

**Table 2. Maximum vertical vibration acceleration on a triangular boss road**

| Simulation speed (km/h) | 10  | 20  | 30  | 40  | 50  | 60  |
|-------------------------|-----|-----|-----|-----|-----|-----|
| Maximum vertical vibration acceleration (m/s²) | 1.282 | 3.578 | 5.846 | 6.367 | 8.989 | 8.884 |

3.2. Random road simulation

Driving on a regular road can be considered as driving on a random road. The national standard GB/T 4970-2009 requires that when the N-class vehicle conduct ride comfort analysis on random roads, it need to be tested at speeds of 30km/h, 40km/h, 50km/h and 60km/h respectively to obtain the vibration acceleration of the passenger seat in the longitudinal, lateral and vertical directions, and calculate the weighted root mean square value of the acceleration in three directions. Fig. 9 to 12 show the three-directional vibration acceleration of the driver's seat when driving on a random road with different speeds. The calculation formula for this value is:

\[ a_w = \left[ \frac{1}{T} \int_0^T a_w^2(t) dt \right]^{\frac{1}{2}} \]  \hspace{1cm} (1)

where, \( T \) is the analysis time of vibration, \( a_w(t) \) represents the weighted acceleration time history, which is obtained from the recorded acceleration time history \( a(t) \) through the corresponding frequency weighting function \( w(f) \),

\[ w(f) = \begin{cases} 
0.5, & 0.5 \leq f < 2 \\
\frac{f}{4}, & 2 \leq f < 4 \\
1, & 4 \leq f < 12.5 \\
\frac{12.5}{f}, & 12.5 \leq f < 80 
\end{cases} \]  \hspace{1cm} (2)

The calculation formula for the root mean square of the total weighted acceleration is:

\[ \bar{a}_{wj} = (k_x^2 \bar{a}_{wx}^2 + k_y^2 \bar{a}_{wy}^2 + k_z^2 \bar{a}_{wz}^2)^{\frac{1}{2}} \]  \hspace{1cm} (3)

where, \( \bar{a}_{wx}, \bar{a}_{wy}, \bar{a}_{wz} \) are respectively weighted root mean square acceleration of x-axis, y-axis, z-axis. \( \bar{a}_{wj} \) is the total weighted root mean square acceleration. \( k_x, k_y \) and \( k_z \) are weighting factors, select \( k_x = k_y = k_z = 1 \).
The vertical acceleration curve of the driver’s seat obtained when driving at a speed of 30km/h is showed in Fig.13, after mathematical processing, the vertical acceleration self-power spectral density curve of the driver's seat can be obtained as shown in Fig. 14.

Multiply the square of frequency weighted function and the vertical vibration acceleration power spectral density of the driver's seat to obtain the weighted power spectral density product curve, as shown in Fig.15. Then use Adams to obtain the integral curve of Fig.16. The maximum value of this integral curve is the weighted root mean square value of the acceleration we need. As shown in Fig. 16, the value is 0.3278m/s² when driving at 30km/h.

It can be seen from Tab.3 and Tab.4 that the driver will have little uncomfortable feeling when driving on the B-class random road at the speed of 30km/h, will not feel uncomfortable at speed of 40km/h, 50km/h and 60km/h.
### Table 3. The standard

| Total weighted root mean square acceleration | Human subjective feeling |
|---------------------------------------------|--------------------------|
| <0.315                                      | I                        |
| 0.315-0.63                                  | II                       |
| 0.5-1                                       | III                      |
| 0.8-1.6                                     | IV                       |
| 1.25-2.5                                    | V                        |
| >2                                          | VI                       |

where, I, II, III, IV, V, VI indicates a gradual increase in discomfort.

### Table 4. Weighted acceleration root mean square value at each speed

| Speed  | 30km/h | 40km/h | 50km/h | 60km/h |
|--------|--------|--------|--------|--------|
| Longitudinal (m/s²)  | 0.0095 | 0.0200 | 0.0283 | 0.0266 |
| Lateral (m/s²)       | 0.0438 | 0.0317 | 0.1089 | 0.1171 |
| Vertical (m/s²)      | 0.3248 | 0.2699 | 0.2696 | 0.2774 |
| Total (m/s²)         | 0.3278 | 0.2724 | 0.2921 | 0.3023 |

| Human subjective feeling | II | I | I | I |

### 4. Conclusion

In this paper, a virtual prototype model of a hybrid heavy truck is established in Adams/car, and simulations are carried out on A-level impulse roads and B-level random roads with different speeds to verify whether there is an impact on human comfort and health during driving. On A-level impulse roads, as long as the maximum acceleration of the truck in the vertical direction is not higher than 31.44 m/s², it will not affect the health of the driver and passengers; On B-level random roads, the driver will have some uncomfortable feeling when driving at 30 km/h, but the driver does not feel uncomfortable at speeds of 40 km/h, 50 km/h, and 60 km/h.

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