Simulation and Optimization of Truck Cab Suspension System Based on ADAMS

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Abstract. Taking the suspension system of the truck cab as the research object, aiming at the three working conditions commonly used by engineering vehicles, cab suspension system dynamics model is established in ADAMS/view. The stiffness and damping of the front and rear suspension are design variables, and the maximum acceleration of the cab floor is minimized as the design objective. ADAMS's own optimization module is used to optimize the suspension parameters, and the optimal matching value of the suspension parameters under the three working conditions is obtained. And On this basis, the three sets of values were optimized by DOE orthogonal test technology, and a set of optimal matching values of suspension parameters suitable for three kinds of road conditions was obtained. Finally, the accuracy of the model and the optimization value of cab suspension parameters are verified by the actual road test results.

1. Introduction

Engineering vehicles are often drive on bumpy and undulating roads, and the ride comfort of vehicles is particularly important. Cab suspension, as an elastic and damping element connecting the frame and cab, directly affects the ride comfort of the driver, so the matching of suspension parameters becomes very critical. [1] Domestic and foreign vehicle enterprices and universities mainly analyze the frequency components in the cab acceleration vibration signal to find out the key components that affect the cab vibration, and obtain the optimal value of suspension parameters through experiments and multi-body dynamics analysis, so as to improve the ride comfort of drivers. [4]

This paper mainly takes a four-coil spring engineering vehicle as the research object and establishes dynamics simulation model of the cab suspension system in ADAMS. Then, the optimal matching values of suspension parameters in three typical working conditions are obtained. Finally, the orthogonal test technique is applied to further optimization so as to obtain a set of mount parameter matching values suitable for three working conditions.

2. Structure analysis of suspension assembly

The structure of cab suspension assembly studied in this paper is shown in the following figure. The front suspension, as shown in figure 2.1, is mainly composed of coil spring, upper bracket and lower bracket. The rear suspension, as shown in figure 2.2, is mainly composed of coil spring, upper bracket, locking mechanism and lower bracket, and the coil spring and the lower bracket have a certain angle.
3. Simulation calculation and model validation

3.1 Model establishment of cab mount assembly

According to the three-dimensional model of cab suspension assembly system provided by the automobile enterprise, it simplifies in CATIA and identifies the position coordinate parameters of important parts. Then, it is imported into ADAMS software, and constraints are imposed on each component to establish a multi-body dynamic simulation model. Considering the cab as a rigid body, vibration blocks are built below the suspension to simulate the effect of the vehicle frame, and excitation is inputted at the four vibration blocks to establish a complete simulation model of the cab suspension system, as shown in figure 3.1. After the establishment of the model, static verification and DOF verification should be carried out to ensure the static balance of the model.

3.2 Simulation calculation of cab suspension

The acceleration time-domain signals collected in experiment are converted into PSD signals in frequency domain, which are used as excitation signals of vibration blocks in simulation. Since the suspension mainly affects the vertical vibration isolation performance, the simulation test mainly analyzes the vertical performance.[7]

In the simulation model, four vibration blocks are used to replace the frame, the excitation signals at the four vibration blocks are used as input signals, and the acceleration signals at the cab floor are used as output signals. Vibration simulation analysis is carried out through vibration module in Adams, due to the main frequency range that affects human comfort is 4-12.5Hz, therefore, in the simulation, the initial frequency calculated by the software is set to 0.1Hz, the cut-off frequency is 20Hz, and the number of simulation steps is set to 200. The comparison between vertical acceleration signal at the cab floor and the test signal is shown in figure 3.2, figure3.3 and figure3.4.
As can be seen from figure 3.2, the simulation results and the test values are very close, and the amplitude corresponding to the two curves at the peak of the wave is shown in table 3.1 above. The error between the two curves is kept within 20%.

Table 3.1 PSD comparison of test and simulation cab floor

| Program               | Pebble road | Stone block road | Flat road |
|-----------------------|-------------|------------------|-----------|
| Maximum value of test | 4.68        | 9.53             | 2.28      |
| (m/s²)²/Hz             | 4.53        | 7.96             | 1.95      |
| Error /%               | 3.2         | 16.5             | 18.8      |

4. Model parameter optimization

4.1 Three typical working conditions were optimized respectively

As can be seen from the simulation results in the previous chapter, the maximum vertical acceleration at the cab floor under the three typical working conditions is very large, which will be optimized in this chapter. The stiffness and damping of the front and rear suspension were design variables, and the maximum PSD of vertical acceleration at the cab floor was minimized as the optimization objective, and the optimization module of ADAMS is applied to optimize the model. Among them, the variation range of front and rear suspension stiffness is set as 30-120N/mm, and the variation range of front and rear suspension damping is set as 3-15N·s/mm. In the simulation calculation, the initial and cut-off frequencies are set as 0.1Hz and 20Hz, and the number of simulation steps is set as 200.

Under the three working conditions, the vertical PSD curve of the cab floor before and after the optimization is shown in figure 4.1, figure 4.2 and figure 4.3. It can be seen that after the optimization of the three working conditions, the target value decreases by 28.1%, 24.5% and 23.6% respectively. The specific target value before and after the optimization are shown in table 4.1 and the suspension
stiffness and damping value before and after the optimization are shown in table 4.2.

Table 4.1 Maximum PSD of vertical acceleration at cab floor before and after optimization

| Program                                      | Initial value | Optimal value |
|----------------------------------------------|---------------|---------------|
| Maximum PSD on pebble road/(m/s²)²/Hz       | 4.53          | 3.26          |
| Maximum PSD on stone block road /(m/s²)²/Hz | 7.96          | 6.01          |
| Maximum PSD on flat road /(m/s²)²/Hz        | 1.95          | 1.49          |

Table 4.2 The values of cab suspension before and after optimization

| Optimization project      | Initial value | Optimal value |
|---------------------------|---------------|---------------|
| The pebble road           |               |               |
| Front stiffness/(N/mm)    | 50            | 105.8         |
| Front damping/(N s/mm)    | 10            | 11.7          |
| Rear stiffness/(N/mm)     | 60            | 82.8          |
| Rear damping/(N s/mm)     | 10            | 12            |
| The stone block road      |               |               |
| Front stiffness/(N/mm)    | 50            | 31.2          |
| Front damping/(N s/mm)    | 10            | 12.03         |
| Rear stiffness/(N/mm)     | 60            | 80.6          |
| Rear damping/(N s/mm)     | 10            | 12.03         |
| The flat road             |               |               |
| Front stiffness/(N/mm)    | 50            | 30            |
| Front damping/(N s/mm)    | 10            | 6             |
| Rear stiffness/(N/mm)     | 60            | 30            |
| Rear damping/(N s/mm)     | 10            | 12            |
4.2 DOE orthogonal experiment optimization

The driving road of the engineering vehicle is composed of three kinds of road: pebble road, stone block road, and flat road, and the previous section has optimized for a single road condition. This section uses DOE orthogonal test technology to integrate the three sets of optimized values obtained in the previous section, and obtains a set of suspension stiffness and damping values suitable for three kinds of working condition. [8]

The experimental excitation curves of three road conditions are integrated to obtain a set of excitation curves superimposed by the three kind of road, which were imported into ADAMS to re-establish the model. The three groups of stiffness and damping optimization values obtained in the above section are taken as test factors to form the orthogonal test table of L9 (3^4) of 4 factors, 3 levels and 9 tests for optimization. The iterative curve of the optimization process is shown in figure4.4. The values of suspension stiffness and damping before and after optimization are shown in table 4.3.

Table 4.3 The suspension stiffness and damping values after orthogonal test optimization

| Project      | stiffness/ (N/mm) | damping/ (N.s/mm) |
|--------------|-------------------|-------------------|
| Front suspension | 30            | 12               |
| Rear suspension  | 80            | 12               |

Figure 4.5 PSD curve of the cab floor before and after optimization

Through figure 4.5, by comparing the PSD curve of acceleration at the cab floor and the PSD curve optimized by orthogonal test under the three road superimposed conditions, it can be seen that the amplitude of the curve decreases by 31.4%, and it can be considered that the stiffness and damping value of the suspension after the optimization is applicable to this superimposed condition.

5. Ride comfort test and analysis

For engineering dumper, it often faces short distance, heavy load and bad road driving conditions. Aiming at this and consulting relevant national standard, the vertical acceleration signal of the cab floor and the vertical acceleration signal of the suspension are collected and analyzed when the vehicle is driving on pebble road, stone block road and flat road.

5.1 The test process

In the test, the acceleration sensor was placed under the suspension of the cab and on the floor of the cab, as shown in figure 5.1 below. In this test, the vehicle speed on the pebble road was set at about 20km/h, the vehicle speed on the stone block road was set at about 40km/h, and the vehicle speed on the flat road was kept at about 60km/h. Two sets of data were collected for each road condition to ensure that the signal was normal before ending.
5.2 The data processing

According to the relevant standards of automobile ride comfort test, the root mean square value of acceleration at the cab floor under different road conditions is calculated, and the results are shown in Table 5.1.

As can be seen from the results in the table, under the three road conditions, the root mean square value of acceleration at the floor is larger, and the ride comfort of stone block road is the worst when driving at medium speed. Therefore, it is necessary to optimize and match the suspension parameters.

| Working condition | category                  | The pebble road | The stone block road | The flat road |
|-------------------|---------------------------|-----------------|----------------------|--------------|
|                   | RMS of X-direction/m s^2  | 0.43            | 0.89                 | 0.42         |
|                   | RMS of Y-direction/m s^2  | 0.88            | 1.69                 | 0.43         |
|                   | RMS of Z-direction/m s^2  | 1.64            | 3.14                 | 0.77         |
|                   | Total weighted RMS/m s^2  | 0.70            | 1.34                 | 0.34         |

Table 5.2 shows the PSD maximum value of vertical acceleration on the cab floor before and after optimization, and the vibration amplitude after optimization is 31.4% lower than that before optimization, achieving a good optimization effect.

| Program | Initial value | Optimal value |
|---------|---------------|---------------|
| PSD amplitude at cab floor / (m/s^2)/Hz | 3.38 | 2.32 |

6. Conclusion
The optimization module of ADAMS is adopted, taking the suspension stiffness and damping value of the cab as design variables and the minimization of the maximum vertical acceleration at the cab floor as the optimization objective, and obtains a set of matching values of suspension parameters suitable for different working conditions. It can be seen from the results before and after optimization that the maximum vertical acceleration at the cab floor decreases obviously.

Through this optimization, it can be seen that changing the stiffness and damping value of cab suspension cannot completely eliminate the peak value of vertical vibration acceleration at the cab floor, but it can weaken the amplitude well, providing a reference basis for further optimization in engineering.

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