Simulation Analysis of Cab Mounting System of Flat-head Truck

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Abstract. Because the working environment of heavy truck with flat head is harsh, it is often in full load or vibration and impact load for a long time, and the cab suspension system receives these responses, and the driver's intuitive feeling is the output response of the system. In this paper, the static and dynamic characteristics of air spring are tested, and the stiffness and motion characteristic curves are obtained. Then, according to the test data, the model of cab air mount system is established in ADAMS software, which simulates the response of cab mount under real vibration and evaluates its vibration reduction performance.

1. Main characteristics and dynamic and static stiffness test of air spring

Air spring is a non-metallic spring which can reduce vibration by compressing compressed air into a flexible sealed container and using the compressibility of air in the sealed container to achieve elastic effect. It is usually composed of three parts: spring, additional air chamber and height control valve. Metal edges are embedded between each section of the spring to prevent radial expansion of the middle part, bear internal pressure and prevent mutual friction. The more nodes connected in series, the better the elasticity of the spring. The advantages are that it has excellent elastic characteristics and height adjustment device, and the height of the car body does not change with the increase and decrease of load; The air spring has a height adjustment mechanism, and the height can be adjusted by adding the volume of the air chamber, and the ride comfort is better; Using air as medium can obviously reduce noise; The disadvantage is that the structure of air spring suspension is more complex and the manufacturing cost is high\cite{1}.

1.1. Static stiffness test of cab air spring

1.1.1. Experimental purpose

The purpose of this test is to obtain the elastic static characteristic curve of the air spring for testing, and further obtain the static stiffness of the air spring for testing.
1.1.2. Test object
The type of air spring used in this test is membrane air spring, and its inflation pressure ranges from 0.5 Mpa to 0.9 Mpa. At rated pressure, the installation height of standard air spring is 270 mm, the gas quality in this group is constant, and the working pressure can be selected according to the load of air spring under different conditions.

1.1.3. Laboratory apparatus
It consists of MTS831 elastic element test bench, air pump, air duct, pressure gauge and clamping tool.

1.1.4. Experimental procedure
During the test, the displacement sensor force and the sensor installed on the system actuator measure the displacement and load data of the air spring respectively.

(1) Fix the air spring on the test bench with clips, as shown in Figure 1.

![Figure 1](image)

Figure 1  Static Stiffness Test Instrument and Clamping Device of Front Air Spring

(2) Check the airtightness of the test pipeline, inflate it to the standard internal pressure of 0.6 Mpa and let it stand for 20 minutes, adjust the air spring to the standard installation height (270 mm), close the valve before disconnecting the air source, and record the load and internal pressure of the air spring in this state.

(3) Stretch and compress the air spring to their respective maximum positions, and then restore the air spring to its standard height (270 mm). Measure and record the relationship between the load and pressure of air spring and the deformation during the test. Repeat one measurement cycle.

(4) Measure the air spring under different initial pressures, and repeat the above steps. Choose different standard internal pressures as 0.2 Mpa, 0.4 Mpa and 0.6 Mpa ..

(5) Test the internal elastic displacement characteristics of two air springs with the same initial load and internal pressure. Under the same conditions, it is necessary to test the compression process repeatedly for at least three times to better ensure the objectivity and accuracy of the test results after compression. Then, matlab software is used to simply process the test data of air springs, and it is obtained that the corresponding elastic displacement produced when the initial internal load and pressure of compressed air springs are 0.3 Mpa, 0.5 Mpa and 0.7 Mpa respectively is called hysteresis loop [2].

1.1.5. Test result analysis
As shown in Figure 2, the static stiffness characteristics of air spring show significant nonlinearity. The motion stiffness of air spring near its standard motion position is small, but its stiffness gradually decreases or increases during the tension and compression movement of spring [3]. As the air pressure inside the air spring chamber gradually decreases or increases, the air pressure will provide more air elasticity for the spring at the same height and displacement.
1.2. Dynamic stiffness test of cab air spring

1.2.1. Test objective
The purpose of the test is to obtain the dynamic stiffness curve of air spring under standard air pressure.

1.2.2. Test instrument
It is basically the same as the air spring static stiffness test instrument and equipment.

1.2.3. Test steps
(1) Fix the air spring on the spring fixture of the test bench with a clamp.
   (2) Check the air tightness of the pipeline;
   (3) Inflate it to the standard internal pressure of 0.6 Mpa and let it stand for 20 minutes, adjust the air spring to the standard installation height (114 mm), first close the valve and then disconnect the air source, and record the load and internal pressure of the air spring in this state. Operate the vibration platform to do sinusoidal vibration with amplitude of 4 mm at different frequencies of 0.5 Hz to 30 Hz and interval of 1 Hz, thus obtaining the dynamic stiffness values at various frequencies [4].

1.2.4. Test result analysis
After data processing, the dynamic stiffness curve of air spring is shown in Figure 3.

2. Establishment of Dynamic Simulation Model of Cab Air Mounted Multi-body System

2.1. Establishment of cab model
After importing the geometric model of the cab into ADAMS software, it began to simplify, simplifying the cab into a quality point; Then edit the components and modify the quality information, add various constraints, and finally verify the cab model and complete the whole modeling process [8]. The cab model is shown in Figure 4.
2.2. Based on the static stiffness test results of air mount, the simulation model is established

The pressure produced by the air pump of common commercial vehicles is between 0.5 and 0.9 MPa, so when modeling, we use the displacement and pressure curve under 0.7 MPa to simulate the actual cab situation. As shown in Figure 6.

Then import this curve into the spline in ADAMS, and use the force function and cubic spline interpolation function in ADAMS software function library, as shown in Figure 7. Establish the simulation model of the left air spring of the front suspension;

\[
\text{Function=AKISPL}[156.5-\text{DM(MARKER\_1007,MSRKER\_1008)},0,\text{SPLINE\_3},0]\[8]
\]

In which:
- \(\text{Dm (marker\_1007, msrker\_1008)}\) - displacement;
- 156.5 — initial height;
- 156.5-\(\text{DM (marker\_1007, msrker\_1008)}\) — relative displacement;
- Marker\_1007 - the reference coordinate system of point I;
- Marker\_1008 - the reference coordinate system of j point;
- Spline\_3 — Spline of ADAMS hollow gas spring elastic characteristic test curve.

Test curve of static stiffness of front air spring under internal pressure of 0.7 MPa.
In the same way, the right air spring of cab front suspension is modeled:

Function=AKISPL[156.5−DM(MARKER_1011,MSRKER_1012),0,SPLINE_3,0]

Since the front air spring does not have the function of a damper, it must be used in conjunction with an additional damper. Similarly, we will simplify the static stiffness curve of the rear air spring, as shown in Figure 8.

![Figure 8 Simplified curve of static stiffness of rear air spring](image)

Then save it as Spline_4 in the same way, then import the curve into SPLINE in ADAMS software, and use the force function and cubic spline interpolation function in software function library to establish the simulation model of rear suspension air spring: rear suspension left air spring:

Function=AKISPL[107.35−DM(MARKER_415,MSRKER_416),0,SPLINE_4,0]

Rear suspension right air spring:

Function=AKISPL[107.35−DM(MARKER_1019,MSRKER_1020),0,SPLINE_4,0]

Finally, the cab air mounting model based on the static stiffness test cab mounting simulation model is shown in Figure 9.

![Figure 9 Simulation model of cab mounting based on static stiffness test results](image)

2.3. Based on the test results of dynamic stiffness of air mount, the simulation model is established

In the dynamic stiffness test of air spring, the stiffness values of the spring at various frequencies are obtained, and then the cab suspension simulation model is established. First, open the previously constructed cab model of the flathead truck, and then input the stiffness and damping values of the front spring and the rear spring in the table, and then establish the air suspension model of the flathead truck cab.

An output channel is established at the centroid position of the cab of the flathead truck, and the output is the displacement of the centroid position of the cab in the Z-axis direction. The output channel is shown in Figure 10.

![Figure 10 Establishing Output Channel in ADAMS](image)
2.4. **Simulation analysis**

After opening the dialog interface of vibration simulation analysis, create a new vibration analysis, and then input the established input and output channels in 1000 steps from 0.5 Hz to 25 Hz.

Then start the vibration analysis, and then enter the post-data processing module, set the data source as Transfer function, select Vibration analysis_50 as the analysis object, select model1. Input_Channel_3 and model1. Output_Channel_3 as the input and output channels, set the Scale modes of x-axis and y-axis as linear, and then get the transfer characteristic curve of cab air mount [5]. It can be seen from the figure that the resonance frequency of cab air mount is 2.40 Hz, and the transmission rate is 1.23%, as shown in Figure 11.

![Figure 11 Transfer characteristic curve of cab mounting model based on static stiffness test results](image)

3. **Summary**

In this paper, the vibration, multi-body dynamics theory and simulation analysis of cab mounting system of flathead truck are studied. According to the data and ADAMS software, the air mounting system of flathead truck cab is modeled. The main conclusions are as follows:

1. The static and dynamic stiffness characteristics of air spring are obtained through experiments. Based on this, the model test of air mount in cab can be carried out.

2. The static stiffness characteristic curve of air spring is used to simulate the air suspension of cab, and then dynamic simulation analysis is carried out. The resonant frequency of most truck chassis suspensions is 1.7Hz to 1.8Hz, and the resonant frequency of tires in running is about 11 Hz. However, 4 ~ 8 Hz is the sensitive area of human body to vibration. The higher the vibration frequency, the more uncomfortable the human body will feel. In this paper, the resonant frequency of cab suspension model is 2.40 Hz, the transmission rate is 1.23%, and the vibration reduction performance is good. It is feasible to build a model based on static stiffness test curve, and then use the model to analyze its dynamic response.

**References**

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