Research on Modal Characteristics of Vehicle Chassis Transmission Shafting Based on ADAMS

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Abstract. Vehicle chassis usually adopts variable speed axial transmission system composed of universal joint transmission shaft and gear pair. The vibration, impact and energy loss are related to the efficiency of power transmission and the safety performance of equipment. Since variable shaft transmission system is the key component of vehicle chassis, vibration and noise reduction is the inevitable way to improve vehicle quality, energy conservation and environmental protection. However, researchers have done a lot of work on the dynamic characteristics of gears, rarely considering the influence of cardan shaft on the modal characteristics of gear pair system. Taking the rear wheel drive system of a vehicle chassis as the research object, the virtual prototype simulation model of the transmission shaft main reducer assembly is established by using the dynamics software ADAMS, and the influence of the stiffness of the shaft and the intermediate support on the noise and vibration characteristics of the rear axle main reducer is analyzed. At the same time, the accuracy of the simulation results is verified by experiments, which provides a reference for the parameter design of the drive shaft and the rear axle final drive.

Keywords: Vehicle chassis, transmission shafting, Modal characteristics, Dynamics simulation.

1. Introduction

All kinds of motorized transport equipment, such as passenger cars, heavy transport vehicles, truck cranes, loaders and other vehicle chassis, use the transmission shaft system to realize the power transmission to the walking system. This type of transmission system can usually be described as the variable shaft transmission system of "universal joint transmission shaft transmission system" generalized model [1]. Variable axis transmission system belongs to flexible transmission system, which can ensure that the torque that causes vibration, impact and energy loss can be output in the form of floating point [2]. The vibration, impact and energy loss are related to the efficiency of power transmission and the safety performance of the equipment. As the variable shaft transmission system is the key component of the vehicle chassis, vibration and noise reduction is an inevitable way to improve the vehicle quality and energy conservation and environmental protection. Therefore, it is very important to study how to reduce the vibration and impact of variable shaft transmission system and realize the energy saving, noise reduction and safe operation of transmission system.
At present, main research gap, time-varying mesh stiffness, high frequency vibration of gear transmission system or the influence of parameters on gear meshing. However, little attention has been paid to the matching performance between the transmission shaft and the final drive. In this paper, the transmission shaft and the main reducer of a certain vehicle chassis are taken as the research object, and the virtual prototype simulation method is used to set different angles between the shafts and different stiffness of the intermediate support, to study the influence of the transmission shaft on the noise and vibration of the main reducer, and to summarize the law of the influence of the transmission shaft on the vibration of the main reducer. Therefore, it lays a solid foundation for improving the parameter matching of transmission shaft and axle.

2. Virtual prototype model of transmission shaft and main reducer

2.1. Building a simple simulation model
In this paper, the common vehicle chassis cross universal joint drive shafting is studied. The 3D solid models of the transmission shaft and the main reducer are established by UG software, and the components are assembled according to the actual assembly relationship. In order to make the simulation process relatively simple and meet the needs of simulation analysis, when studying the influence of the transmission shaft on the noise and vibration of the main reducer, those parts of the transmission shaft main reducer assembly that have no influence on the simulation can be deleted [3], and then the three-dimensional model can be imported into the dynamics analysis software ADAMS. The final simple simulation model is shown in Figure1.

Figure 1. Simple model.

2.2. Set kinematic constraints
Before virtual simulation, add kinematic constraints to components. The transmission shaft rotates around its own axis, so we use a rotating pair to simulate the motion pair between the gearbox and the first transmission shaft; the cross axis universal joint rotates around its own axis, so we use a rotating pair on the constraint of the three joints; accordingly, they can achieve the desired motion transfer function. The specific motion pairs are shown in Figure 2.

The translation pair is used for the motion pair between the sliding spline and the driving fork of the universal joint, which can simulate the actual motion of the sliding spline in the process of shaft motion. The middle support is not only connected to the transmission fork through the cylindrical pair, but also connected to the ground through the fixed pair, so the actual motion state of the middle support can be simulated, as shown in Figure 3.

Figure 2. Universal joint pair.  
Figure 3. Sliding spline pair
The power take-off transmission shaft of the vehicle chassis is connected with the driving bevel gear of the main reducer through a coupling flange, which can realize the power transmission of the engine. In the simulation model, the spline connection between the connecting flange mechanism and the shaft end of the driving gear is omitted; the output shaft and the driving spiral bevel gear are directly connected through the rotating pair to realize the power transmission. The rotation axis of the driven spiral bevel gear is perpendicular to its end face, and the constraint of the driven gear is also simulated by the rotation pair, as shown in Figure 4.

![Figure 4. Driving driven gear pair](image)

3. Virtual simulation analysis
Based on the virtual simulation method, this paper mainly studies the influence of the angle between axles and the stiffness of the middle support on the noise and vibration characteristics of the rear axle final drive.

3.1. The influence of angle between axes on angular acceleration
According to the actual length of the transmission shaft, in order to meet the needs of the research, we set the angles as 0°, 2°, 5°, 8°, 10°. In the simulation, the downward movement distance of the second shaft is set as the design variable, and the angular velocity of the main and driven spiral bevel gears is set as the objective function. The dynamic response of active and passive gears was studied with engine speed of 2500 r/min and shift times of 2. From the simulation, the angular velocity fluctuation curves of driving gear and driven gear under different inter axle angles are shown in Fig. 5 and Fig. 6.

![Figure 5. Driving gear angular velocity curve](image)
The input angular velocity function of transmission shaft and main reducer is \text{STEP}(\text{time}, 0, 0, 1.2, 1500d). When the angle between shafts changes from $0^\circ$ to $5^\circ$, the fluctuation amplitude of angular velocity of driving gear and driven gear gradually decreases, while when the angle changes from $5^\circ$ to $10^\circ$, the fluctuation amplitude of angular velocity gradually increases. The change of angle value from $0^\circ$ to $10^\circ$ corresponds to the change from trail_1 to trail_5. The simulation curve shows that the vibration of driving gear and driven gear is minimum when the angle between shafts is $5^\circ$.

### 3.2. Influence of stiffness of intermediate support on noise and vibration of rear axle

This paper adopts the method of controlling a single variable, assuming that the angle between the shafts is $5^\circ$, analyzes the contact simulation of the driving gear and the driven gear, and studies the influence of the intermediate support stiffness on the noise and vibration of the main reducer.

Because the stiffness values of x-axis and z-axis change at the same time, the variable control matrix in ADAMS is used to ensure that the two design variables change at the same time. As shown in Figure 7, the variable control matrix is $[-7, -7, -6, -6, -5, -5, ..., 5, 6, 6, 7, 7]$. The torque value of the gear is obtained by simulation, and the simulation curves are shown in figures 8 and 9.
According to these two curves, we can draw the conclusion that when the stiffness of the intermediate support is between $4.0 \times 10^5$ N/m and $5.0 \times 10^5$ N/m, the torque fluctuation of the gear is the smallest.

4. Experimental research and analysis

The actual parameters of the vehicle chassis are adopted. The angle between axes is 7° and 5° respectively. One photoelectric sensor is used to measure velocity, and two vibration sensors are used to measure axial and vertical vibration. The measured signal is amplified by the charge amplifier, then the analog signal is converted into digital signal and input into the computer. Finally, after the computer software analysis and information processing, the angular velocity angular acceleration amplitude curve is shown in Figure 10-11.
It can be seen from figure 10-11 that the angle between the shafts and the stiffness of the middle support have a great influence on the final drive. The experimental results show that when the angle between axles is 5 ° and the stiffness of the middle support is 500 N / mm, the vibration and interior noise of the main reducer are the minimum, and the experimental data are highly consistent with the simulation results.

5. Conclusion

The simulation and experiment results show that the torsional vibration of the vehicle chassis transmission shaft main reducer model will be affected when the angle between the shafts changes. When the angle between the shafts is 5 degrees, the transmission shaft has the least influence on the noise and vibration of the main reducer. The stiffness of the intermediate support has a great influence on the contact between the driving and driven gears of the main reducer. When the stiffness of the intermediate support is about 500 N / mm, the vibration of the main reducer is the smallest. The simulation and experimental results provide a reference for the parameter matching between the transmission shaft and the rear axle.

Reference

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