Simulation and Experimental Research on Vibration and Noise of Transmission

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Abstract. To solve the problem of vibration and noise of transmission, the finite element model and boundary element model of transmission case were established to modal analysis, vibration response analysis and radiated noise analysis and prediction. The characteristics of vibration and radiation noise of transmission case were simulated by the finite element method combined with boundary element method. The constant mesh gear pair and a box body resonance were the noise source of transmission was determined through the noise and vibration bench test. The scheme of gear modification was presented in order to achieve the purpose of reducing noise of transmission.

Introduction

With a four-speed automatic mechanical transmission of a type of electric bus, this paper utilizes finite element combined with boundary element model for the transmission system under the excitation of gearbox vibration and noise. The noise is identified by vibration test, the improvement is proposed to reduce the noise of the transmission.Organization of the Text.

Analysis of gearbox body vibration and noise simulation

The process of vibration and noise simulation is shown in Fig.1.

Model analysis of the body

Import the 3D model into Hypermesh, and the tetrahedral element was used for meshing. The finite element model and orientation definition of the box under free mode are shown in Figure 2.

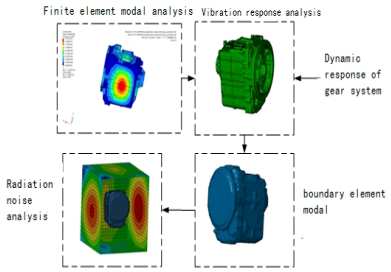

Fig 1 The process of vibration and noise simulation

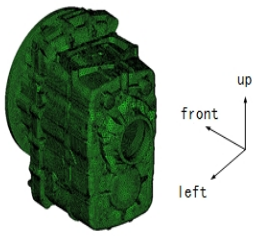

Fig 2 Finite element model and orientation definition of the body

Noise analysis of the transmission was done, take the first-ten-step frequencies, the vibration mode is shown in Figure 3, and the modal contrast analysis is shown in Table 1.

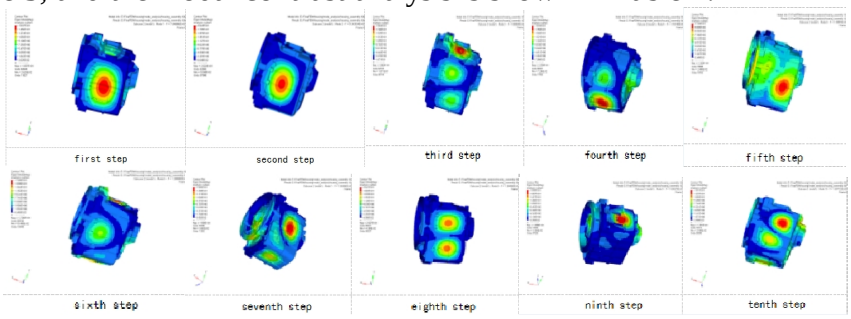

Fig 3 the first-ten-step frequencies of the body

Table 1, Analysis of the first-ten-step frequencies

Modal	Frequency(Hz)	Modal shape
first	754.7	Bending vibration, The displacement of the middle position on two sides of the box body is larger.
second	934.3	Bending vibration, The displacement of the middle position on two sides of the box body is larger. Contrary to the vibration direction of the first mode.
third	1082.6	On the side of the box body displacement is large
fourth	1118.1	The lower side of the box vibration displacement is larger
fifth	1159.9	Box body's left and right vibration displacement is larger
sixth	1285.9	The upper and lower sides of the box vibration displacement is larger
seventh	1363.6	Box body's left and right vibration displacement is larger
eighth	1384.1	Bending vibration, The vibration displacement near and below the box body is larger and the vibration direction is opposite.
ninth	1526.3	The local vibration on the side of the box
tenth	1597.7	Torsional vibration

The left and right sides ,upper and lower sides of the body are weak parts,by improving the structure of the body, the natural frequency of the gearbox can be avoided as far as possible to the frequency range of the transmission.

Analysis of the transmission-body-surface vibration simulation

The body's finite element model was imported into LMS.Virtual.Lab, the material properties and boundary conditions of gearbox were defined, and the Nastran solver was used to solve the transmission constraint mode. The vibration response signal of the bearing seat was taken as the excitation of the box vibration response analysis, and the vibration response was analyzed in LMS.Virtual.Lab .

Transmission noise prediction based on acoustic boundary element method

The finite element model of transmission box structure was imported into LMS Virtual. Lab software, and established the boundary element model of transmission,shown in Fig 4.

By setting the point grid in the sound field to view the specified location in LMS Virtual. Lab,shown in Fig 5.

Fig 4 boundary element model of the body

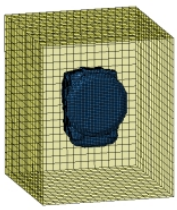

Fig 5 The grid point model

Mostly,the radiation noise of the left and right sides of the box is larger, and the radiated noise of the upper and lower sides of the box is also higher.The radiated noise of transmission is affected by the vibration characteristics of the gear system and the inherent characteristics of the body.

Transmission vibration and noise test

This experiment analysed the overall noise level of the transmission, to study the noise effect of different conditions on the transmission, vibration and noise processing of bench test data, according to the source of spectrum analysis and order analysis method to identify the transmission of vibration and noise.

Transmission vibration noise bench test

The experiment was carried out in the semi anechoic room, which consisted of input motor, measured transmission, output shaft, rear axle, speed up box and load motor.

Analysis of the transmission-noise-test results

Record the maximum value of the noise during the test.According to the results of transmission noise test, the noise level of transmission was analyzed, and the radiation noise characteristics of gearbox were studied.

Change the input speed of the transmission, record the noise data of three measuring points, and test results of 1 test point is shown in Fig 6.

The noise test results of each block increase with the increase of rotating speed, and with the increase of the gear position, the noise is bigger, and the fourth gear noise is the largest at the same speed.

The test results in this paper are only the third gear for different measuring positions and different input torque, the no-load noise test results and the input torque to the noise test of 400Nm three measuring points of the results are shown in Figure7 and Figure 8.

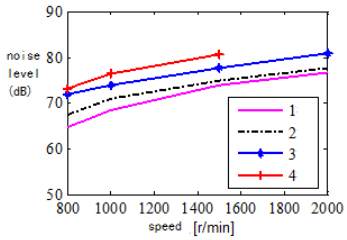

Fig 6 Comparison of noise in each gear

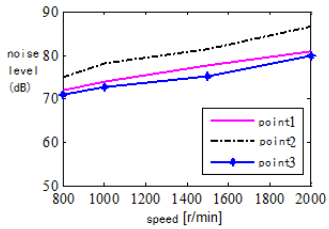

Fig 7 noise change with speed at no-load

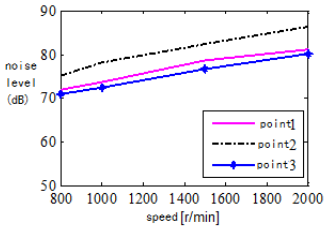

Fig 8 noise with speed in 400Nm

With the increase of speed, the noise test results of each measuring point increases gradually, and the 2 sound level meter results were larger than the other two points, 3 sound level meter results measured minimum radiation noise of gearbox which is less than the left and right sides of the radiation noise.The input torque has little effect on the transmission noise test results.

Analysis of the test results and identification of vibration and noise sources

Take lifting speed test for each gearbox under different input torque, The transmission constant mesh gear pair is 24 order, the order of the amplitude of acceleration is three times and four times of the constant gear, it can be preliminarily determined that the acceleration caused by the constant mesh gear is higher.

The output-shaft-bearing-seat acceleration sensor collected Y direction acceleration amplitude under 400 Nm is shown in Figure 9.

According to the analysis of the vibration and noise test results, it can be seen that the main reasons of the excessive noise of the transmission are the following two: the meshing vibration and the resonance of the body.

Input torque was 400Nm, input speed was 1500r/min, the output shaft bearing seat near the body surface node vibration simulation results (shown in Figure 10) and test results were compared.The simulation results show that the frequency of acceleration peak coincides with the experimental results, which verifies the correctness of the vibration simulation analysis method.

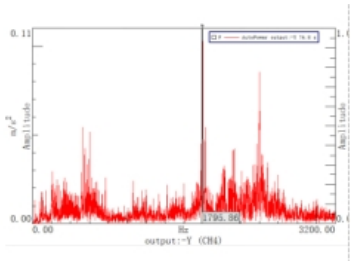

Fig 9 Acceleration spectrum on Y direction under 400Nm

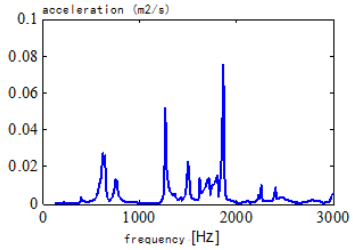

Fig 10 Variation of noise with speed in 400Nm

Study on vibration and noise reduction of transmission

This paper improves the gear transmission system by means of gear modification, so as to improve the whole noise level of the transmission.The gear after modification is shown in Fig 11.

Fig 11 constant-meshing-gear-pair practicality picture after modification

As shown in Fig 12-15, after modification, the noise of each gear is reduced in different degrees.

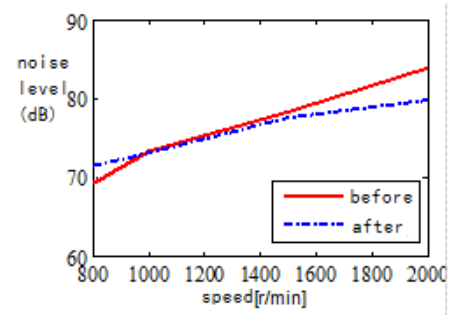

Fig 12 Noise contrast before and after improvement of first

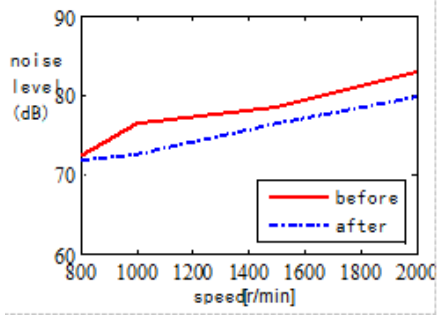

Fig 13 Noise contrast before and after improvement of second

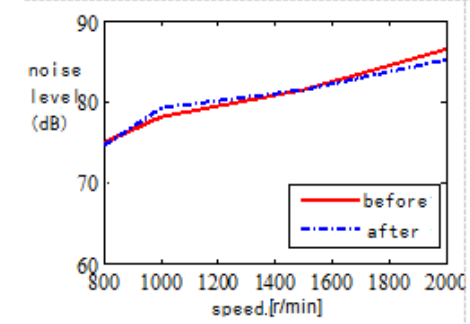

Fig 14 Noise contrast before and after improvement of third

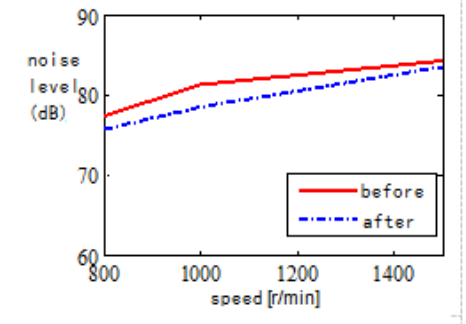

Fig 15 Noise contrast before and after improvement of fourth

Conclusions

Research on mechanical automatic transmission of electric bus, and The vibration and noise characteristics of transmission are simulated by finite element method and boundary element method, The results show that the noise is radiated from the left and right sides of the body, The position of the radiation noise is related to the position of the body's natural vibration mode , The natural vibration mode of the body has a great influence on the radiation noise characteristics of the transmission. The vibration and noise sources of the transmission are resonance of constant meshing gear pair and body identified by the vibration noise test, a scheme for modification of continuously meshing gear pair is put forward, and the test of the gearbox after modification shows that the improved scheme can effectively reduce the transmission noise.

Acknowledgments

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