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Vibration Noise Analysis of Double Power Washing Machine Reducer

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Abstract

In order to predict the vibration and whistling noise of the dual-power washing machine reducer, the three-dimensional model of the reducer gear train is constructed separately using Romax software, and the transmission error of the gears and the vibration response of the gears, bearings and reducer housing under the transmission error excitation are simulated. The shell vibration displacement is defined as the solved boundary condition, and the boundary element mesh model of the reducer shell is established by using LMS Virtual.Lab Acoustics software to perform acoustic simulation. The results show that the maximum sound pressure of the reducer is 88.3 dB, which affects the user's laundry experience.

Keywords

Reducer; Gears;Vibration and Noise; Acoustic simulation.

1. INTRODUCTION

In recent years, the quality of washing machines has become more and more demanding. In the traditional washing machine, the washing wheel drives the clothes and water in the washing machine to make directional rotation in order to achieve the purpose of washing clothes, but when the clothes are rotated in one direction, they are particularly easy to be knotted and tangled together, which leads to a poor washing effect. In order to achieve better laundry effect, the dual-powered wave washer was born. Dual-powered means that the wave wheel and the inner tube rotate in two different directions to produce a similar "rubbing" effect on the clothes during the washing process, and the cleanliness is higher than that of the wave washer.

The reducer is the most important device for transferring power between the motor and the inner drum and the wave wheel of a dual-power washing machine, which has the problem of violent vibration and high noise [1,2]. Scholars have studied the vibration reduction of the liquid balance ring and boom of the wave washer [3, 4,5], and no scholars have yet conducted vibration and noise reduction studies specifically for the gearbox of the washing machine reducer. The prediction methods of gearbox vibration noise mainly include empirical formula method [7] and numerical method, which in turn includes finite element method (FEM) [6], boundary element method (BEM) [8], FEM/BEM [9,10] and statistical energy method (SEA) [11， 12].

In this paper, the research object is the reducer of a brand-developed dual-powered wave washer, which is predicted by noise simulation because of its vibration and whistling noise that affects user experience during washing. The dynamic response of the reducer structure is first analyzed using the FEM/BEM method, and then the shell vibration displacement is used as the boundary condition for acoustic analysis using the boundary element method.

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2. MODEL OF THE REDUCER

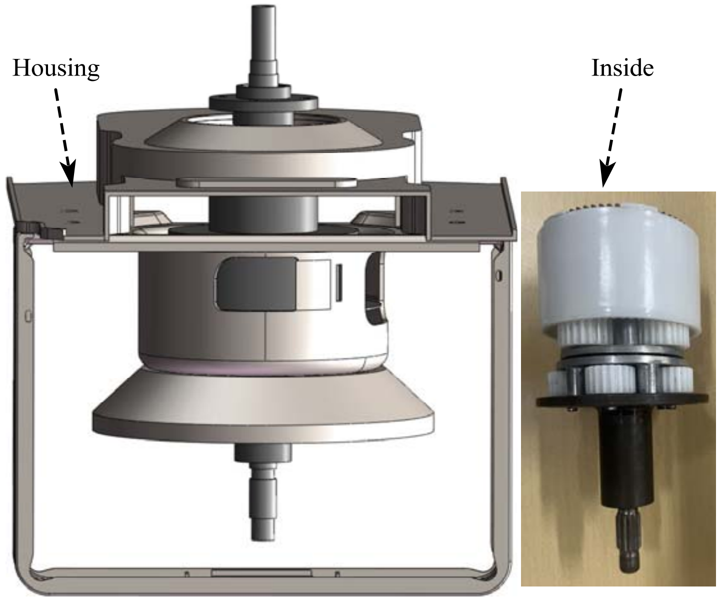

Figure 1. 3D model of the reducer

Clothes machine reducer uses two planetary wheel system in tandem with the secondary reducer of the composite wheel system. As shown in Figure 1, the use of the galaxy wheel system in the reducer is to take advantage of the planetary wheel system is compact and has a large ratio, can withstand a large load; can be converted from a single unidirectional input into simultaneous, coaxial bidirectional output and other advantages.

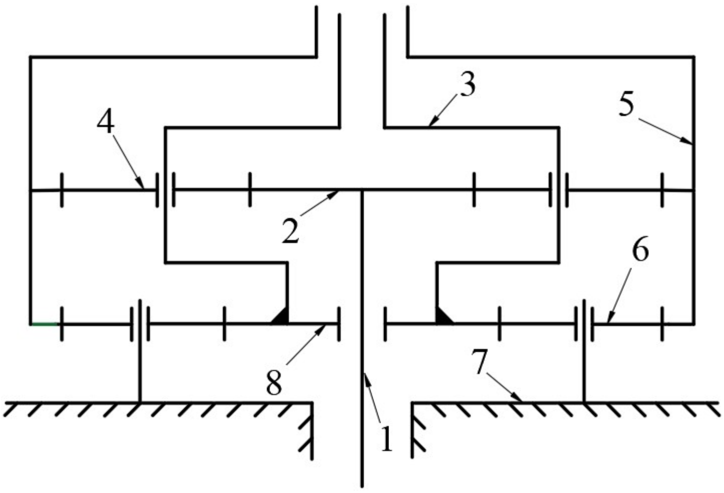

Figure 2. Transmission principle

The transmission route is shown Figure 2, and the low speed stage planetary frame is fixed at all times during laundering. The output (1) is rotated by the input shaft 1 by driving the high speed stage sun wheel 2 (HS) to drive the high speed stage planetary gear 4 (HP), and the high speed stage planetary wheel 4 (HP) to drive the 3 high speed stage planetary frame. The upper end of the low speed stage sun wheel 8(LS) is connected to the lower end of the high speed stage planetary frame 3 made into internal spline, and the high speed stage planetary frame 3 drives

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the low speed stage sun wheel 8(LS) to rotate, while the high speed stage planetary frame 3 drives the washing machine wave wheel to rotate; the output (2) is driven by the low speed stage sun wheel 8(LS) to rotate the low speed stage planetary wheel 6(LP), and the low speed stage planetary wheel 6(LP) drives the gear ring 5(R) rotates, and the gear ring 5(R) drives the inner drum of the washing machine.

Washing machine reducer gear material parameters are shown in Table 1.

Table 1. Macro parameters of speed reducer

Parameters	High speed grade		Ring	Low speed grade	
	Sun gear	Planetary wheel		Sun gear	Planetary wheel
Number of teeth	19	23	65	27	19
Modulus			1		
Pressure angle			20		
Number of planetary wheels	4			5	
Transmission ratio	5.842			-14.065	

3. VIBRATION RESPONSE ANALYSIS OF THE HOUSING

As shown in Figure 3, according to the actual parameters of the reducer model to establish its rigid-flexible coupling model, the shell for dynamic condensation treatment, according to the needs of the study of vibration noise, the condensation frequency range is set at 0-1200Hz. motor input speed 650 RPM, input power 200 W.

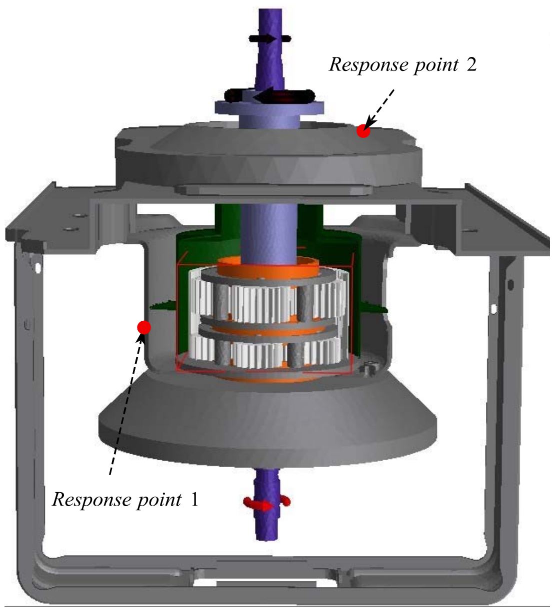

Figure 3. Planetary wheel distribution

3.1. Transmission error analysis

Transmission error is one of the main factors affecting gear vibration noise, the greater the transmission error, the more violent the vibration generated by the gear in the transmission process, the greater the accompanying whistling noise. The theoretical expression of dynamic transmission error is:

$$DTE = R_p\theta_p(t) - R_g\theta_g(t) \tag{1}$$

Where DTE is the dynamic transmission error; $\theta_i(t)(i = p,\mathrm{g})$ is the torsional vibration displacement; $R_i(t)(i = p,\mathrm{g})$ is the radius of the master and driven wheel pitch circle.

Double power washing machine reducer gear set as an example, using Romax software transmission error analysis module under rated conditions before and after the optimization of meshing gear simulation analysis of transmission error is shown in the following Figure 4.

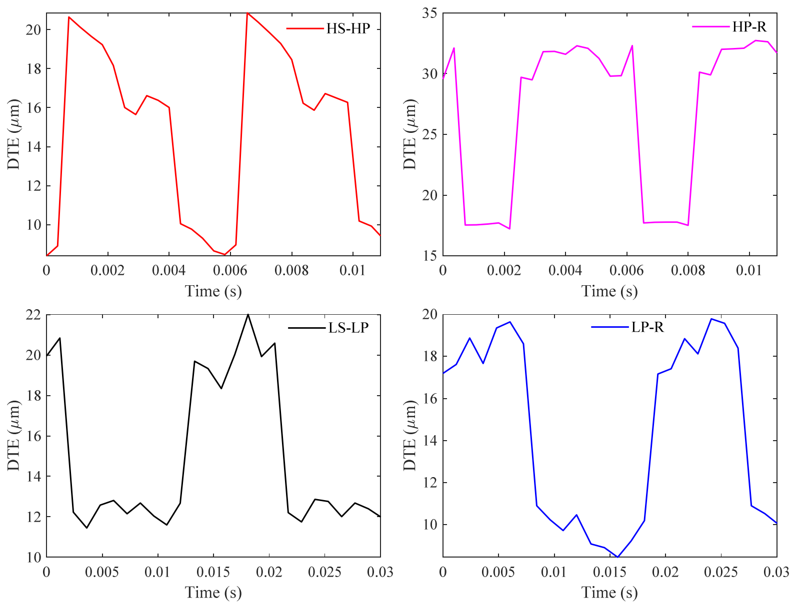

Figure 4. Time domain diagram of DTE

The transmission error of the reducer is shown in the figure. The meshing transmission error range of the high speed sun wheel and high speed planetary wheel is 8.4μm--20.65μm, and the amplitude is 12.25μm. The meshing transmission error interval of the high speed level planetary wheel and gear ring is 17.23μm--32.29μm with an amplitude of 15.06μm. The meshing transmission error interval of the low speed level sun wheel and low speed level planetary wheel is 11.45μm--22.01μm with an amplitude of 10.56μm. The meshing transmission error interval of the low speed level planetary wheel and gear ring is 8.45 μm--1978μm, the amplitude is 11.33μm. The transmission error is too large, causing the washing machine vibration.

3.2. Acceleration analysis of the housing

The reducer produces vibration noise under excitation, and this noise is mainly propagated through the shell structure so the simulation shell vibration response can present and predict the reducer noise situation. Through the established reducer simulation model, the response points on the shell are shown, and the transmission error is introduced into the dynamic response analysis as internal excitation, and the vibration acceleration of the 2 response points on the reducer shell is obtained as shown in Figure 5.

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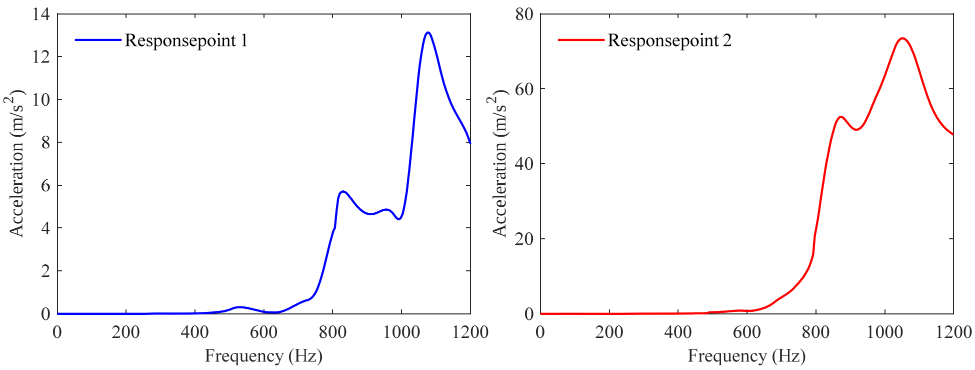

Figure 5. Housing vibration acceleration

The acceleration of the response point of the shell at low frequencies are almost 0. The acceleration response point 1 appears at 826Hz with a peak of 5.68 N and 1070Hz with a peak of 13.01 N. The acceleration response point 2 appears at 879Hz with a peak of 52.31 N and 1052Hz with a peak of 73.46 N. The response point 2 is closer to the output bearing, so the acceleration of the response point 2 is too large. More softy causes the box vibration.

4. ACOUSTIC SIMULATION ANALYSIS

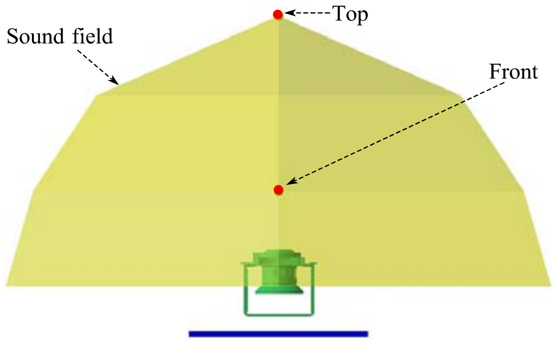

Figure 6. Acoustic boundary element model

The vibration response of Romax was exported as boundary conditions to Acoustics, an acoustic simulation module in LMS Virtual. Lab, and the acoustic radiation simulation of the reducer shell was analyzed using the acoustic boundary element method. A hemispherical ISO field point mesh model is used and a symmetry plane is defined directly below the reducer for simulating the ground with total reflection. The established complete acoustic simulation model is shown in Figure 6.

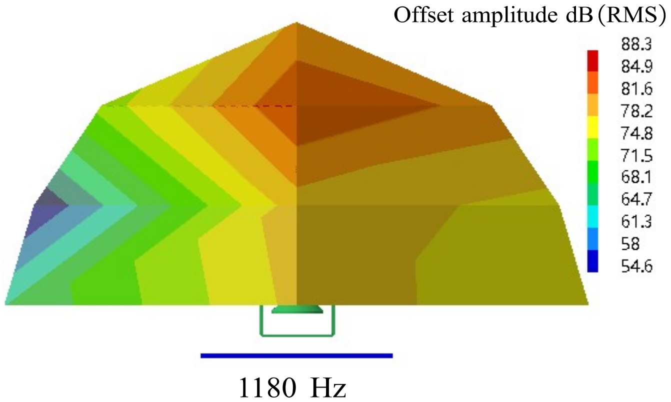

Figure 7. Radiation noise cloud map

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The maximum sound pressure amplitude of the sound field is shown in Figure 7, the maximum frequency of the average radiation noise of the reducer appears at 1180Hz, the maximum sound pressure at this frequency reaches 88.3dB, and the maximum sound pressure appears in the above the front of the sound field.

5. CONCLUSION

Simulation of the shell vibration response under the transmission error excitation using Romax, the results show that the case vibration acceleration is too large, causing the vibration of the reducer affects the user experience, and the acoustic simulation using LMS Virtual.Lab Acoustics, the results show that the maximum sound pressure of the shell 88.3Db, the noise is too large to affect the user experience, and the design of the reducer should be optimized.

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