Research of ArtemiS in a Ring-Plate Cycloid Reducer

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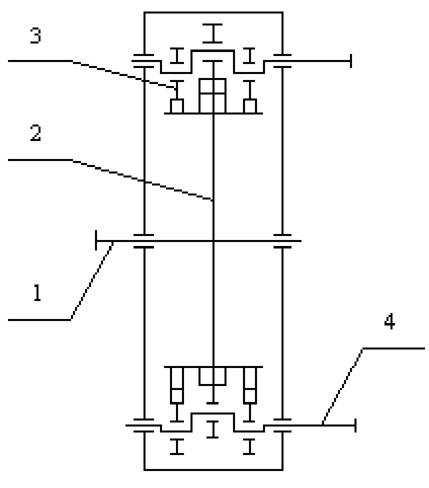
***Abstract*—The noise and vibration of a ring-plate pin-cycloid gear reducer driven by two motors are measured respectively at different rotational speeds and different loads. The data are collected and analyzed using the HEAD acoustics multi-channel noise test and analysis system. The ArtemiS is a set of analysis system for improving product quality in all areas of sound and vibration. From the frequency spectrum analysis, we can draw the following conclusions: The vibration acceleration of input shaft of X direction increase with the rotational speed and loads goes up. The vibration acceleration of input shaft of Z direction doesn't vary much with the rotational and loads vary. The vibration acceleration of output shaft of Z direction doesn't vary much with the rotational and loads vary. The vibration acceleration of input shaft of X direction increase with the rotational speed and speed goes up. When the rotational speed is certain, the sound pressure level curves have basically the same variation trends. The loudness increases as the speed goes up. The loudness mainly concentrates on low frequency bands. The sharpness decreases as the speed goes up.**

***Index Terms*—ring-plate cycloid gear reducer; ArtemiS; noise**

I. Introduction

Noise pollution, water pollution and air pollution are the world's three major environmental pollution problems. Mechanical noise becomes one of the main noise sources with the development of the industry. The mechanical noise hazards on the human body are various. Noise can cause ear discomfort, such as tinnitus, hearing loss, sleep disturbances and other harmful effects. According to clinical statistics, if people work and live in high noise environment chronically, they are easily to get deafness. Noise can reduce efficiency. The study found that noise can make people feel upset and they can not concentrate on their work. Noise can also cause nervous system disorders such as mental disorders, endocrine disorders or even the accident rate increased. Noisy environment make people dizziness, headache, insomnia, dreaminess, malaise, memory loss and fear, irritability, low self-esteem and even insanity. Noise can harm children's physical and mental health. According to statistics, in today's world there are more than 70 million deaf, a considerable part of which is caused by the noise.



1. output shaft 2. cycloid gear
3. ring-plate with pin gear 4. input shaft

Figure 1. Transmission sketch of the Ring-Plate Cycloid reducer

A ring-plate-type cycloid gear reducer driven by two motors provides more advantages, including low volume, light weight, a high reduction ratio, smooth transmission and so on[1-3]. The transmission sketch diagram of the ring-plate-type cycloid gear reducer is shown in Fig. 1[4].

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Two input shafts are driven by two motors respectively. The ring-plates mounted on the input shaft rotate and the cycloid gear rotates, then the output shaft rotates. At present, the noise and vibration study of the ring-plate-type cycloid reducer need to be studied. Some studies of the ring-plate type reducer and planetary gear reducer have been done[5-7]. However, the noise of the double

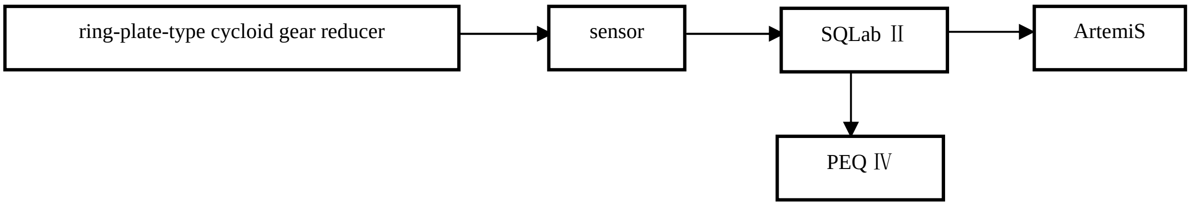

Figure 2. Data collection and analysis process

crank ring-plate-type cycloid reducer hasn’t been studied. In this paper, the noise and vibration tests of the ring-plate-type cycloid gear reducer are made and the vibration and noise characteristics of ring-plate-type cycloid gear reducer are obtained.

II. Test Content

A.. Test Equipments

The HEAD acoustics multi-channel noise test and analysis system is selected for the measurement. The system is made of SQLab Ⅱ data acquisition recorder, HMS Ⅲ artificial head, PEQ ⅣDigital Equalizer, Microphones and acceleration sensors, ArtemiS software and so on[6]. The SQLab Ⅱ data acquisition recorder is a multi-channel analog and digital I/O front end with a variety of available conditioning. The HMS Ⅲartificial head is a stand-alone, mobile measuring device that is ready to perform aurally accurate binaural recordings immediately after powering up. The programmable equalizer PEQ Ⅳ provides the highest quality reproduction of aurally-accurate recordings. The data collection and analysis process of the HEAD acoustics multi-channel noise test and analysis system is shown in Fig. 2.

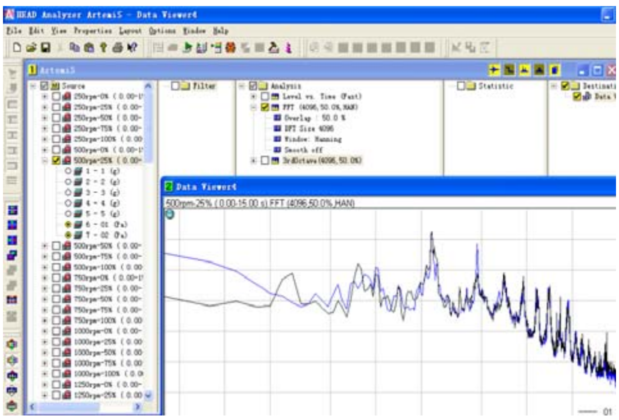

Figure 3. Interface of Artemis

The ArtemiS is the abbreviation of Advanced Research Technology for Measurement and Investigation of Sound and Vibration. The ArtemiS is a recording, analysis and playback software, which was developed to deal with tasks in the field of sound and vibration quickly and efficiently. Simultaneous listening, analyzing and interactive filtering is of vital importance when using ArtemiS. The ArtemiS improves and expedites your testing process. Its intuitive interface and ease of use allow for a quick test configuration and analysis. A analysis interface of ArtemiS is shown in Fig. 3.

B. Test Setup and Recording

For the measurement of noise, a microphone is placed vertically 1m above the reducer, a microphone is placed horizontally 1m away from the reducer.

Four vibration test points were positioned in the test procedure. The location of the vibration test points is shown in Fig. 4. The detail information of test points is shown in Table I.

TABLE I.
Test point location explanation

Point name	Test point location
1	On the reducer, near the input shaft(X direction)
2	On the reducer, near the output shaft(Z direction)
3	On the reducer, near the output shaft(X direction)
4	On the reducer (Z direction)
01	Noise test, 1m vertically above the reducer
02	Noise test, 1m horizontally away from the reducer

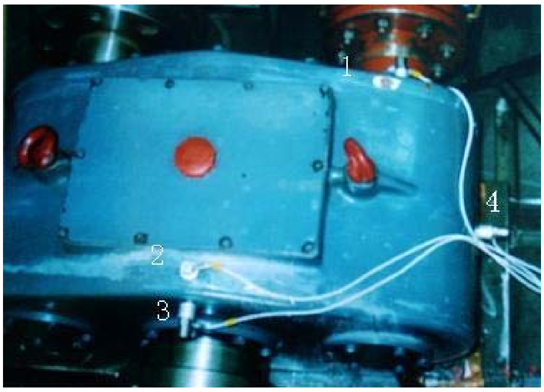

Figure 4. Test point location

III. TEST RESULTS AND ANALYSIS

A. Modal Analysis of Main Parts

The motion differential equation for the ring-plate pin-cycloid gear reducer system can be expressed as

$$[M]\{\ddot{x}(t)\}+[C]\{\dot{x}(t)\}+[K]\{x(t)\}=\{F(t)\} \quad (1)$$

Here, [M] is mass matrix; [C] is damping matrix; [K] is stiffness matrix; {x} is displacement vector; { $\dot{x}$ } is velocity vector; { $\ddot{x}$ } is acceleration vector; and {F} is excitation vector[8,9].

Let $\{x\}=[\varphi][q]$, $[\varphi]$ is vibration mode matrix, [q] is modal matrix, the equation (1) can be expressed as:

$$\left([K]-w^2[M]+j\omega[C]\right)[\varphi][q]=\{F\} \quad (2)$$

Thus, the vibration characteristics of the parts can be obtained through the equation (2), including the natural frequencies and the corresponding vibration modes. The three dimensional model of the cycloid gear of the reducer is established and the meshing of the cycloid gear is shown in Fig. 5.

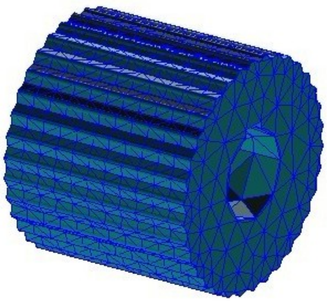

Figure 5. Meshing of cycloid gear

The modality analysis is carried out on the three model by the use of ANSYS. The order of the extracted of modal is 10 and the method of the extracted is block Lanczos. The first five order nature frequencies of cycloid gear are shown in Table Ⅱ. The first order vibration model of the cycloid gear is shown Fig. 6.

TABLE Ⅱ.
NATURAL FREQUENCY OF CYCLOID GEAR

order	1	2	3	4	5
f[Hz]	357	515	824	1565	1826

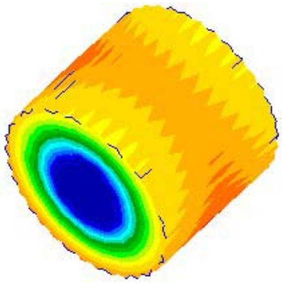

Figure 6. Vibration model of cycloid gear

B.Noise Frequency Spectrum Analysis

Table Ⅲ shows the sound pressure level of different work conditions. Fig. 7 shows the noise frequency spectrum diagram at 500 rotations per minute of test point 01 under the loads of 50%, 70% and 80% of the full load. Fig. 8 shows the noise frequency spectrum diagram at 750 rotations per minute of test point 01 under different loads. Fig. 9 shows the noise frequency spectrum diagram at 1000 rotations per minute of test point 01. Fig. 10 shows the noise frequency spectrum diagram at 500 rotations per minute of test point 02. Fig. 11 shows the noise frequency spectrum diagram at 750 rotations per minute of test point 02.

TABLE Ⅲ.
SOUND PRESSURE LEVEL

Rotation speed	load	SPL of test point 01 /dB(A)	SPL of test point 02 /dB(A)
500	50%	69.1	68.0
500	70%	69.9	68.9
500	80%	70.4	69.8
750	50%	74.7	73.0
750	75%	75.6	74.5
750	80%	76.0	75.0
1000	50%	77.3	76.2
1000	70%	78.0	76.9
1000	80%	79.2	78.2

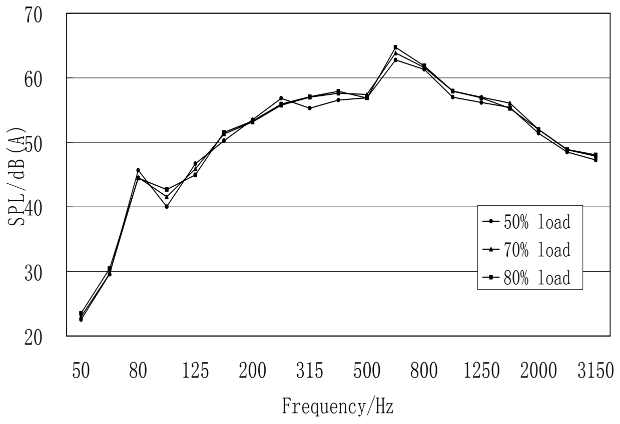

Figure 7. Spectrum diagram of different loads at the speed of 500r/min of test point 01.

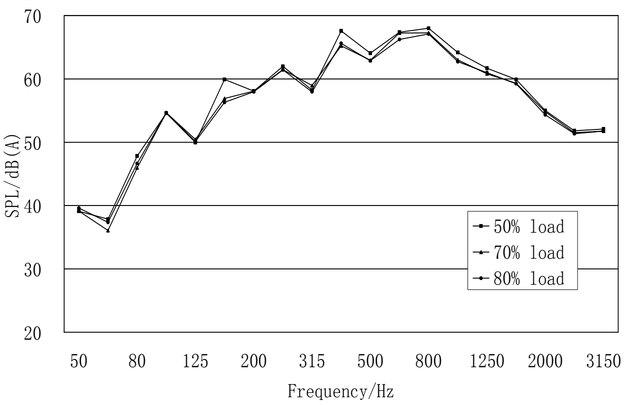

Figure8. Spectrum diagram of different loads at the speed of 750r/min of test point 01.

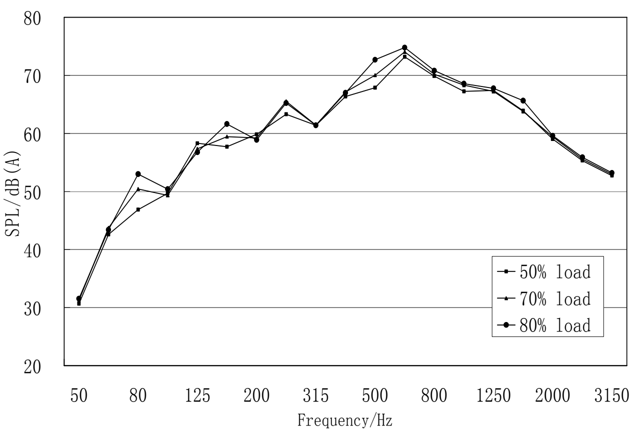

Figure 9. Spectrum diagram of different loads at the speed of 1000r/min of test point 01.

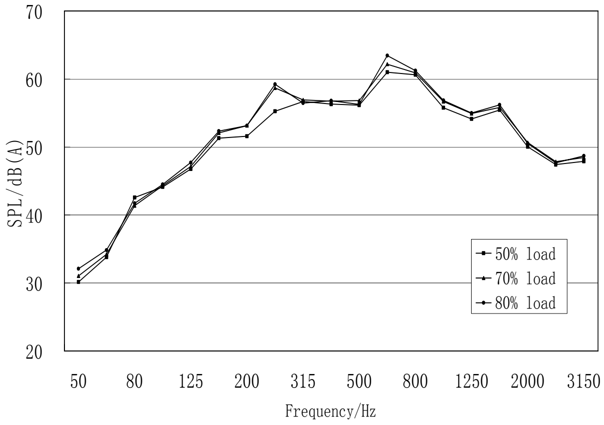

Figure 10. Spectrum diagram of different loads at the speed of 500r/min of test point 02.

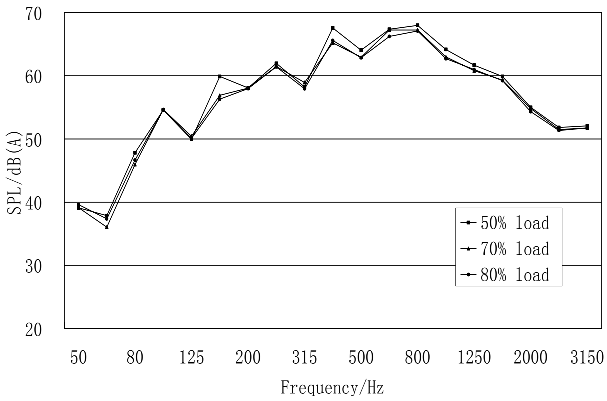

Figure 11. Spectrum diagram of different loads at the speed of 750r/min of test point 02.

From the above diagrams, we can know the followings. When the rotational speed is certain, the sound pressure level curves have basically the same variation trend. At the speed of 500 rotations per minute, the main noise frequency band of test point 01 is from 500 to 1250Hz. At the speed of 750 rotations per minute, the main noise frequency band of test point 01 is from 400 to 1250Hz. At the speed of 1000 rotations per minute, the main noise frequency band of test point 01 is from 400 to 1600Hz. The sound pressure level of test point 01 is a little bit bigger than that of mic02. The trend of test point 02 sound pressure level is basically same as that of 01. The sound pressure level of the two test points goes up with the increase of the rotational speed.

C. Vibration Frequency Spectrum Analysis

Fig. 12 to 15 shows the vibration frequency spectrum diagram at 750 rotations per minute of test point 1,2,3,4 under the loads of 50%, 70% and 80% of the full load. When the rotational speed is certain, the trends of vibration acceleration curves are basically with the changing of load. The peak frequencies are basically the same, but the peak values vary.

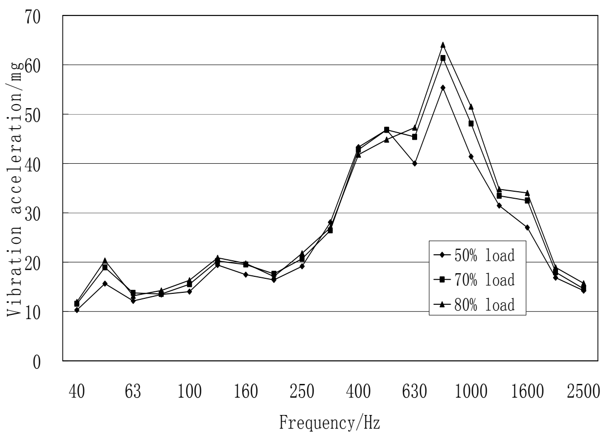

Figure 12. Spectrum diagram of different loads at the speed of750r/min of test point 1.

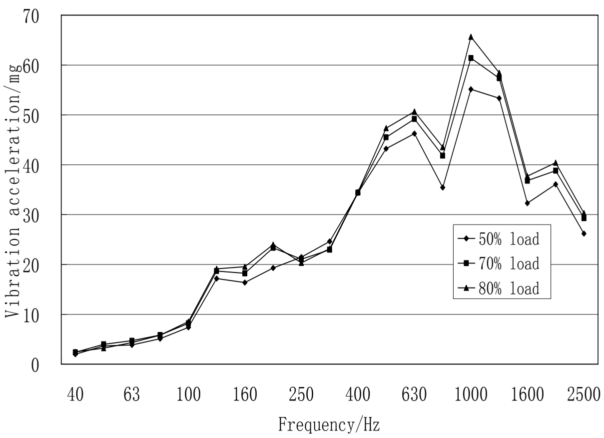

Figure 13. Spectrum diagram of different loads at the speed of 750r/min of test point 2.

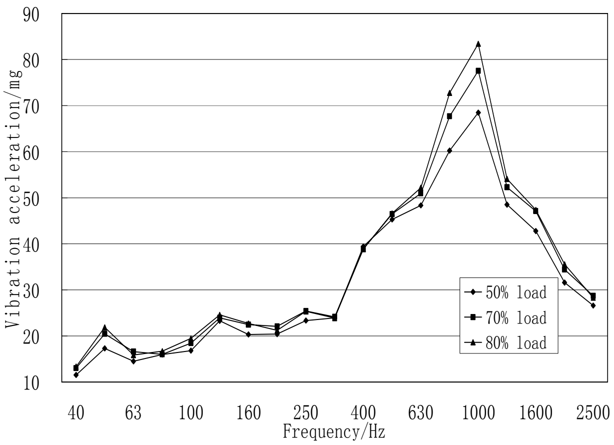

Figure 14. Spectrum diagram of different loads at the speed of 750r/min of test point 3.

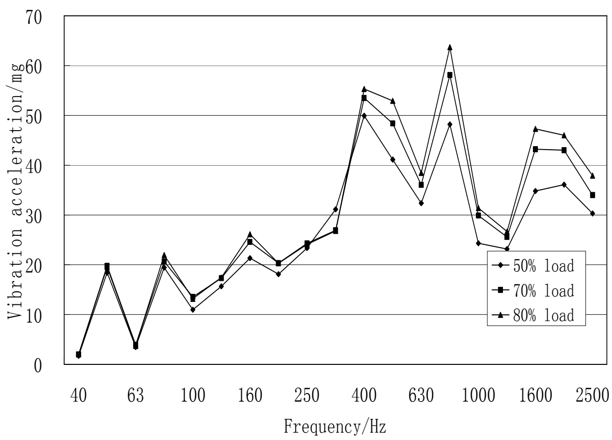

Figure 15. spectrum diagram of different loads at the speed of 750r/min of test point 4.

From the above diagrams, we can know the followings. The vibration acceleration of input shaft of X direction increase with the rotational speed and loads goes up. The vibration acceleration of input shaft of Z direction doesn't vary much with the rotational and loads vary. The vibration acceleration of output shaft of Z direction doesn't vary much with the rotational and loads vary. The vibration acceleration of input shaft of X direction increase with the rotational speed and speed goes up.

D. Sound Quality Analysis

From the above analysis, we found that the sound pressure level of the ring-plate pin-cycloid gear reducer is not too high but the people around the reducer still feel uncomfortable. So, the feeling of people should be taken into consideration besides sound pressure level. That is, psychoacoustics analysis is necessary. Psychoacoustics is the scientific study of sound perception. More specifically, it is the branch of science studying the psychological and physiological responses associated with sound. There are many aspects in psychoacoustics field such as loudness, sharpness, fluctuation strength, roughness and etc..

Loudness is the attribute of auditory sensation in terms of which sounds can be ordered on a scale extending from quiet to loud. Loudness analysis can lead to more precise results than magnitude estimations. For this reason the loudness level is calculated. Loudness can be expressed as[10]

$$N = \int_0^{24} N' dz \qquad (3)$$

Where N' is specific loudness which can be expressed as

$$N' = 0.08\left(\frac{E_{TQ}}{E_0}\right)^{0.23}\left[\left(0.5 + 0.5\frac{E}{E_{TQ}}\right)^{0.23} - 1\right] \qquad (4)$$

Where E_{TQ} is the excitation at threshold in quiet and E_0 is the excitation that corresponds to the reference intensity $I_0 = 10^{-12}$ W/m^2.

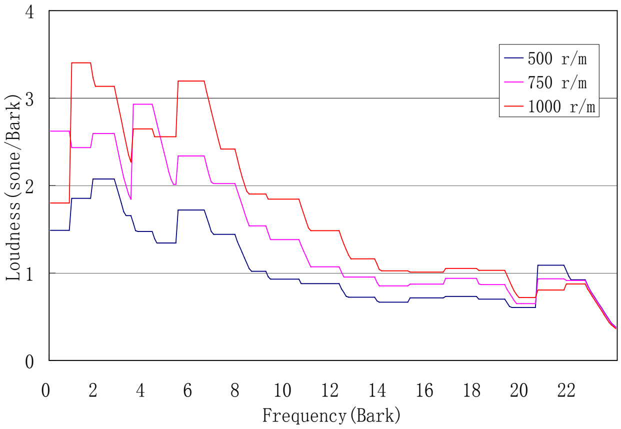

Figure 16. Point 01 loudness of different speeds at 50% load.

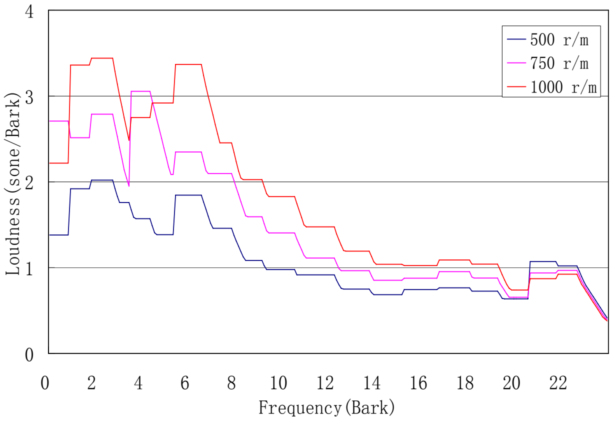

Figure 17. Point 01 loudness of different speeds at 70% load.

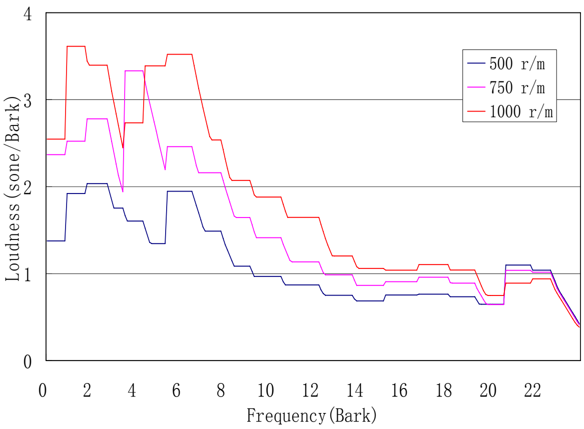

Figure 18. Point 01 loudness of different speeds at 80% load.

Fig. 16 to 18 shows the loudness of test point 01 at different speeds under the loads of 50%, 70% and 80% of the full load. From the diagrams, we can know the followings. The loudness of test point 01 increases as the speed goes up. The loudness mainly concentrates on low frequency bands. The trends of three diagrams are basically same.

Sharpness is a sensation which can be considered separately, and it is possible, for example, to compare the sharpness of one sound with the sharpness of another. One of the important variables influencing the sensation of sharpness is the spectral contents. The Sharpness can be expressed as[7]

$$S = 0.11 \frac{\int_0^{24} N'(z)g(z)dz}{\int_0^{24} N'(z)dz} \qquad (5)$$

Where S is the sharpness to be calculated and the denominator gives the total loudness N which has already been calculated.

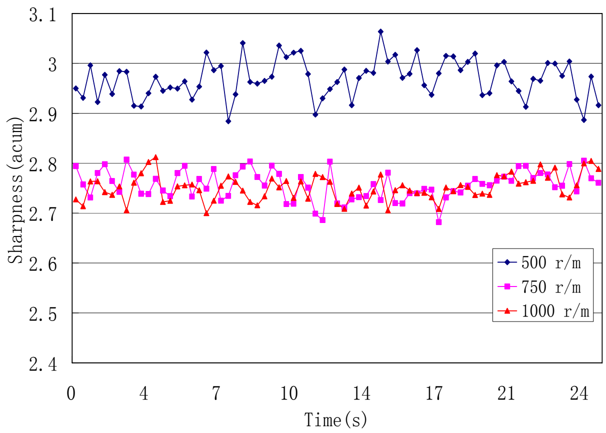

Figure 19. Point 01sharpness of different speeds at 50% load.

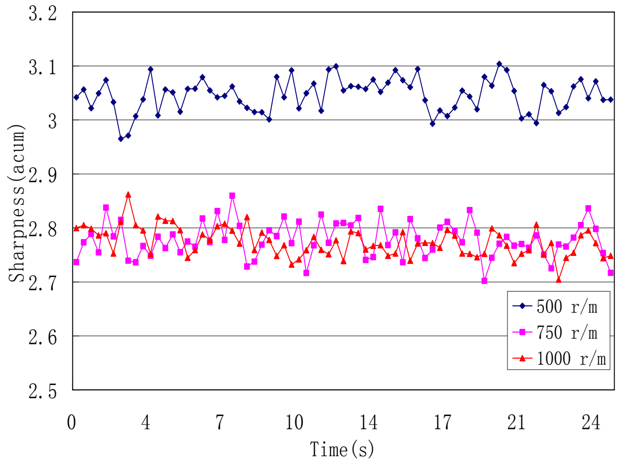

Figure 20. Point 01sharpness of different speeds at 70%load.

The sharpness of test point 01 at the speed of 500 rotations per minute is higher than that of 750 rpm and 1000 rpm, which is very different from the trends of the sound pressure level and vibration acceleration. The trend of sharpness curves of test point 01 at the speed of 750 rpm is basically same as that of 1000 rpm. The sharpness of the test point 01 at the speed 500 rpm is 3.02 acum. The sharpness of the test point at the speed 750 rpm is

2.78 acum. The sharpness of the test point 01 at the speed 500 rpm is 2.77 acum.

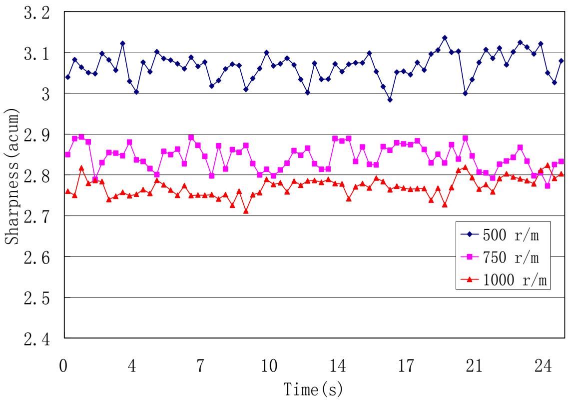

Figure 21. Point 01sharpness of different speeds at 80%load.

Fig. 19 to 21 shows the sharpness of test point 01 at different speeds under the loads of 50%, 70% and 80% of the full load. From the diagrams, we can know the followings. The sharpness of test point 01 decreases as the speed goes up.

IV. CONCLUSION

A ring-plate-type cycloid gear reducer is a new type reducer. The noise and vibration study of the reducer is very important. In this paper, the noise and vibration tests of the ring-plate-type cycloid gear reducer are made and the vibration and noise characteristics of ring-plate-type cycloid gear reducer are obtained. The three dimensional model of the cycloid gear of the ring-plate-type cycloid reducer with is established, the modality analysis are carried out on the model by the use of ANSYS. The natural frequencies and the corresponding vibration models of the cycloid gear are gained. The sound quality of the reducer is also analyzed.

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