Analysis and Research on Vibration Severity of Planetary Shifting Mechanism

Shenlong Li*, Qiang Zhang, Liang Li and Qingku Xing

Key Laboratory of vehicle transmission, China North Vehicle Research Institute, Beijing 100072, China

*Corresponding author e-mail: 15092148939@163.com, lishenlong2004@sina.com, angela19841022@sina.com, xingqingkun@163.com

Abstract. The vibration severity indicates the severity of the vibration and is usually expressed by the maximum, average or root mean square value of the displacement, velocity and acceleration that characterize the vibration level. In this paper, based on the calculation of vibration severity, the arrangement of test measuring points, the selection of typical working conditions and the analysis of test results, the vibration severity of planet Shifting mechanism is tested and studied, and the rating is completed according to the relevant evaluation method of national standard, which provides support for the vibration analysis of transmission device and the research and development of planet transmission mechanism.

1. Introduction

The vibration severity test of the planetary Shifting mechanism was carried out, and the test results were objectively analyzed, and the test plan and basic data were obtained [1]. Vibration severity is an important index to characterize and evaluate the vibration severity of transmission device [2]. Through the vibration acceleration test of the special design bench, the comprehensive dynamic response of the external excitation and the internal excitation of the target prototype is obtained comprehensively [3], and the vibration severity of the planet shifting mechanism is analyzed and evaluated [4].

2. Calculation method of vibration severity

The mechanical vibration severity refers to the total maximum mechanical vibration velocity in the selected frequency range (10~1000 Hz) calculated by the measured value in a selected position and direction under a certain working condition range. The root mean square value. The formula for calculating the vibration severity is as follows:

$$v_s = \sqrt{\left(\sum \frac{v_x}{N_x}\right)^2 + \left(\sum \frac{v_y}{N_y}\right)^2 + \left(\sum \frac{v_z}{N_z}\right)^2}$$

where:

- $v_s$ — vibration severity, unit: mm / s;
$v_{x}, \ v_{y}, \ v_{z}$ — the root mean square value of the vibration speeds of three mutually perpendicular directions of X, Y and Z, respectively: unit: mm/s;

$N_{x}, \ N_{y}, \ N_{z}$ — the number of measuring points in the X, Y, and Z directions, respectively.

If the measured signal is a vibration acceleration signal, the unit is mm/s², then the vibration severity in the frequency range $f_{a} \sim f_{b}$ is:

$$v_{rms} = \sqrt{\frac{1}{2} \sum_{k=1}^{N} \left( \frac{A_{k}}{2\pi f_{k}} \right)^{2}} = \frac{1}{\sqrt{2\pi f_{b}}} \sqrt{\sum_{k=1}^{N} \left( \frac{k}{N} \right)^{2}}$$

In the formula:

$A_{k}$ - Amplitude of vibration acceleration;

$f_{k}$ - Frequency.

The vibration severity calculated from multiple sensor measurements is:

$$v_{rms} = \left( \frac{\sum v_{rmsx}^{2}}{N_{x}} \right)^{1/2} + \left( \frac{\sum v_{rmsy}^{2}}{N_{y}} \right)^{1/2} + \left( \frac{\sum v_{rmsz}^{2}}{N_{z}} \right)^{1/2}$$

3. Planetary Shifting Mechanism test bench and measuring point arrangement

The vibration transmission test bench of the planetary Shifting Mechanism is composed of a driving motor, a speed increasing box, a planetary Shifting Mechanism box and a loading motor, and realizes driving and loading of the planetary shifting mechanism; The hydraulic station provides multi-way lubrication of the planetary shifting mechanism with 2.0Mpa operating oil pressure and different flow rates. The torque meter, rotation speed sensor and pressure sensor are used for torque, speed and pressure tests respectively.
The acceleration sensor for testing the vibration severity is arranged on the box of the planetary shifting mechanism, and the IMC acquisition system realizes the acceleration collection processing of the test point. The overall arrangement of the test gantry is shown in Fig. 1.

The Planetary Shifting Mechanism is installed and fixed in the box, the input end is connected with the speed increasing box, the output end is connected with the loading motor, the box realizes the fixing of the shifting mechanism, the sealing and the connection with other test function modules, the Planetary Shifting Mechanism and the package The box fixed connection relationship is shown in Figure 2.

Figure. 2 Location of the vibration severity measurement point of the planetary shifting mechanism

According to Fig. 3, four sensors are arranged outside the box of the Planetary Shifting Mechanism. According to the actual situation of the test site and the box, the type, direction and corresponding collecting channel of the sensor are determined as shown in Table 1.

| Serial number (Analytical adoption) | Sensor label | Sensor type | direction | Corresponding position | Corresponding acquisition channel |
|------------------------------------|--------------|-------------|-----------|------------------------|-----------------------------------|
| 1                                  | 1#z          | Three-way   | -X        | Pedestal               | 3                                 |
| 2                                  | 1#y          | -Y          | 2         |                        |
| 3                                  | 1#x          | -Z          | 1         |                        |
| 4                                  | 2#           | One-way     | -X        | 4                      |
| 5                                  | 3#           | One-way     | +Y        | 5                      |
| 6                                  | 4#x          | Three-way   | +X        | 8                      |
| 7                                  | 4#y          | -Y          | 9                      |
| 8                                  | 4#z          | -Z          | 10                     |

4. Vibration severity test, calculation and rating

4.1. Development of test conditions
According to the power of the test bench and the ability of the loading motor, combined with the technical index of the prototype of the Planetary Shifting Mechanism, the vibration severity test condition of the Planetary Shifting Mechanism is determined. For the five forward gears and one reverse gear of the prototype, the no-load tests are carried out at the input speed of 1500, 2000, 2500, 3000rpm, and two kinds of loading tests are carried out when the input speed is 1500, 2500, 3000rpm, covering the common and extreme operating conditions of the prototype.

4.2. Vibration severity test calculation results
Through the vibration acceleration test, the vibration acceleration of each test point is obtained, and the calculation of the vibration severity is obtained according to the formula of the vibration severity, and the vibration severity calculation results under 60 working conditions are obtained, as shown in Table 2.
Table. 2 Calculation results of vibration severity of 60 kinds of working conditions of test prototype

| Seria | Working condition name | Vibration severity mm/s | Seria | Working condition name | Vibration severity mm/s |
|-------|------------------------|-------------------------|-------|------------------------|-------------------------|
| 1     | First gear _1500rpm 0Nm | 1.10                    | 31    | Fourth gear _1500rpm 0Nm | 1.83                    |
| 2     | First gear _1500rpm 580Nm | 1.40                    | 32    | Fourth gear _1500rpm 2113Nm | 2.56                    |
| 3     | First gear _1500rpm 1000Nm | 1.59                    | 33    | Fourth gear _1500rpm 2874Nm | 3.13                    |
| 4     | First gear _2000rpm 0Nm | 1.95                    | 34    | Fourth gear _2000rpm 0Nm | 2.65                    |
| 5     | First gear _2500rpm 0Nm | 6.87                    | 35    | Fourth gear _2500rpm 0Nm | 4.88                    |
| 6     | First gear _2500rpm 583Nm | 3.13                    | 36    | Fourth gear _2500rpm 1413Nm | 7.13                    |
| 7     | First gear _2500rpm 1093Nm | 3.01                    | 37    | Fourth gear _2500rpm 2850Nm | 6.10                    |
| 8     | First gear _3000rpm 0Nm | 5.11                    | 38    | Fourth gear _3000rpm 0Nm | 6.62                    |
| 9     | First gear _3000rpm 567Nm | 1.75                    | 39    | Fourth gear _3000rpm 1375Nm | 9.28                    |
| 10    | First gear _3000rpm 1095Nm | 2.08                    | 40    | Fourth gear _3000rpm 2450Nm | 10.47                   |
| 11    | Second gear _1500rpm 0Nm | 1.63                    | 41    | Fifth gear _1500rpm 0Nm | 1.19                    |
| 12    | Second gear _1500rpm 1081Nm | 1.95                    | 42    | Fifth gear _1500rpm 2305Nm | 2.17                    |
| 13    | Second gear _1500rpm 2050Nm | 2.18                    | 43    | Fifth gear _1500rpm 2915Nm | 2.57                    |
| 14    | Second gear _2000rpm 0Nm | 2.50                    | 44    | Fifth gear _2000rpm 0Nm | 2.40                    |
| 15    | Second gear _2500rpm 0Nm | 4.66                    | 45    | Fifth gear _2500rpm 0Nm | 5.91                    |
| 16    | Second gear _2500rpm 924Nm | 6.02                    | 46    | Fifth gear _2500rpm 1448Nm | 8.54                    |
| 17    | Second gear _2500rpm 1447Nm | 6.07                    | 47    | Fifth gear _2500rpm 2855Nm | 9.81                    |
| 18    | Second gear _3000rpm 0Nm | 6.35                    | 48    | Fifth gear _3000rpm 0Nm | 5.39                    |
| 19    | Second gear _3000rpm 660Nm | 6.82                    | 49    | Fifth gear _3000rpm 1330Nm | 8.86                    |
| 20    | Second gear _3000rpm 1442Nm | 6.39                    | 50    | Fifth gear _3000rpm 2680Nm | 13.89                   |
| 21    | Third gear _1500rpm 0Nm | 1.16                    | 51    | Six gears _1500rpm 0Nm | 1.48                    |
| 22    | Third gear _1500rpm 2175Nm | 2.27                    | 52    | Six gears _1500rpm 868Nm | 2.91                    |
| 23    | Third gear _1500rpm 2902Nm | 2.36                    | 53    | Six gears _1500rpm 1403Nm | 3.25                    |
|   | Third gear _2000rpm_0Nm |   | Six gears _2000rpm_0Nm |   |
|---|------------------------|---|------------------------|---|
| 24|                        | 3.31 | 54                     | 2.17 |
| 25| Third gear _2500rpm_0Nm | 9.30 | 55                     | 3.04 |
| 26| Third gear _2500rpm_1422Nm | 9.85 | 56                     | 3.86 |
| 27| Third gear _2500rpm_2819Nm | 10.92 | 57                     | 5.04 |
| 28| Third gear _3000rpm_0Nm | 8.38 | 58                     | 3.13 |
| 29| Third gear _3000rpm_1320Nm | 10.35 | 59                     | 4.63 |
| 30| Third gear _3000rpm_2665Nm | 13.73 | 60                     | 5.44 |

In order to facilitate analysis, the vibration severity drawing of Table 2 shows that the vertical coordinates are vibration severity, the unit is mm/s, horizontal coordinate working condition serial number 1/10, 11/20 is second, 21/30 is three, 31/40 is four, 41/50 is five, 51/60 is six, green line is 1500 r/min, blue dot is 2000 r/min, orange line is 2500 r/min, red line is 3000 r/min. The green line is the working speed of 1500 r/min, the blue dot is 2000 r/min, the orange line is 2500 r/min, and the red line is 3000 r/min.

Figure 3: Vibration severity and rating results under 60 operating conditions

Provide analysis table 2 and Figure 4, you can find:

①The general trend of vibration severity is: in addition to the first gear, the vibration severity in each gear increases with the increase of the rotational speed and the increase of the torque;

②The maximum vibration severity under the 60 working conditions is 13.89 mm/s, corresponding to working condition 50 (5 steps, speed 3000 r/min, torque 2680 Nm), the second largest value is 13.73 mm/s, corresponding Working condition 30 (3 steps, speed 3000 r/min, torque 2665 Nm).

4.3. Vibration severity rating
According to the vibration severity distribution table of the internal equipment of the diesel engine in the method for evaluating the mechanical vibration severity of the internal equipment of the diesel
engine, the speed change mechanism belongs to the class IV equipment which is directly installed in the vehicle body of the diesel engine. The vibration severity level of the noise meter refers to the order of magnitude of the vibration severity from 0.28 mm/s to 112.0 mm/s in the range of 1: 1.6 or 4 dB.

In the scope of evaluation, the vibration level is divided into A, a good working state, B, a normal working state, C, a tolerance working state and D, not allowed to work.

In figure 4, when the input speed of the planet transmission mechanism is 3000 r/min and the input torque is 2680 Nm, the vibration severity reaches the maximum value of the test, which is 13.89 mm/s; at the input speed of 3000 r/min in the third stage and 13.73 mm/s at the input torque of 2665 min. The vibration severity of the planet transmission mechanism under these two conditions is in the tolerant working state of class C.

| Vibration severity level Vrms mm/s | Decibel/ dB | Machine and equipment classification |
|----------------------------------|------------|--------------------------------------|
| 0.28–0.45                        | 93         | A A A A                             |
| 0.45–0.71                        | 97         | A A A A                             |
| 0.71–1.12                        | 101        | B B A A                             |
| 1.12–1.80                        | 105        | B B A A                             |
| 1.80–2.80                        | 109        | C C C B                             |
| 2.80–4.50                        | 113        | C C C B                             |
| 4.50–7.10                        | 117        | C C C B                             |
| 7.10–11.2                        | 121        | C C C B                             |
| 11.2–18.0                        | 125        | C C C B                             |
| 18.0–28.0                        | 129        | C C C B                             |
| 28.0–45.0                        | 133        | C C C B                             |
| 45.0–71.0                        | 137        |                            D D D      |
| 71.0–112.0                       | 141        |                            D D D      |

5. Conclusion

In this paper, the vibration acceleration test of the Planetary Shifting Mechanism is carried out, and the vibration severity analysis of the test results is completed. The specific conclusions are as follows:

1. The relationship between the vibration severity and the load of the Planetary Shifting Mechanism is tested and analyzed. Except for the individual operating points of the first and second gears, the vibration severity of the Planetary Shifting Mechanism increases with the increase of the load, showing a linear increasing trend.

2. The relationship between the vibration severity and the input speed of the Planetary Shifting Mechanism under different gears is obtained. The results show that the vibration severity of the planetary Shifting mechanism increases gradually with the increase of the input speed in the test 1500–3000rpm.

3. The technical index of vibration severity of crawler vehicle transmission is ≤28mm/s. The maximum vibration severity test and calculation of the prototype of the target Planetary Shifting Mechanism is 13.89 mm/s.

References

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