Based on the Gear Reducer Gear Meshing Characteristic of Modification Simulation Research

Ma Xin Tan, Liu Ming Ku

Vehicles and Traffic Engineering, Henan University of Science and Technology, Luoyang, Henan 471000, China
Email: 1455581995@qq.com

Abstract: How to reduce the influence of poor meshing quality caused by the meshing misalignment of reducer gear pair, a novel micro gear modification strategy based on genetic algorithm is proposed in this paper. The system simulation model of speed reducer gear pair was established by Romax firstly, and the influence of poor meshing quality from the meshing misalignment of reducer gear pair are analyzed, which was optimized by using the method of novel micro gear modification strategy based on genetic algorithm. Modeling analysis demonstrates that the sound pressure level decreased by 3.6 dB by using the method of micro gear modification strategy and the overall noise peak disappeared, vibration noise was effectively improved after modification.

1. Foreword
With the development of social benefit, gear transmission is developing towards high speed, heavy load and light weight. The transmission environment of gearbox system will become worse. When the gear is engaged, the contact collision of the contact gear is caused by the vibration of the protruding of the tooth surface and the axis of the depression, resulting in the wear of the tooth surface and the impact vibration[1-2]. The meshing dislocation of the gears refers to the uneven contact of the gear along the tooth width due to the transverse deflection of the support shaft. The results indicate that the meshing dislocation can cause the load of the tooth surface to be biased[3-4], increase the transfer error volatility. Then the vibration and noise of the meshing gears are caused[5-6]. Due to the existence of the gear meshing displacement, the distribution of load along the width of the tooth is uneven and the load is biased[7]. In engineering application, the deviation of the actual conjugate surface of the gear is difficult to measure, and the degree of the gear pair deviation from its ideal meshing position can be represented by the meshing dislocation, which can be used to analyze its influence on the meshing characteristics of the meshing gear.

The main factor of the perfect involute gear vibration is the pulsation of the intergear force, which is based on the involute gear profile itself. Therefore, from the theoretical point of view analysis, the involute gear transmission has certain vibration, to reduce or eliminate the noise, can only seek new tooth profile curve. In fact, there is no so-called "ideal" gear, the gear has assembly error and production error in the engineering system, and the gear will have shape change in the influence of pressure. The meshing overlap of gears is usually not an integer, and the gear logarithm of meshing can change periodically over time. In addition, in the process of gear meshing, there is a variation of the shape elasticity of the tooth root activity to the tooth surface. The above mentioned factors can lead to the change of the overall rigidity of the gears. In the gear meshing stage, the dynamic excitation which
is based on the existence of the overall rigidity of the meshing is a rigid incentive, which is an exponential type of excitation. Error incentive in the process is: because the gear assembly error and processing error caused by gear meshing error of involute gear meshing form changes, then change the gear instantaneous transmission ratio, lead to friction and collision between each tooth, so will appear in the gear mesh phase error [8]. In general, the large factor that causes the gear oscillator noise is the error of the distance between the two teeth and the error of the shape. Meshing impact because of gear error and the role of the pressure on elastic shape change and other factors, the gear mesh stage, real and in principle of meshes into meshes into node has certain error, leading to meshes into shock.

Gear meshing transmission process is complex, only under the condition of the absolute ideal to achieve absolute smooth delivery process, which exist in the actual working condition of the elastic deformation of gear tooth, load distribution, manufacturing and assembling error factors will affect the stability of gear transmission (called a "incentive"), and thus produce shock, vibration and noise. Gear meshing dislocation is an important index to measure the stability of gear drive. Based on a certain type of reducer as the research object, this paper analysis the influence the characteristics of the gear pair meshing engagement dislocation. Using Romax genetic algorithm (GA) to carry out the gear micro modification research, to improve the meshing gears caused by misalignment problem such as vibration and noise.

2. Gear Box System and Romax Model

The target reduction model is built through Romax. Before the simulation analysis, it is necessary to complete the modeling, loading and complete static analysis of the transmission system in the module of Romax to make the preliminary data preparation work for the later simulation analysis. Modeling method for target reducer: according to each gear shaft in space the actual location of the axis of the model is set up first, and then add other parts on the shaft after the definition, including contains the actual parameters and the actual material of the gear, roller bearings and needle roller bearings. Gear model according to the actual parameters through the parameterized modeling, bearing model is selected in the database Romax, finally the simulation analysis in the gear micro modification and analysis module by changing the parameters to complete. One of the main, driven wheel pressure Angle is 17.5 °, modulus of 8 mm, spiral Angle for 13 °, 31, 115, respectively, and the number of tooth width is 200 mm. The material, size and position of all parts of the target reducer are consistent with the actual situation, and the structure is shown in figure 1.

![Figure 1 Simulation Analysis Model](image)

3. The Influence of Meshing Dislocation on Meshing Characteristics

Finally according to the various working condition of setting system model simulation, it is concluded that average meshing gear pair displacement quantity is 44.11 microns. The displacement of the gear system causes the gear system to be elastic deformation, so that the deflection of the axis leads to the contact between the gears to produce the gap of the gear. The influence of meshing dislocation on the load distribution of the gear pair is shown in FIG. 2 and FIG. 3. It can be seen from FIG. 3 that the distribution of tooth surface load along the width of the teeth is uneven, and the maximum unit load is increased by 984N/mm to 1091N/mm, with an increase of 11%, and the uneven load distribution caused by the meshing dislocation will affect the vibration noise of the gear.
Further analysis of the influence of meshing dislocation on the transmission error of gear is analyzed, as shown in fig.4 and fig.5. The maximum fluctuation of the transmission error of the gear is increased from 4.99 μm to 5.60 μm, which is up by 12%. 

Figure 2 The Load Distribution of Gear Pair is not Considered when Meshing Dislocation

Figure 3 The Load Distribution of Gear Pair of Gears when Meshing Dislocation is Considered

Figure 4 Regardless of the Meshing Gear Transmission Error when Dislocation
Figure 5 Considers Gear Transmission Error in Meshing Dislocation

From the analysis, it can be concluded that the meshing dislocation has a great influence on the tooth surface load and the gear transfer error of the gear pair, which causes the load distribution of the tooth surface to be biased, and the static transfer error fluctuates greatly, which eventually leads to the increase of vibration and noise of the gears.

4. Gear Optimization Design and Analysis

References are shown in the references[9]. It is not good to pursue the quality of gear processing, but the gear repair is a practical method in real production. In the absence of the need to increase the equipment investment, the gear modification can reduce the gear deformation and various errors, and obtain the ideal meshing quality, thus improving the transmission efficiency. In this paper, the optimization design of tooth modification and tooth profile is carried out by using Romax software itself. The genetic algorithm (GA) is selected in the four optimization methods of Romax gear microgeometry research tools. The evolutionary algebra of genetic algorithm selects 10 generations, the population size selection 50, the variation probability is 0.25, the crossover probability is 0.5. Optimization design variable selection the initiative on the right side of the tooth surface of gear tooth and tooth profile modification, tooth to drum modification range is set to the amount of (0, 25) microns, tooth to slope modification range is set to the amount of (-40, 40) microns, mending the tooth profile edge range is set to (0, 50) microns, rolling Angle range is set to microns (21.731° - 30.759°). The mean minimum of gear driving error is the objective function. Confirmed to repair tooth drum quantity is 23.21 microns, tooth to slope modification amount to 17.39 μm, mending the tooth profile edge is 43.23 microns, repair the edge rolling Angle of the starting value is 25.178°, parameter Settings as shown in table 1. After comprehensive repair, the gear unit length load diagram 6, the gear transmission error curve diagram 7 is shown below.

| Tab. 1 Gear Repair Parameters |
|-------------------------------|
| Modification Methods | Modification Object | Value Range | Optimal Values |
| Profile Repair | Repair Value/μm | 0-50 | 43.23 |
| | Rolling Angle/° | 21.731-30.759 | 25.178 |
| Tooth Repair | Tooth Repair | 0-25 | 23.21 |
Contrast analysis of the data before and after modification, the tooth unit maximum load of 748 N/mm down to 524 N/mm, was reduced by 29%, the maximum wave vice gear transmission error by 4.11 microns down to 0.81 μm, was reduced by 80%, after a tooth to modification and tooth profile modification, steady transmission error fluctuation range and amplitude fluctuation reductions and carrying capacity of the gear teeth, gear mesh mesh vibration and noise reduction. It can be seen that reducing the fluctuation amplitude of gear transfer error will improve the vibration noise characteristics of the whole transmission system.

5. Test Verification of Gear Vibration Noise Simulation

In the semi-anechoic chamber experiment room, the data acquisition system was conducted to collect the noise of the gear noise, and the input torque was 78N·m, and the speed range was from 500 ~ 5000r/min. The data acquisition system of German Head Acoustics is used to test the noise. Test result is shown in figure 8, we can see that the mean total sound pressure level of 43.7 dB before modification, reduce to 40.1 dB after practice, through to the micro gears modification makes the sound pressure level decreased 3.6 dB, the overall noise peak disappear after modification, vibration noise was effectively improved.
6. Conclusion

(1) The simulation model of the reducer is established, and the load distribution and transmission error of gear between gears are affected by the meshing mismatch between gears. Above all, meshing dislocation of helical gear pair meshing characteristics have great influence, will increase the gear vibration and noise, therefore, before the dynamics analysis of gear pair, need to comprehensively consider the effect of gear engagement dislocation of the whole system.

(2) The load distribution of gear tooth surface is more uniform than that of unprocessed gear, and the transmission error is reduced. Reasonable modification can improve the tooth face, therefore, load distribution, reduce the transmission error, not only improves the service life of gear, and avoiding the phenomenon of partial load gear drive is more stable, reduce the vibration and noise reduction. by improving the unit load distribution and reducing the maximum wave momentum of the transmission error, the sound pressure level was reduced by 3.6 dB.

References

[1] Yang benyang, chu chao mei, tang haichuan, et al. Research on influence of gear repair parameters on transmission characteristics of gearbox [J]. Mechanical transmission, 2012(9):8-11.
[2] Xiao qing, sun yuehai. Analysis on the contact analysis of gear pair with error in installation [J]. Mechanical design and research, 2015(6):44-47.
[3] Lias M R, Awang M, Rao T V V L N. A Numerical FEM Solution of Gear Root Stress in Offset Axial Mesh Misalignment[J]. Applied Mechanics & Materials, 2013, 393(393):375-380.
[4] Hotait M A, Kahraman A, Nishino T. An Investigation of Root Stresses of Hypoid Gears with Misalignments[J]. Journal of Mechanical Design, 2011, 133(7):071006.
[5] Guo fan, zhang jun. Analysis of the analysis and repair reliability of planetary frame flexible planetary drive [J]. Mechanical transmission, 2014(9):1-4.
[6] Zhu C, Song C, Lim T C, et al. Pitch cone design and influence of misalignments on tooth contact behaviors of crossed beveloid gears[J]. Mechanism & Machine Theory, 2013, 59(59):48-64.
[7] Yang jianjun, liu wei, zhang hua, etc. Based on ROMAX's gear modification optimization design and experimental study [J]. Mechanical transmission, 2015(10):158-161.
[8] Hu jianrong. Research on structural damage diagnosis based on modal analysis [D]. Southwest jiaotong university, 2006.
[9] tang fish, chang shan, ho yulong, et al. Research on the influence of tooth profile on contact force of tooth surface [J]. Modern machinery, 2010(4):7-9.