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Simulation Analysis for the Motion of New Type of Gear with Circular Arc Tooth Trace

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Abstract. The new type of gear with circular arc tooth line is a new type of gear with good meshing ability, high degree of overlap, good smoothness of transmission, almost no noise, theoretical basis for high-speed operation, and can adapt to long working hours. According to its tooth equations, the three-dimensional model of the gear was established in SolidWorks, and after the assembly of the major and minor gears was completed, the Motion analysis module was used to simulate the kinematics of the new circular arc cylindrical gear, and the corresponding angular velocity curves of the master and driven wheels were obtained. In order to better understand the effect of the fluctuation of the kinematic speed of the circular arc cylindrical gear at different modulus, different tooth widths and different tooth numbers, kinematic analysis was carried out by ANSYS analysis software. A modal finite element analysis of the new circular cylindrical gear was also carried out to calculate the first 15 orders of inherent frequency and principal vibration pattern of the circular cylindrical gear, as well as the corresponding maximum deformation. The results show that: (1) the actual ratio of the gear in the transmission process and the theoretical value of 1.463 and 1.458 respectively and the two ratio curves basically match, indicating that the smoothness of the transmission is good. (2) The larger the modulus of the gear, the more teeth and the width of the teeth between 0.33d and 0.43d, the smaller the speed fluctuation coefficient of the gear pair in the transmission process, the better the transmission smoothness. (3) Through the solution results, it is determined that the arc tooth line cylindrical gear basically does not deform at the low order inherent frequency, while at the middle order inherent frequency, it shows the convex vibration, the highest deformation, and the main vibration pattern tends to elliptical at the high order inherent frequency.

Keywords. Circular tooth line cylindrical gear; tooth surface equation; motion simulation; motion analysis

1. Introduction

Cycloidal gears have the advantages of good meshing performance, high overlap ratio, no axial force, high transmission efficiency, and strong tooth contact strength. They can be used as a new type of transmission mechanism to replace straight, helical, and herringbone cylindrical gears in many occasions. In recent years, extensive research has been conducted on cycloidal gears both domestically and abroad. Wang Xiaogang et al. [1] proposed a tooth surface equation and studied the influence of tooth contact stress under different tooth profile radii; Li Qin et al. [2] completed parameterized

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modeling design based on UG secondary development technology and improved modeling efficiency; Jiang Biqiong et al. [3] analyzed gear contact stress and found that the tooth contact stress of four-arc cycloidal gears was about 80% of that of double-arc cycloidal gears; Andrei et al. [4] used the single-disk cutter method to cut convex and concave tooth surfaces of cycloidal gears and obtained the advantages of high bending strength and low noise through finite element analysis; CHENYC et al. [5-6] based on the derivation of tooth surface equation, studied its transmission error. However, it is found in relevant literature that the research on the motion characteristics of cycloidal gears is not yet comprehensive [7-10].

This article analyzes the motion simulation of cycloidal gears under different modulus, tooth width, and number of teeth conditions using SolidWorks and ANSYS software.

2. Modeling of Cycloidal Gears

2.1 Tooth Surface Equation

At the middle section of the gear's axial direction, according to its forming principle, the expression of tooth surface equation that can be obtained is:

$$\begin{cases} x_1 = R_{b1}\cos(\alpha+\beta) + \alpha R_{b1}\sin(\alpha+\beta) \\ y_1 = R_{b1}\sin(\alpha+\beta) - \alpha R_{b1}\cos(\alpha+\beta) \\ z_1 = h \end{cases} \tag{1}$$

Where -b/2≤h≤b/2, b is the tooth width.

2.2 Establishment of Cycloidal Gear Model

The solid model of the cycloidal cylindrical gear was established using SolidWorks software, as shown in Figure 1.

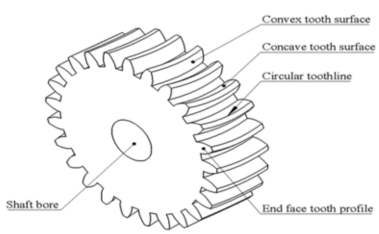

Figure 1. Shows the model of the new circular arc involute cylindrical gear with teeth line.

3. Motion Analysis of Cycloidal Gear

3.1 Simulation of Cycloidal Cylindrical Gear Motion

Based on the modeling parameters of the designed cycloidal cylindrical gear, the kinematic simulation of the new type of gear with an arc tooth profile was carried out using the Motion module in SolidWorks. As shown in Figure 2, the transmission ratio of the gear transmission is basically consistent with the theoretical value. Comparing the cycloidal cylindrical gear with the involute gear, it can be seen from Figure 3 that under the same parameters, the cycloidal cylindrical gear has a lower and more stable speed fluctuation coefficient δ during the overall motion. In summary, this indicates that the transmission stability of the gear with the arc tooth profile is better than that of the involute gear.

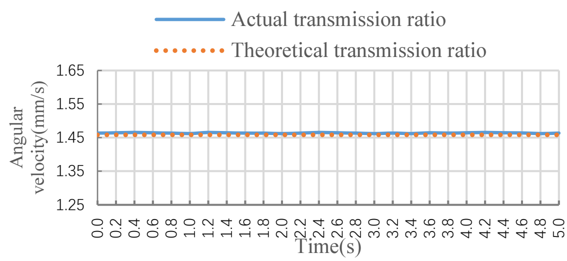

Figure 2. Curve of Actual Transmission Ratio and Theoretical Transmission Ratio of Gear Pair

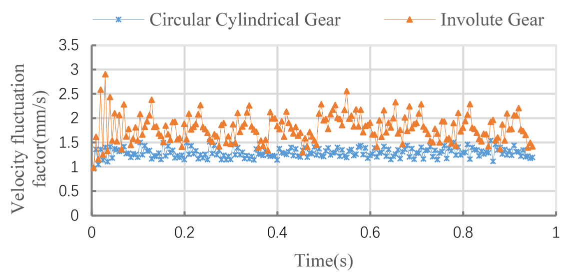

Figure 3. Velocity fluctuation coefficient δ Comparison Chart

3.2 Effect of Module on Gear Velocity Fluctuation

3.2.1 Model Building and Simulation Parameter Setting

Four sets of different gear transmission parameter data were set in advance, and the gear models under different modules were established using SolidWorks software, as shown in Table 1. By importing the gear mechanism model into the Transient Structural module in ANSYS Workbench for motion simulation analysis, various parameters of the gear are set and the results are analyzed as follows.

Table 1 Parameter Settings for Circular Arc Cylindrical Gears

serial number	Module	tooth width	Pinion teeth	Number of teeth on large gears	angle of pressure
a	2	20	24	35	20
b	3	20	24	35	20
c	4	20	24	35	20
d	5	20	24	35	20

3.2.2 Simulation Results Analysis

During the gear motion, when the speed of the driven wheel changed more steadily, the stable speed output curve was selected, that is, the motion interval from 0.2s to 0.9s.

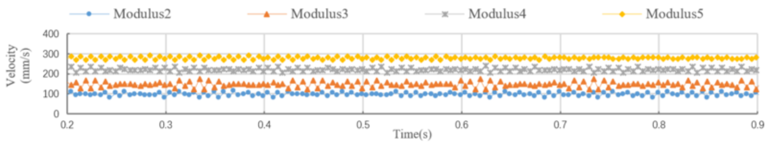

Figure 4. Curve of Speed of Driven Wheel Changing with Modulus

From Figure 4, it can be seen that the trend of the driven wheel speed curve fluctuations all revolves around a certain same speed and presents regular changes. Analyzing the above data, it can be concluded that: As the fluctuation of the driven wheel speed shows a decreasing trend with the increase of module, the stability of the gear transmission gradually improves with the increase of module.

3.3 The Effect of Tooth Width on Gear Speed Fluctuation

3.3.1 Modeling and Simulation Analysis

Four sets of gear drive parameter data with different module numbers were set up in advance and gear models under different modules were created using SolidWorks software. By importing the gear mechanism model into the Transient Structural module in ANSYS Workbench for motion simulation analysis, various parameters of the gear are set and the results are analyzed as follows. As shown in Figure 5, the trend of the driven wheel speed curve shows periodic changes. In order to better observe the change of the driven wheel speed fluctuation coefficient, based on the theoretical formula of speed fluctuation, the speed fluctuation coefficient δ was calculated for each tooth width and the trend chart was drawn as shown in Figure 6.

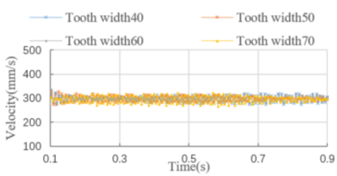

Figure 5. Speed variation of driven wheels

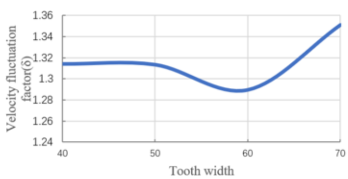

Figure 6. Fluctuation trend of driven wheel speed

According to Figure 6, it can be seen that with the increase of tooth surface width, the speed variation of the gear first tends to be gentle, then gradually decreases, and finally rises rapidly. Therefore, the smoothness of the gear transmission first improves and then deteriorates. Therefore, when designing involute cylindrical gears, the tooth width should be selected between 0.33d~0.43d, and the speed fluctuation coefficient of the gear transmission in this range is relatively small.

3.4 The Effect of Number of Teeth on Gear Speed Fluctuation

3.4.1 Model Establishment

Different gear pairs parameters with different number of teeth were selected, and 5 sets of gear pairs models with different number of teeth were constructed and analyzed by motion simulation.

3.4.2 Simulation Results Analysis

Through ANSYS simulation analysis, the gear speed curve is obtained as shown in the following figure:

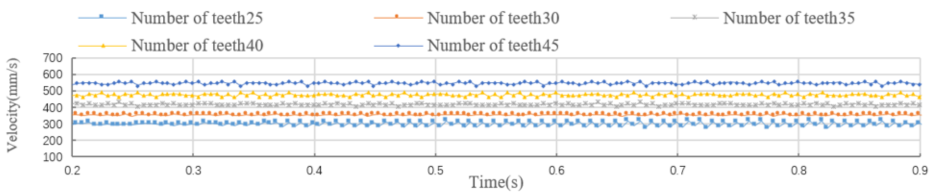

Figure 7. Curve of the variation of driven wheel speed with the number of teeth

As can be seen from Figure 7, the speed of the driven wheel gradually decreases with the increase of the number of teeth, and within a certain speed range, it constantly fluctuates in a periodic manner. According to the formula for speed fluctuation coefficient δ, when the number of teeth is 25, the maximum value of the speed fluctuation coefficient δ of the driven wheel can reach 1.314141, indicating poor transmission stability of this gear and a decreasing trend as the number of teeth increases. Conclusion: The smoothness of gear transmission improves with the increase of the number of teeth.

4. Conclusion

(1) Through motion simulation, it is found that the actual transmission ratio of the gear pair is basically consistent with the theoretical value curve, indicating that the stability of the circular arc involute cylindrical gear in the transmission process is good.

(2) By changing the module of the gear for simulation analysis, the results show that with the increase of the module, the fluctuation of the speed of the driven wheel shows a gradually decreasing trend. As the speed fluctuation coefficient decreases, the smoothness of gear transmission gradually improves.

(3) By changing the tooth width of the gear, it is found that the speed fluctuation coefficient δ of the driven wheel shows

a trend of gradual flattening, then decreasing, and finally rapidly increasing with the increase of the tooth width. Therefore, when designing involute cylindrical gears, the tooth width should be selected between 0.33d~0.43d.

(4) By changing the number of teeth of the gear, it is found that the speed fluctuation coefficient of the gear pair gradually decreases with the increase of the number of teeth, and the stability of transmission is improved.

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