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Original Research Article

Design and simulation of a two-tooth-difference cycloidal pinwheel RV reducer

Xian Zhang, Junhua Bao
Dalian Jiaotong University, Dalian, Liaoning, 116028, China

Abstract: To address the requirements of industrial robot joint drives for high precision, high load capacity, high smoothness, and compact structure, a design and simulation study of a double-difference cycloidal pinwheel RV reducer was conducted. First, basic parameters such as the number of teeth on the pinwheel and the cycloidal wheel were determined based on the principles of cycloidal pinwheel transmission. Subsequently, models of components such as the cycloidal wheel and pinwheel were created and assembled, and a dynamic model was established in RecurDyn. Simulation results indicate that after the system reaches steady state, the output speed curve remains stable, with an error of 0.21% relative to the theoretical gear ratio. Contact force analysis shows that the maximum contact force occurs between the pinion and cycloid wheel 1. SMISES equivalent stress contour plots reveal that high stresses are primarily concentrated in the meshing contact area between the cycloid wheel and the pinion. The research results indicate that the designed reducer possesses good motion transmission accuracy, meshing stability, and load-carrying capacity. It provides a strong theoretical basis and technical support for the design and application of double-difference cycloidal pinwheel RV reducers, thereby promoting their further development in the field of industrial robot joint drives.
Keywords: two-tooth difference; cycloidal pinwheel drive; 3D modeling; RecurDyn simulation

1. Introduction

As the application of industrial robots continues to expand in fields such as welding, assembly, material handling, and precision machining, joint drive systems place higher demands on reducers in terms of transmission accuracy, load-carrying capacity, stiffness, backlash, operational smoothness, and structural compactness[1]. The performance of two-stage cycloidal pinwheel RV reducers is primarily influenced by factors such as the tooth profile parameters of the cycloidal wheels, the stiffness and damping of the contact pairs, the output load, and the meshing clearance[2].

This paper focuses on two-stage cycloidal pinwheel RV reducers and analyzes their dynamic simulation models. By analyzing the reducer's output speed, gear ratio, contact forces, and contact stress contour plots, this study provides a basis for subsequent structural optimization, aims to correct tooth profile defects, and seeks to improve the transmission performance and service life of two-stage cycloidal pinwheel RV reducers.

2. Structural design of a two-tooth-difference cycloidal pinwheel RV reducer

Based on the design principles and characteristics of cycloidal pinwheel drives[3], a two-stage cycloidal pinwheel RV reducer was designed; its basic parameters are shown in **Table 2.1**.

Table 2.1. Basic parameters of two-tooth-difference cycloidal pinwheel RV gear reducers.

Number of teeth on the pinion Z_b	Number of teeth on the cycloidal gear Z_c	Eccentricity e	Pin-tooth sleeve radius r_z	Center circle radius of the pinion R_z
24	22	0.95	3	34.5

Based on the basic parameters and strength design requirements, calculate the tooth width, root circle diameter, tip circle diameter, and tooth height of the cycloidal gear, and determine the relevant structural dimensions of the pin holes and the output mechanism[4]. The structural parameters of the two-stage cycloidal pinwheel RV reducer are shown in **Table 2.2**.

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Table 2.2. Structural parameters of a two-tooth-difference cycloidal pinwheel RV reducer.

Center hole radius of the cycloidal gear	Radius of the center circle of the pin hole	Pin hole radius	Pin radius	Number of pins
17.5	24	3	2	12

3. 3D modeling of a two-tooth-difference cycloidal RV gear reducer

In SolidWorks, sketch the cycloidal gear profile, create the cycloidal gear profile by extruding a boss, then extrude to cut out the cycloidal gear's center hole, and finally extrude to cut out the pin hole[5], as shown in **Figure 3.1**. Import each component into the assembly model one by one, then assemble them to form a complete assembly, as shown in **Figure 3.2**.

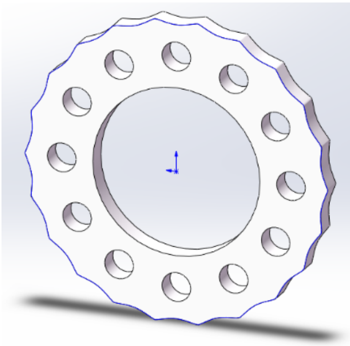

Figure 3.1. Cycloidal gear.

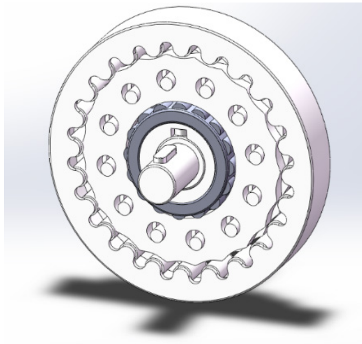

Figure 3.2. Assembly.

4. Dynamic simulation analysis of a two-tooth-difference cycloidal RV reducer

A simulation analysis of the dynamic model was performed in RecurDyn[6] and the transmission ratio was calculated after the simulation was completed, as shown in **Figure 4.1**. The system reached steady state after 0.1 seconds, and the calculated average value was 11.0231. The error between this value and the theoretically calculated transmission ratio was 0.21%, indicating that the reducer designed in this study possesses high motion transmission accuracy and stability. Contact stress analysis[7] was performed, and the contact force curves between the two cycloidal wheels and the pinion, as well as between the two cycloidal wheels and the pins, were output in the post-processing module, as shown in **Figure 4.2**. After 0.1 seconds, the system enters a stable operating phase, and none of the four sets of contact forces exhibit significant sudden changes or divergence, indicating that the contact pairs are properly configured and the meshing process is smooth.

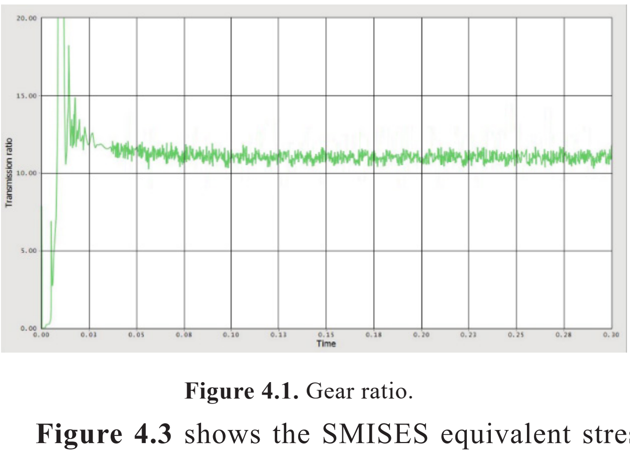

Figure 4.1. Gear ratio.

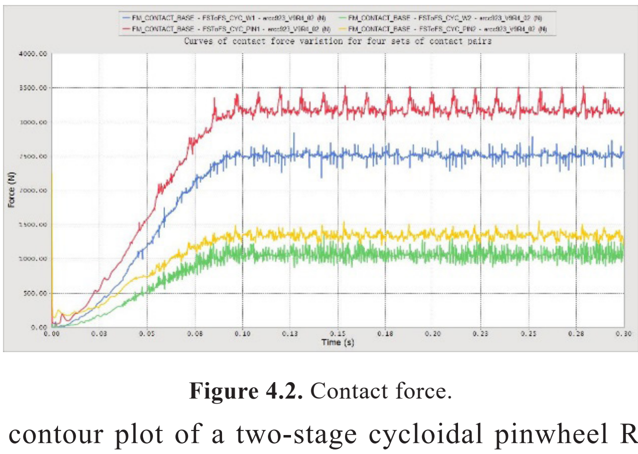

Figure 4.2. Contact force.

Figure 4.3 shows the SMISES equivalent stress contour plot of a two-stage cycloidal pinwheel RV reducer during steady-state operation. The overall stress distribution in the model exhibits a distinct pattern of local concentration. Most non-contact regions experience relatively low stress. As the input shaft continues to rotate, the contact positions between the cycloidal gear and the pinion continuously change, causing the stress concentration zones to shift periodically. The high-stress regions align with the actual power transmission path, indicating that the model's contact configuration and the results of the dynamic simulation are reasonably accurate.

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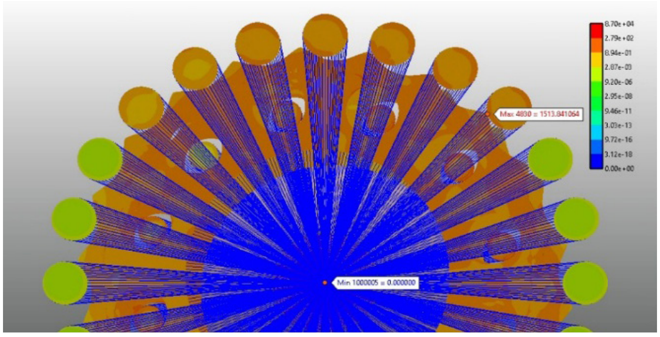

Figure 4.3. Contact stress contour plot.

5. Conclusion

This paper focuses on the structural design, 3D modeling, and dynamic simulation analysis of a two-stage cycloidal pinwheel RV reducer. Simulation results indicate that all four contact pairs exhibit slight periodic fluctuations during the steady-state phase, with no significant abrupt changes or divergence observed. SMISES equivalent stress contour plots reveal that high stresses are primarily concentrated in the meshing contact areas between the cycloidal gear and the pinion. The locations of maximum stress align with the primary load-bearing regions corresponding to peak contact forces, indicating that the configuration of the contact pairs and the power transmission path are well-designed.

The two-tooth-difference cycloidal pinwheel RV reducer designed in this paper can achieve relatively stable multi-tooth meshing and load transmission, meeting the basic requirements for smoothness and transmission accuracy in robotic joint drives. Future research could build upon the existing dynamic simulations to further optimize the cycloidal wheel tooth profile modification, pin hole structure, and contact parameters, thereby enhancing the reducer's load-carrying capacity and service life.

References

[1] Liyang Chen, Yangyi Xiao, Bingzhong Zeng, et al. Design and Testing of a Compact Cycloidal Pinwheel Reducer for Robots [J/OL]. Journal of Engineering Design, 1–11 [2026-06-08].

[2] Feng Zhihua. Analysis of the Transmission Characteristics of RV Gear Reducers [J]. Metrology and Testing Technology, 2016, 43(9): 58–60.

[3] Qi Lu, Weidong He. Parametric Modeling and Multibody Dynamics Simulation of RV Reducers [J]. Mechanical Transmission, 2021, 45(9): 87–91.

[4] Jiqiang Bai. A Study on the Design of a Two-Tooth-Difference Cycloidal Pinion Planetary Gear System [D]. Chongqing University, 2004.

[5] Lin Mu. Calculation of Gear Load Capacity in Two-Stage Planetary Reducers [J]. Mechanical Transmission, 2006, (1): 45–46+88.

[6] Zongze Wu, Zhi Gao. Handbook of Mechanical Design: 3rd Edition [M]. China Machine Press: 2019.

[7] Zuoxin Wei. Analysis of Contact Forces and Geometric Optimization of a Two-Tooth-Difference Cycloidal Pinwheel [D]. Dalian Jiaotong University, 2022.