정밀 트랜스미션용 사이클로이드 유성감속기

New Type of Cycloid Planetary Reducer for Precision Transmission

*Jing Zhang[1], Bingkui Chen[1], Qi Zhang[2], Jaejun Koo[2], #Sungki Lyu(sklyu@gnu.ac.kr)[2]
[1]Chongqing Uni. PR. China, [2]School of Mechanical & Aerospace Eng., Gyeongsang Nat. Uni.,

Key words : Cycloid Reducer, Precision Transmission, Angular Transmission Error, Hysteresis Curve

1. Introduction

Cycloid planetary reducer has been widely used in speed reduction and torque conversion especially for precision transmission in recent decades, thanks to its advantages of high compactness, high reduction ratio, high torque capability and light weight comparing with other transmission drives.[1,2] Existing typical cycloid reducer for precision transmission application like RV (Rotary Vector), Factory Automation (FA) from Japan and TWINSPIN[3] from Slovak are frequently adopted. Nevertheless, complex structure and high quality requirement for manufacture handicap the development of these types of reducer.

In this paper, we propose a new type of cycloid planetary gear characterized with conic tooth section which leads to capability for backlash adjustment. Mesh principle and virtual design model is carried out first. Further, prototype manufacture and experiments for transmission angular error and hysteresis curve has been conducted.

2. Meshing Principle and Virtual Model Structure

Traditionally, cycloid planetary gear and pin are all cylindrical, which cause high sensitivity between system and manufacture process. To solve this problem, conic tooth section cycloid has been put forward by which backlash could be adjusted to zero through the relative movement of cycloid plate and pin.

On the basis of mesh principle and differential geometry [4], new tooth equation is developed by enveloping approach. In figure.1 define grounded coordinate XOY , define pin profile $\Sigma^{(1)}$ on coordinate $x_1o_1y_1$ and cycloid tooth profile $\Sigma^{(2)}$ on $x_2o_2y_2$. According to transmission ratio for one tooth difference cycloid gear set, cycloid gear will rotate φ_b while pin rotate φ_g , represented in new coordinate $x_2'o_2'y_2'$ and $x_1'o_1'y_1'$ respectively. e is eccentricity, r_z is radius of pin and R_z is pitch radius of pin.

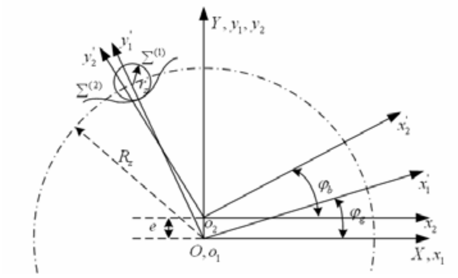


Figure.1 Coordinate transform

Pin's profile equation defined as

$$\begin{cases} x_1 = f(m)\cos\theta \\ y_1 = R_z + f(m)\sin\theta \\ z_1 = m \end{cases}$$

For conical pin

$f(m) = km + r_z$, k is slop

From pin profile to cycloid tooth profile

$$\begin{cases} \sum^{(2)} = M_{21} \sum^{(1)} \\ n_1 \bullet v_1^{12} = 0 \end{cases}$$

M_{21} is coordinate transform matrix

$$M_{21} = \begin{bmatrix} \cos(\varphi_g - \varphi_b) & \sin(\varphi_g - \varphi_b) & 0 & -e\sin(\varphi_g) \\ -\sin(\varphi_g - \varphi_b) & \cos(\varphi_g - \varphi_b) & 0 & -e\cos(\varphi_g) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Then cycloid tooth equation is

$$\begin{cases} x = R_Z\left[\cos\varphi - \dfrac{K_1}{z_b}\cos(z_b\varphi)\right] - (m\cdot\tan\theta + r_{Z0})\sin\beta \\ y = R_Z\left[\sin\varphi - \dfrac{K_1}{z_b}\sin(z_b\varphi)\right] + (m\cdot\tan\theta + r_{Z0})\cos\beta \\ z = m \end{cases}$$

In which, z_b is cycloid tooth number, r_{z0} is larger radius of pin, θ is conic angle.

$$\sin\beta = \frac{-K_1\cos(z_b\varphi) + \cos\varphi}{\sqrt{1 + K_1^2 - 2K_1\cos(z_g\varphi)}}$$

$$\cos\beta = \frac{K_1\sin(z_b\varphi) - \sin\varphi}{\sqrt{1 + K_1^2 - 2K_1\cos(z_g\varphi)}}$$

Typical conic section cycloid planetary gear set shape is shown in Figure.2

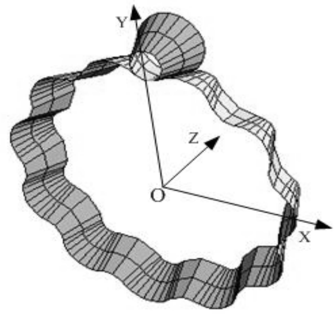


Figure.2 Conic planetary gear set

Based on new cycloid tooth geometry, one double disc cycloid reducer has been developed. See Figure.3. This type of reducer has advantage of capability to take axial load and adjustable backlash.

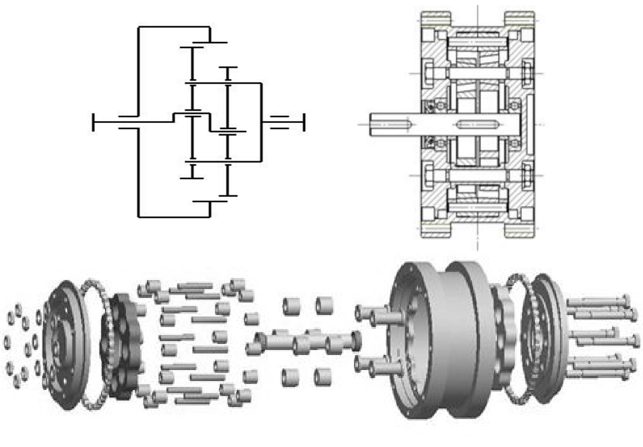


Figure.3 Double disc conic cycloid reducer

3. Prototype and Experimental Study

For conic cycloid planetary reducer, manufacture and measurement is comparative complex than cylindrical tooth. Special conic cutter is required for cycloid tooth generation and three-dimension measuring machine is used for tooth error measurement. One prototype for double-disc reducer is shown in Firgure.4.

Figure.4 Double disc conic cycloid reducer

For precision transmission application, there are two mean factors to judge accuracy: angular error and hysteresis curve.

Angular transmission error refers to a difference between the theoretical output revolution angle and the actual angle revolution angle when any revolution angle is the input, and is expressed as

$$\Delta\varphi_e = \Delta\varphi_{in} / i - \Delta\varphi_{out}$$

Figure.5 Transmission Angular Error Test Rig

Test rig is shown in Figure.5. Measurement has been conducted under torque 100Nm, and result shows in Figure.6. Maximum angular error is less than 1.4 arcmin.

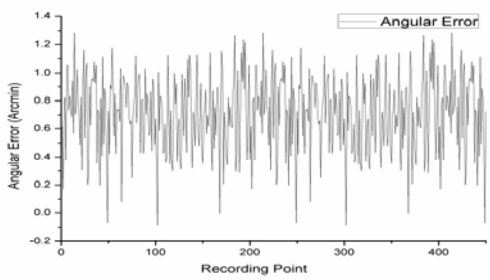
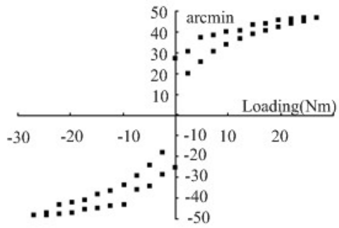


Figure.5 Angular Error Test Result

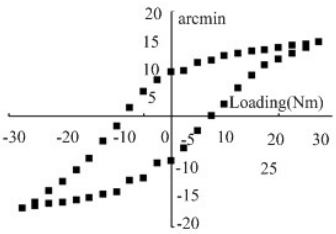
Hysteresis curve represents the key characteristics of cycloid transfer case: torsional rigidity (stiffness), lost motion (the torsion angle at the middle point of the hysteresis curve width at 3% of rated torque) and backlash (the torsion angles when torque is approaching zero). Test rig has been set up shown in Figure.6.

Figure.6 Hysteresis Curve Test Rig

Measurement approach: torque applied on output shaft from 0Nm to rated torque (30Nm) and fixed input shaft, recording the torsion angle of output shaft along the torque change; release the load from max to min, record the torsion angle; reverse the torque, redone the measurement along with torque variation. Results have been compared between before and after backlash adjustment. (Using adjusting device to apply axial force on cycloid disc) Figure.7 shows the hysteresis curve. We can find system backlash is reduced from approximately 50 arcmin (a) to less than 20 arcmin (b) after adjustment, lost motion reduced consequently and system rigidity (stiffness) increased. This means system accuracy is higher owing to backlash adjustment.



(a)



(b)

Figure.6 Hysteresis curve

4. Conclusions

New type of cycloid planetary reducer with variable tooth section has been proposed to meet precision transmission requirement. Tooth equation is generated through differential geometry and mesh principle. New configuration for double disc conic planetary reducer has been developed and prototype is also produced. Test result shows that new type of cycloid reducer not only has high accuracy like other precision reducer, one unique advantage is adjustable backlash lead to much higher reliable accuracy than others. It has benefit for wildly application in precision transmission area.

Acknowledgement

This study was supported by the Korea Industrial Technology Foundation & the grant No. RTI04-01-03 from the MOCIE, Korea

Reference

1. J.G. Blanche and D.C.H Yang, "Cycloid Drives With Machining Tolerances," ASME J. Mech. Transm. Automn Des Vol.111, 337-344, 1989.
2. D.C.H Yang and J.G Blanche, "Design and Application Guidences for Cycloid Drives with Machining Tolerances," Mech. Mach. Theory, Vol.25, No5, 1990, 487-501. 1990
3. MOTION TECHNOLOGIES Twinspin/Solution for Precision. http://motiontech.com.au, 2003.
4. F.L. Litvin, Alberto Demenego, Daniele Vecchiato, "Formation by branches of envelope to parametric families of surfaces and curves," Computer methods in applied mechanics and engineering, 4587~4608. 190 (2001)