Dynamic Formation and Parametric Visual Design of the Cycloid Gear Profile

Qiao xuetao
Zhengzhou research institute of mechanical engineering
Zhongyuan University of Technology
No. 41 Zhongyuan Road Zhengzhou
Henan Province, China
+86-371-62506827
xtqiao@126.com

Chen chunshan
Zhongyuan University of Technology
No. 41 Zhongyuan Road Zhengzhou
Henan Province, China
+86-371-67698172
1491994452@qq.com

Wang changlu
Zhengzhou research institute of mechanical engineering
No.10 Fengyang Street, Zhengzhou
High & New Technology Industries Development Zone
Henan Province, China
+86-371-67710950
wangcl@zrime.com.cn

Wei leyu
Zhengzhou research institute of mechanical engineering
North China University of Water Resources and Electric Power
No.36, Beihuan Road, Zhengzhou,
Henan Province, China
+86-371-65790233
34523626@qq.com

Zhang liyong*
Zhengzhou research institute of Advanced Equipment & Information Industry Technology
Science Avenue and Pine Road intersection angle, Zhengzhou High & New Technology Industries Development Zone
Henan Province, China
+86-371-85511303
thunderzh@126.com
*corresponding author

Wang weigong
Zhengzhou research institute of mechanical engineering
No.10 Fengyang Street, Zhengzhou
High & New Technology Industries Development Zone
Henan Province, China
+86-371-67710950
2538098051@qq.com

ABSTRACT

Cycloid gear is one of RV Reducer core components used in Robot. Its accuracy of the tooth profile curve plays an important role in meshing transmission of RV Reducer. According to the mathematical model of cycloid curve, three kinds of dynamic forming process of cycloid are respectively realized by means of MATLAB software, which have strong simulation and graphics designing functions, including the wheel rolling along a straight line, along outside the circumference of a circle and along inside the circumference of a circle. Then, visual design of the cycloid tooth profile curve is developed in paper, including epicycloid and hypocycloid. And flow chart for parametric design of cycloid curve is done. Finally, parametric design of three kinds of cycloid curve is realized by GUI program. These works will lay the foundation for the cycloid gear's designing and profile modification and NC machining, and so on.

CCS Concepts

• **Robotics and Mechanical Engineering**

Keywords

Cycloidal Gear Profile; RV reducer; Visual Design

AIACT '17, April 07-09, 2017, Wuhan, China

ACM ISBN 978-1-4503-5231-4/17/04…$15.00
http://dx.doi.org/10.1145/3080845.3080860

1. INTRODUCTION

The promulgation of Industry 4.0 and the "Made in China (2025)" greatly promoted the development of industrial robot industry. However, as the core component of industrial robot, RV reducer has been one of the key technologies of restricting the development of robot industry in China. While, cycloid gear is the important part in RV reducer. The cycloid tooth profile curve of designing, modification, processing and so on would directly affect the all performance of RV reducer. Therefore, many domestic and foreign scholars have made a lot of further research about the cycloid equation and its properties [1-4]. From dynamic simulation perspective, the visual parametric design of cycloid profile by using Matlab software will be done in paper, in order to further study the dynamic performance of the RV reducer.

2. THE MATHEMATICAL MODEL OF CYCLOID CURVE

According to the definition of cycloid, the cycloid curve is a point moving trajectory generated by a point on the circumference of a circle that rolls along a curve (which is called baseline). When the baseline is a straight line, the trajectory is a flat cycloid or an amplitude cycloid.

Let a moving circle, whose radius is r, roll along X axis from coordinate origin, then

Its parameter equation is

$$\begin{cases} x = r(\varphi - \sin\varphi) \\ y = r(1 - \cos\varphi) \end{cases} \quad (1)$$

In which φ is central angle that moving circle has rolled, as shown in Figure 1.

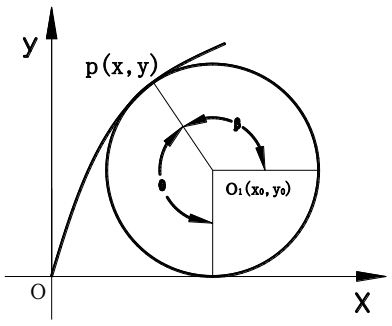


Figure1. The formation of cycloid

When the baseline is a circle, whose radius is R , if the moving circle is pure rolling along outside of the base circle, the trajectory is an epicycloid or a variable amplitude epicycloid; if the moving circle is pure rolling along inside of the base circle, the trajectory is a hypocycloid or a variable amplitude hypocycloid.

There are two methods to realize cycloid curve, including the circumscribed external rolling and the endonuclease external rolling. As shown in Fig 2, a moving circle, whose radius is r, is pure rolling along a base circle, whose radius is R . When the moving circle rolls from point A_1 to point A_2, the rotating angle in the moving circle is β, the corresponding central angle of a base circle is θ.

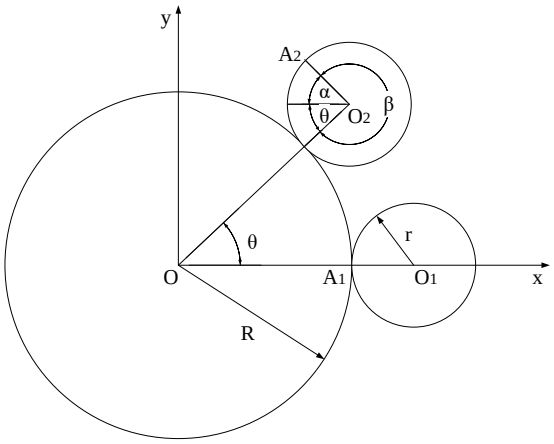


Figure 2. The formation of epicycloid

According to the above geometric relations, the parameter equation of epicycloid can be derived

$$\begin{cases} x=(R+r)\cos\theta-\cos\left(1+\dfrac{R}{r}\right)\theta \\ y=(R+r)\sin\theta-\sin\left(1+\dfrac{R}{r}\right)\theta \end{cases} \quad (2)$$

Simultaneously, the parameter equation of hypocycloid is:

$$\begin{cases} x=(R-r)\cos\theta+\cos\left(1-\dfrac{R}{r}\right)\theta \\ y=(R-r)\sin\theta+\sin\left(1-\dfrac{R}{r}\right)\theta \end{cases} \quad (3)$$

3. DYNAMIC FORMATION AND VISUAL DESIGN OF THE CYCLOID

3.1 Dynamic formation process of the cycloid curve

Based on the principle of the formation of cycloid and its equation, the formation process of the cycloid curve can be divided into two sections, that is, the circle moving along the line and circular motion of the point on the circumference. Simulation process of cycloid motion is realized by for loop program in Matlab, and saved by getframe function, as shown in fig. 3.

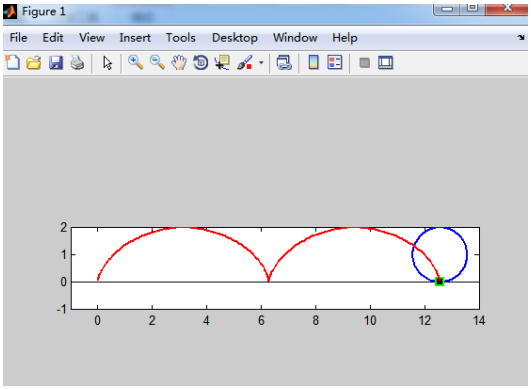
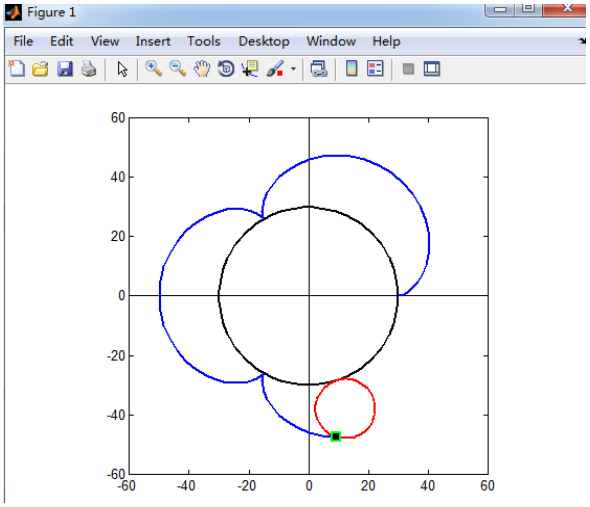


Figure 3. The dynamic trajectory of flat cycloid

3.1.1 Epicycloid dynamic formation process

First set the basic parameters of the base circle and dynamic circle, such as base circle radius r=10, rolling radius R=30, move round in office a little along the base circle rolling, rolling track is the cycloid. According to the above cycloid equation, the rolling numerous uniform, on the dynamic circle tag, make moving round rolling, slip along the base circle do not write logic program, dynamic simulation graphics as shown in figure 4.



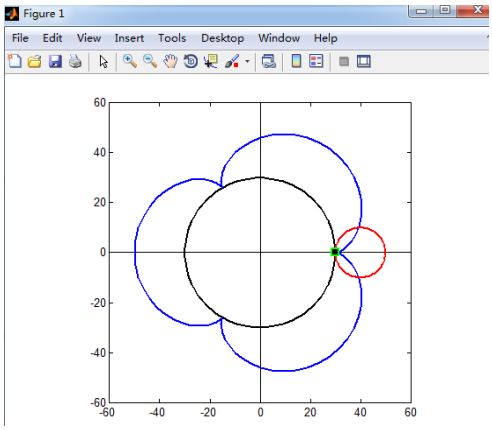


Figure 4. Dynamic trajectories of the epicycloid

3.1.2 Hypocycloid dynamic formation process

Difference between hypocycloid and epicycloid mainly lies in the round, respectively in the base circle on both sides of inside and outside. Therefore, the M documentation of Matlab software related to the original epicycloid program symbols are changed with the number processing, the cycloid trajectory can be realized the dynamic design of simulation graphics as shown in figure 5.

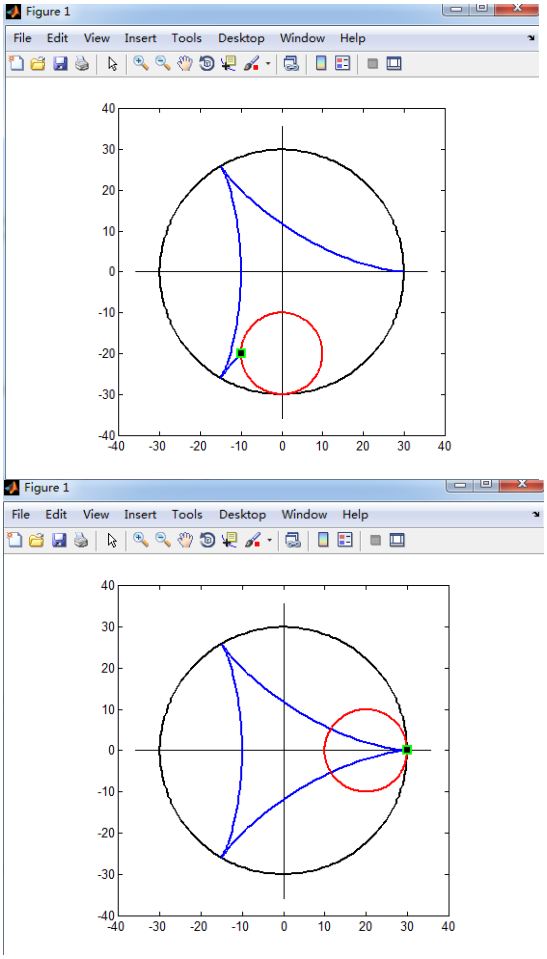


Figure 5. Dynamic trajectories of the hypocycloid

3.2 Dynamic formation and visual design of cycloid

To realize dynamic visual design of different parameters cycloid curve and cycloidal gear profile, the following flow diagram is specially presented, as shown in figure 6. By visualizing the graphical user interface（GUI）background program, the user can freely set the related parameters, and directly observe the forming process of visual difference cycloid lays the foundation for further cycloid tooth profile curve design, GUI interface as shown in figure 7. To check the more direct parameterized effect, the rolling motion is specially kept, as shown in figure 8. Figure 9 is the internal cycloid, just in the rolling radius of base circle radius is larger than the form.

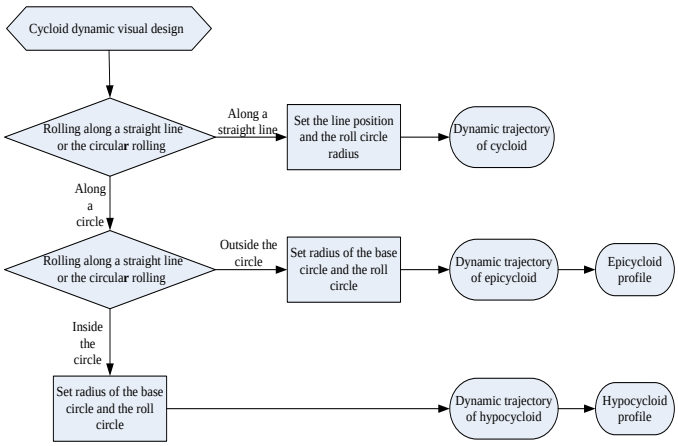


Figure 6. Flow chart of cycloid dynamic visual design

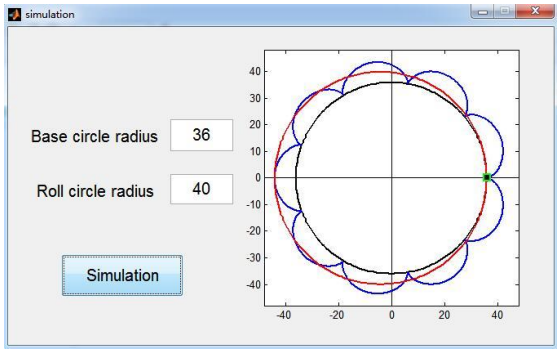


Figure 7. GUI interface of cycloid dynamic trajectory

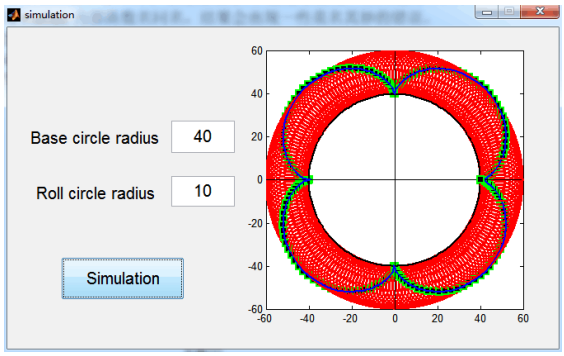


Figure 8. Dynamic visual design of epicycloid

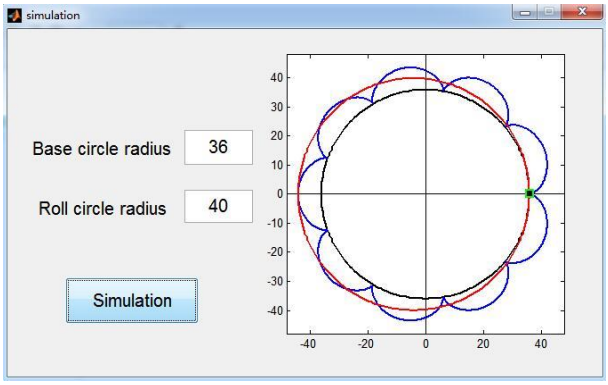


Figure 9. Dynamic visual design of hypocycloid

3.3 Software development for parametric visual design of cycloid gear profile

The purpose of studying the cycloid curve is to obtain more accurate cycloid gear profile. Therefore, on basis of the aforesaid discussion and related literatures [5-11], the software for different parametric visual design of cycloid curve/gear profile is developed in paper. The interface of the software is shown in fig. 10. Some functions could be realized in the software, such as flat cycloid or hypocycloid or epicycloid or cycloid gear profile with different parameters. The software will provide convenience for geometric modeling of the cycloid gear profile. Some interfaces of dynamic visual design for the different parameters cycloidal type curve are designed, as shown in figs. 11-13. Some different parameters cycloid gear could be designed by the software, as shown in figs. 14.

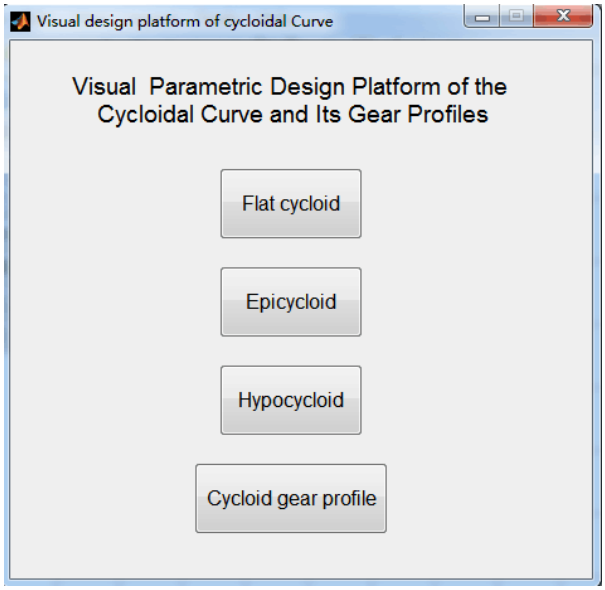


Figure 10. The interface of dynamic visual design platform for the cycloid curve and its gear profiles

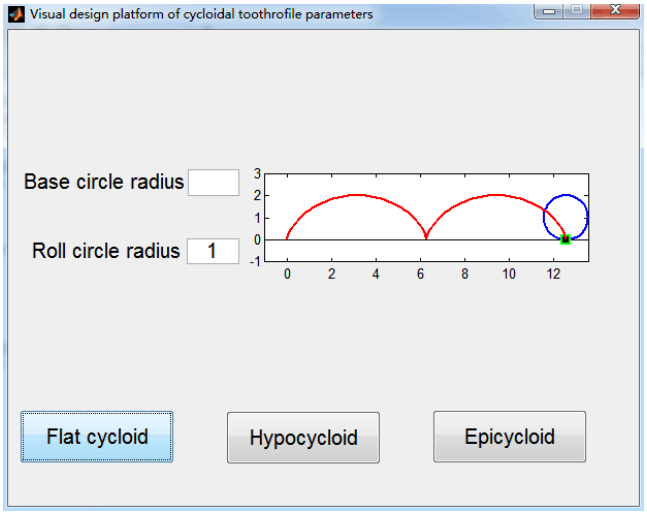


Figure 11. The interface of dynamic visual design for the different parameters flat cycloid curve

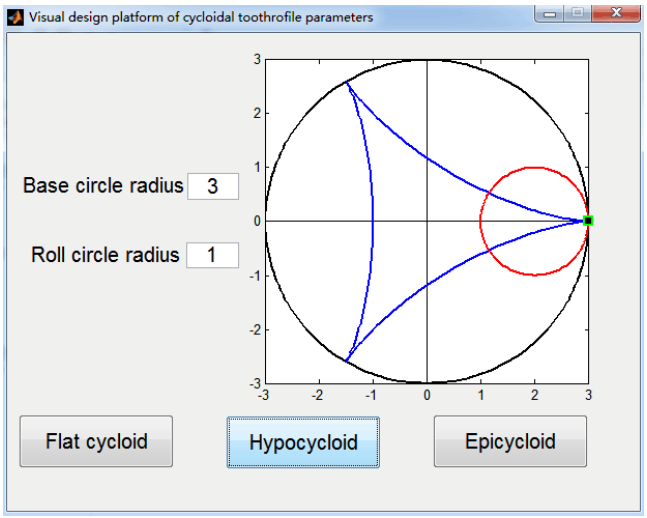


Figure 12. The interface of dynamic visual design for the different parameters hypocycloid curve

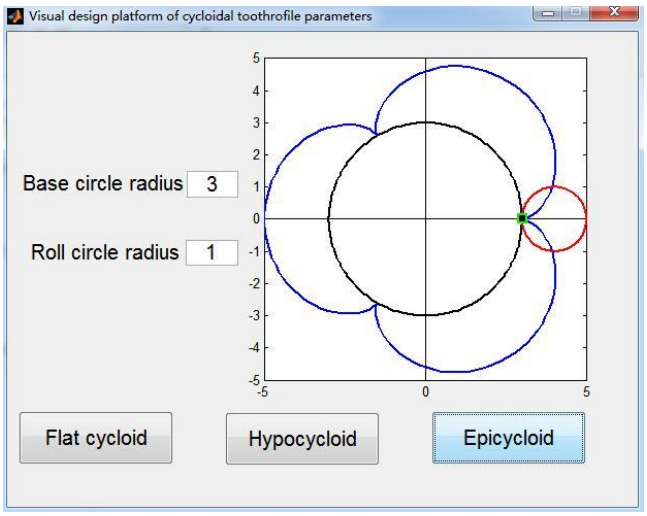


Figure 13. The interface of dynamic visual design for the different parameters epicycloid curve

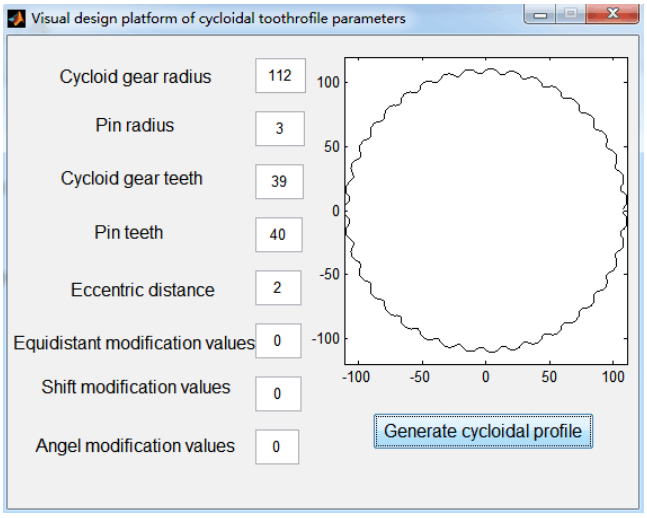


Figure 14. The interface of dynamic visual design for the different parameters cycloid gear

4. CONCLUSION

Based on the analysis of the mathematical model of cycloid curve, three kinds of dynamic forming process of cycloid are respectively realized by means of MATLAB software, which have strong simulation and graphics designing functions, including the wheel rolling along a straight line, along outside the circumference of a circle and along inside the circumference of a circle. Then, visual design of the cycloid tooth profile curve is developed in paper, including epicycloid and hypocycloid. And flow chart for parametric design of cycloid curve is done. Next, parametric design of three kinds of cycloid curve is realized by GUI program. Finally, software for different parametric visual design of cycloid curve/gear profile is developed in paper. These works would provide the effective analysis and basis for studying on the meshing theory and tooth profile modification of the cycloidal gear used in RV reducer.

5. ACKNOWLEDGMENTS

The project were supported by Henan province Science and Technology Major Project （ 161100210100 ） and the Key Laboratory of modern manufacturing equipment and instruments of Henan（No.2017MEI001）.

6. REFERENCES

[1] W. Baomin. Research onCycloid Characteristics [J]. Mechanical Science and Technology, 2002, 21（1）: 61～62

[2] Yii-Wen Hwang,Chiu-Fan Hsieh.Geometry Design and Analysis for Trochoidal Type Speed Reducers: with Conjugate Envelopes[J].Transactions of the CSME,2006,30（2）;261～278

[3] Z. Linlin. Dynamic Model Based on Mathematica 7.0 Design Epicycloid Trajectory [J].Journal of Xiangyang Vocational and Technical College,2013,12（1）;31～33

[4] W. Wentao, X. Honghai, L. Xueao, F. Yubin. The Theoretical Study About Characteristics of Curtate Cycloid and Its Tooth Profile [J].Machinery Design & Manufacture,2016,32（1）;94～97

[5] S.K Malhotra,M.A Parameswaran.Analysis of a Cycloid Speed Reducer[J].Mechanism and Machine Theory,1983,18（6）;491～499

[6] Faydor L. Litvin,Pin-Hao Feng.Computerized design and generation of cycloidal gearings[J].Mechanism and Machine Theory,1996,31（7）;891～911

[7] Z. Luoping,H. Zhenyu,Z. Fengshou,S. Shaojie. Research on Tooth Shape of RV Reducer Cycloidal Gear [J].Machine Tool & Hydraulics,2016,44（1）;32～35

[8] Giorgio Figliolini,Hellmuth Stachel,Jorge Angeles.On the synthesis of spatial cycloidal gears[J].Meccanica,2013,48（5）;1239～1249

[9] Ivan PANTIĆ,Mirko BLAGOJEVIĆ.Kinematic Analysis of Single-Stage Cycloidal Speed Reducer [J].Mechine Design,2015,7（4）;113～118

[10] A. I. Siritsyn,V. N. Bashkirov,E. V. Shirokikh,D. A. Sinitsyn.Kinematic Precision of a Planetary Cycloid–Pin Machine–Tool Drive[J].Russian Engineering Research,2016,36（2）;89～92

[11] H. Yi, S. Chaosheng. Visual design of cycloid pin gear planetary reducer [J].Digital Manufacturing Industry,2006,（6）;52～53