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Modal Analysis of Cycloid Used in RV Reducer

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Abstract: Cycloid part is the key part of the robot RV reducer and its performance directly affects the the movement accuracy of the reducer. The modal of cycloid is established in finite element analysis system, analyzes cvcloidal gear's natural characteristics with the ANSYS Workbench software, it is the foundation of the dynamic analysis of the RV reducer.

Keywords: cycloid part;RV reducer;modal analysis; finite element analysis

I. INTRODUCTION

At present, the robot is more and more widely used in industrial production， with the development of technology, the industrial robots have strong market development prospect.

In 1926, the Lorenz Blanc who is German creatively proposed less teeth planetary transmission mechanism.The planetary transmission mechanism is with epicycloid as tooth profile curve, which is the earliest cycloid drive, due to one of the two meshing gears using pin wheel, the transmission was also called cycloidal pin wheel planetary gear transmission.In the 1970s, a West German manufacturing company produced two kinds of winches which used double cranks and planetary reducer with less teeth .However,the French patent office also released a kind of planetary reducer,which includes a kind of cycloid and involute,this kind of reducer is very similar to the structure of RV reducer.The concept of RV transmission was first proposed by Japanese Teijin Co.,Ltd. (Teijin Seiki Co., Ltd) in the early eighties of the last century,due to the market ask for motion accuracy quickiy improve at this time,making this compancy started to develop deceleration device that can be used to improve robot performance and motion accuracy,and then named as RV transmission.Up to now,Japan's Sumitomo heavy machinery company is one of the biggest scale enterprises which manufacturing cycloidal wheel reducer of the global,basically has monopolized the market in the field of reducer in global,especially enter into 1990s,this company has launched some models of deceleration device,such as the "200 series", "R-V series", "Fa high precision transmission series","FT transmission series".Its product has a big drive ratio,the first order transmission ratio is beyween 6 and 119;it has broad range of applications.not only the universal transmission,but also the professional robot drive.

RV drive is a new kind of transmission ， it is developed on the basis of traditional needle swing planetary transmission.It is not only overcome the general pin cycloid transmission faults,but also owns a series of advantages,such as small volume,light weight,large range of transmission ratio,long life,stable accuracy,high efficiency and stable transmission.Increasingly attracted widespread attention at home and abroad.Therefore, it is widely used in the mechanical and electrical drive, especially in the field of robot.RV reducer is a new form of cycloid transmission mechanism which is composed of an involute planetary transmission mechanism and a cycloidal pin wheel planet transmission mechanism in actually,in the low speed end of the RV reducer, the output shaft is directly connected with the pin.the transmission error will be directly reflected in the output shaft. The main structure of RV reducer is the planetary transmission structure.In this structure,the cycolidal part is one of the most important part.Therefore, the transmission accuracy of the cycolidal part is the key factor to determine the accuracy of RV reducer.

II. BUILDING SOLID MODELS

2.1 Coordinate equation of the cycloidal

According to reference[1],coordinate equation of the cycloidal in the cartesian coordinate system is expressed as follows:

$$X=dr_p \cdot \sin\left(\left(1-i\right)\cdot \alpha\right)-dr_{rp} \cdot \sin\left(i\cdot \alpha\right) \quad (1)$$

$$Y=dr_p \cdot \cos\left(\left(1-i\right)\cdot \alpha\right)+dr_{rp} \cdot \cos\left(i \cdot \alpha\right) \tag{2}$$

$\alpha=360 \cdot Z_c \cdot t$; t=0~1; $Z_p = Z_c + 1$; $K = A \cdot Z_p / (r_p + \Delta r_p)$ is the short amplitude coefficient; $i = Z_p / Z_c$ is relative transmission ratio; ; $\triangle r_{rp}$ is isometric profile;r_p is distance and shape modification.

$$S_r = 1 + K^2 - 2 \cdot K \cdot \cos\alpha \tag{3}$$

$$dr_p = r_p + \Delta r_p - \left(r_p + \Delta r_p\right) \cdot Sr^{1/2} \tag{4}$$

$$dr_{rp} = -\left(A / \left(r_p + \Delta r_p\right)\right) \cdot \left(\left(r_p + \Delta r_p\right) - Z_p \cdot \left(r_p + \Delta r_p\right) \cdot Sr^{-1/2}\right) \tag{5}$$

2.2 Solid model

A solid model is established as shown in Fig. 1.

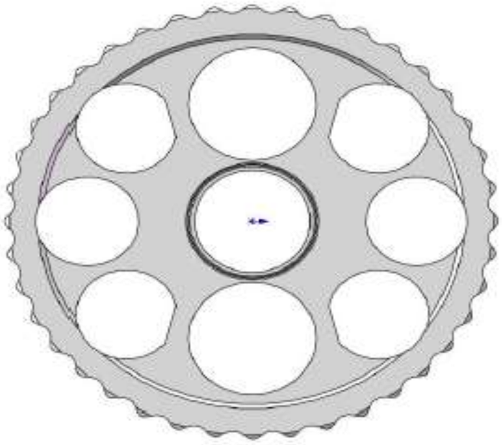

Fig.1 SolidWorks solid model

III. FINITE ELEMENT INTRODUCTION

The method of finite[2] elements is one of the main tools for the numerical treatment of elliptic andparabolic partial differential equations.Because it is based on the variational formulation of the differential equation,it is much more flexible than finite difference methods and finite volume methods,and can thus be applied to more complicated problems.For a long time,the development of finite elements was carried out in parallel by both mathematicians and engineers,without either group acknowledging the other.Finite element method is the most widely used numerical calculation method in the engineering analysis field today,such as mechanical engineering,aerospace, automobile, shipbuilding, civil engineering.In recent years,with the development and progress of computer technology, the finite element method has been developed and popularized rapidly and has become an integral part of computer aided engineering.

The results of finite element method in the engineering field have attracted the attention of the mathematical world.In the last century 60 to 70s, the mathematical workers made a scientific and effective research on the error of the finite element, convergence and stability of the results.Scholars in China have done a lot of fruitful work in the early stage of the development of the finite element method,such as Chen Boping's researching method of structure matrix,Qian Lingxi ' s researching based on complementary energy principle;Qian Weichang ' s researching based on generalized variational principle;Fengkang has put forward a new idea based on the variational problem.

IV. MODAL ANALYSIS

Modal analysis is a numerical technique of calculating the structures vibration, which includes natural frequencies and modes of vibration.Modal analysis is the most basic dynamic analysis, but it has a very wide range of practical value.Modal analysis can help designers to determine the natural frequency and vibration mode of the structure, so as to avoid the resonance of the structure design, and guide the engineers to predict the vibration mode of the structure under different loads.In addition, modal analysis is also useful to estimate the kinetics in other analysis parameters, such as transient dynamic analysis.In order to ensure the accuracy of3 | calculating dynamic response, transient dynamic analysis usually requires the structure of a self vibration period of not less than 25 points calculation.Modal analysis can determine the structure self vibration cycle, thereby helping to determine a reasonable transient analysis time[3].

RV reducer has the advantages of small size, light weight, large range of transmission ratio, hightransmission efficiency, stable transmission, simple structure, large bearing capacity, etc., and it is widely used in many industry fields.With the increase in high speed, heavy load and running smoothly,if the structure of RV reducer is reasonable,it's dynamic performance will have problems and generate larger vibration and noise in the working process.In order to ensure the natural frequency and vibration mode and avoid the resonance and the occurrence of harmful vibration mode,it is necessary to have finite element modal analysis on cycloid part and thus it makes the foundation for the further dynamic analysis.

4.1 Modal analysis foundation

According to the reference[4], the modal analysis of the non damping is a classical eigenvalue problem, and the motion equation of the dynamic problem is shown as follows:

$$[\mathrm{M}]\{\mathrm{x}''\}+[K]\{\mathrm{x}\}=\{0\} \quad (6)$$

The free vibration of structure is harmonic vibration,namely the displacement is a sine function: $x = x\sin(\omega t)$ （7）

Combined (6) and (7) can be obtained:

$$([K]-\omega^2[M])\{\mathrm{x}\}=\{0\} \quad (8)$$

The (6) is a classical eigenvalue problem and it's eigenvalue is ω_i^2,and ω_i is self vibration circle frequency, $f=\omega_i/2\pi$ is self vibration frequency.

4.2 Finite element modal analysis

(1) Importing SolidWorks solid model into ANSYS Workbench.

(2) Adding engineering data source,namely define Young ' s Modulus(EX=206GPa),Poisson ' s Ratio(μ =0.3),Density(ρ=7850Kg /m3).

(3) Dividing mesh,namely define Relevance is 100,Element Size is 1e-3m,Relevance Center is Fine,Smoothing is High,the other is default settings.The generated number of nodes and elements is respectively 116389 and 68799,and Mesh Metric is None.

(4) Imposed loads and constraints， namely the X, Y and Z direction displacement of the middle circular hole is 0,the rotational speed of the cycloid gear is 5 rad/s.

(5) Extracting the first eight mode.The result is shown in Fig.2.

Tabular Data

	Mode	Frequency [Hz]
1	1.	2237.2
2	2.	2603.5
3	3.	2780.2
4	4.	3361.4
5	5.	3431.
6	6.	3668.2
7	7.	6777.3
8	8.	6897.8

Fig.2 The first eight mode

(6)Total Deformation analysis is shown in Fig.3~Fig.10.

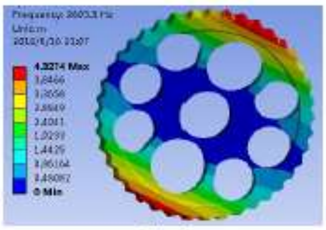

Fig.3
The first stage modal total deformation

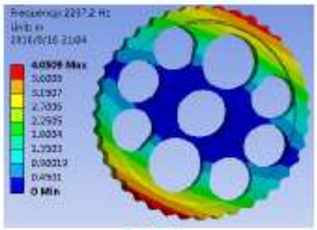

Fig.4
The second stage modal total deformation

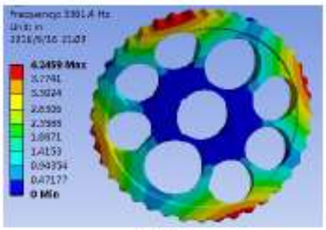

Fig.5
The third stage modal total deformation

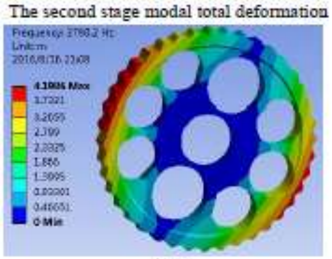

Fig.6
The forth stage modal total deformation

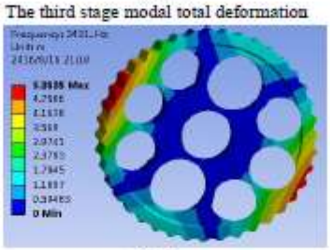

Fig.7

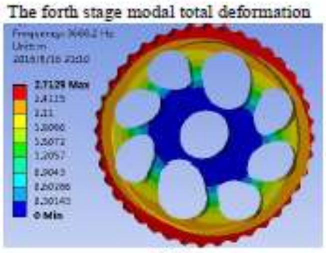

Fig.8

The fifth stage modal total deformation

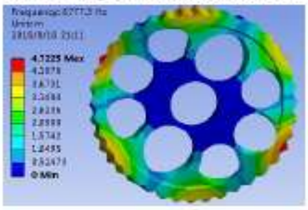

Fig.9

The sixth stage modal total deformation

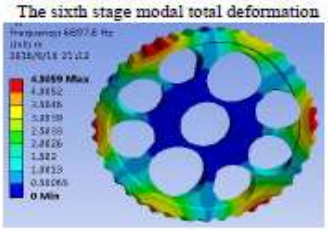

Fig.10

The seventh stage modal total deformation

The eighth stage modal total deformation

V. CONCLUSION

There is a first eighth stage natural frequency through ANSYS Workbench analysis of cycloid part,it provides a theoretical basis for the dynamic performance test of cycloid drive and makes a foundation for further dynamic analysis.

REFERENCES

[1]. Junjun Xiao,Weidong He.Modal Analysis of Cycloid of RV Reducer[J].Mechanical Engineer,2009(9):46-47.
[2]. Dhatt, Gouri; Lefranois, Emmanuel; Touzot, Gilbert..Finite Element Method[M].WILEY,2012-10(1).
[3]. Jinfeng Xu.Completely self a pass[M].Publishing House of Electronics Industry,2014(1):183.
[4]. Daryi L.Logan.A First Course in the Finite Element Method. Publishing House of Electronics Industry,2014(8):3