IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 05, Issue 10 (October. 2015), ||V3|| PP 01-06

Dynamic Characteristics Analysis of Helicopter Planetary Gear Train

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ABSTRACT: Helicopter planetary gear train with compact structure, large transmission range, powerful bearing capacity, is one of the most important part of helicopter drive system. But because of sympathetic vibration, drive systems are easily destroyed in the actual work condition, which can cause an immeasurable loss. So in the design stages of planetary gear train, it is important to get the inherent characteristic in the actual working conditions by finite element method .In this paper, use the three-dimensional modeling software CATIA to establish the parametric Three-dimensional entity model and assembly of gear in the planetary gear train .Then have a interference analysis, and a data conversion. After three-dimensional solid model of planetary gear train is imported into the finite element software WORKBENCH, the contact among all the parts will be automatically identified .According to the actual work condition of planetary gear train, add corresponding constraints to the sun wheel, planet wheel, gear ring, disc planet carrier. Finally, conduct a modal analysis for finite element model of the entire planet gear train to get the first ten steps natural frequency and corresponding vibration mode .Using this method, we can avoid these areas to prevent sympathetic vibration in the whole design process of the planetary gear train, so as to improve the quality of the gear system, as well as to lay a foundation for the dynamic response calculation and analysis of the planetary gear train.

Keywords: *helicopter; planetary gear train; dynamic characteristics analysis*

I. INTRODUCTIONS

Planetary gear train with compact structure, small Volume, large capacity, large range of transmission and high efficiency, is a kind of advanced gear transmission mechanism. In the practical work, resonance and deformation may occur in the planetary gear train, they will affect transmission stability and accuracy, and even cause the destruction of the entire transmission system. So, in the design of planetary gear system, we not only make it meet the conditions of stiffness and strength but also prevent its happen resonance. In the planetary gear train design phase, it is necessary to obtain the inherent characteristic, but the experimental data of inherent characteristics are difficult to get, only theoretical calculation can obtain the parameters of dynamics analysis. At present, the finite element analysis method is the best way. Generally, existing research have the modal analysis only for a single gear[1]. There are very few researches on modal analysis of the planetary gear train[2][3][8]. In this paper, we choose a 2 K-H planetary gear train as the research object.

1 CATIA Parameterized Modeling of Planetary Gear Train

1.1 The Geometric Parameters of Gears in Planetary Gear Train

The geometric parameters of each gear in planetary gear train are shown in table 1. The addendum coefficient ha * = 1, tip clearance coefficient c * = 0.25.

Table 1 The geometric parameters of gears in planetary gear train

	Tooth number	Modulus(mm)	Pressure angle (degree)	Tooth width(mm)
Sun gear	92	2.5	20	12
Planet gear	32	2.5	20	12
Gear ring	28	2.5	20	12

1.2 Planetary Gear Train Parameterized Modeling

Because the gears have complex curved surface and the CATIA has more powerful curved surface modeling function, we used the CATIA to modeling in this article. The followings are the detailed modeling steps.

a) Cylindrical spur gear modulus, tooth number and pressure Angle are set to change parameters by using the f (x) of knowledge base in the CATIA.

b) According to the cylindrical spur gear geometry size formula and set parameters, base circle radius, reference circle radius, root circle radius and addendum circle can be calculated, then the corresponding circle are drawn.

c) Parameterized equation of the involute about x and y is established by using rule base Fog, then the involute is drawn. Create a mirror plane and mirror the involute.

d) According to the boundary of the tooth profile, a complete tooth shape is drawn, and stretched into entity.

e) After arraying gear teeth along the reference circle, the complete cylindrical spur gear entity is got.

The three-dimensional entity models the sun gear and the planet gears are obtained by changing the parameters we have set. Modeling method of ring gear is similar to that of cylindrical spur gear, so we will not introduce. After drawing the disc planet carrier, we assemble them and have interference analysis. Therefore we can get three-dimensional entity model of planetary gear train, as shown in figure 1.

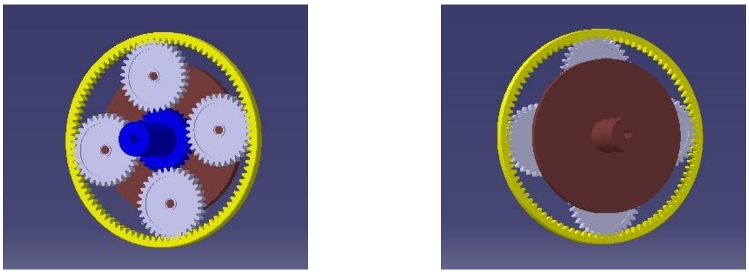


Fig.1 Three-dimensional entity model of planetary gear train

II. MODAL ANALYSIS OF PLANETARY GEAR TRAIN

2.1 Importing of Entity Model and Contact Settings

The built three-dimensional entity model data in CATIA convert into the igs, and is imported into the WORKBENCH. It will automatically identify the contacts among all the parts, and the default contacts are Bonded. The modal analysis is a purely linear analysis, so there are only two linear contacts that are Bonded and No Separation. The Bonded is that the contact surfaces and lines are not allowed to relative slide or separation; The No Separation is that the surfaces of contact area are not allowed to separate, but can have small slide without friction. So choosing No Separation is more suitable to the actual situation.

2.2 Model Material Property Settings

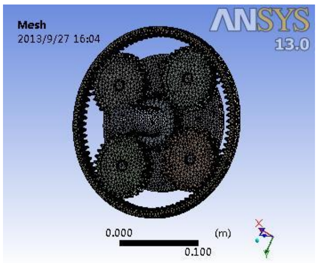
Setting material properties of the parts according to table 2 in Engineering Data

Table 2 Material properties of the parts

	Density（kg/m^3）	Poisson ratio	Elasticity modulus（pa）
Sun gear	7910	0.27	2.02×10^{11}
Planet gear	7910	0.27	2.02×10^{11}
Gear ring	7850	0.28	2.12×10^{11}
Disc planet carrier	7850	0.28	2.12×10^{11}

2.3 Meshing of Model

After setting material properties, we have a meshing for whole planet gear train.
In this paper, the free meshing is used, 167120 units and 280566 nodes are got. The mesh model is shown in figure 2.



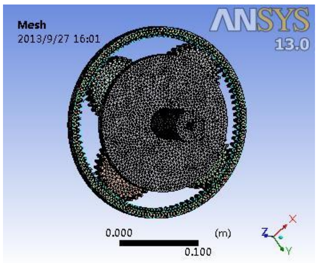


Fig. 2 The mesh model

2.4 Imposing Degrees of Freedom Constraints

Prestress is not considered in modal analysis of the planetary gear train. In the WORKBENCH, we impose corresponding constraints for sun gear, planet gears, gear ring , disc planet carrier according to their actual working conditions.

a) Gear ring constraint: Because gear ring is fixed in the practical work, a Fixed Support is added in the outer surface of the gear ring.

b) Sun gear constraint: Sun gear is inputting power gear, and has the rotational freedom, so a Cylindrical Support is added in the center hole of sun gear, and the tangent is set to Free, the axis and radial are set to Fixed. Therefore, the sun gear has the rotational freedom.

c) Planet gear constraint: The planet gears have a rotation around its own axis and a revolution around the sun gear, so a Cylindrical Support is added in the center hole of planet gear, and the axis is set to Fixed, the tangent and radial are set to Free.

d) Disc planet carrier constraint: the disc planet carrier and the planet gear are connected by a small shaft fixed on the disc planet carrier, so Cylindrical Supports are added in outer surfaces of the small shafts, and the tangent is set to Free, the axis and radial are set to Fixed.

2.5 Solution

After adding constraints, we set the method to extract the modal to Subspace. We know that high natural frequencies and mode shapes impact on the system is negligible, the accuracy is sufficient by usually take 5-10 order, considering to the actual situation and computation time, 10 order is the modal order of the solver. The first 10 order natural frequencies are shown in table 3. The first 10 vibration modes are shown in figure 3.

Table 3 The first 10 order natural frequencies

order	inherent frequency（Hz）	order	inherent frequency（Hz）
1	1711.6	6	3562.3
2	2668.2	7	3564.6
3	3257.6	8	3564.8
4	3263	9	3937.4
5	3519	10	4207.3

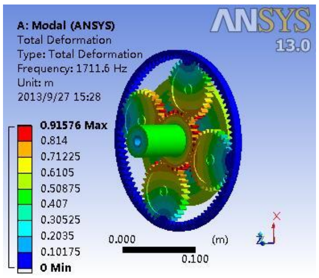
2.6 Result Analysis

1) The first 10 order natural frequency of planetary gear train is concluded from table 3. In case of resonance, advancing to avoid these frequency region on design the planetary gear train is indispensable.

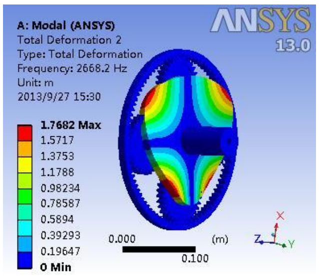
2) From the figure 3，The first 10 vibration modes of planetary gear train are the torsion ,swing vibration of sun gear, planet gear and disc planetary carrier, the ring gear vibration is relatively small.

III. CONCLUSION

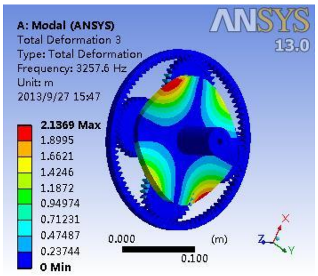
Parametric entity modeling of the planetary gear train is established by the three-dimensional modeling software CATIA. The established model is imported into WORKBENCH by data conversion. The natural frequencies and the corresponding vibration modes of the first 10 order are calculated, distribution of the natural frequency



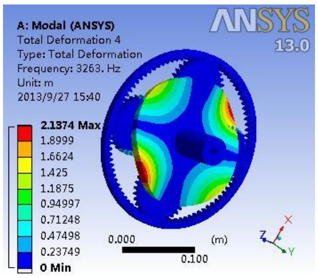
The first order



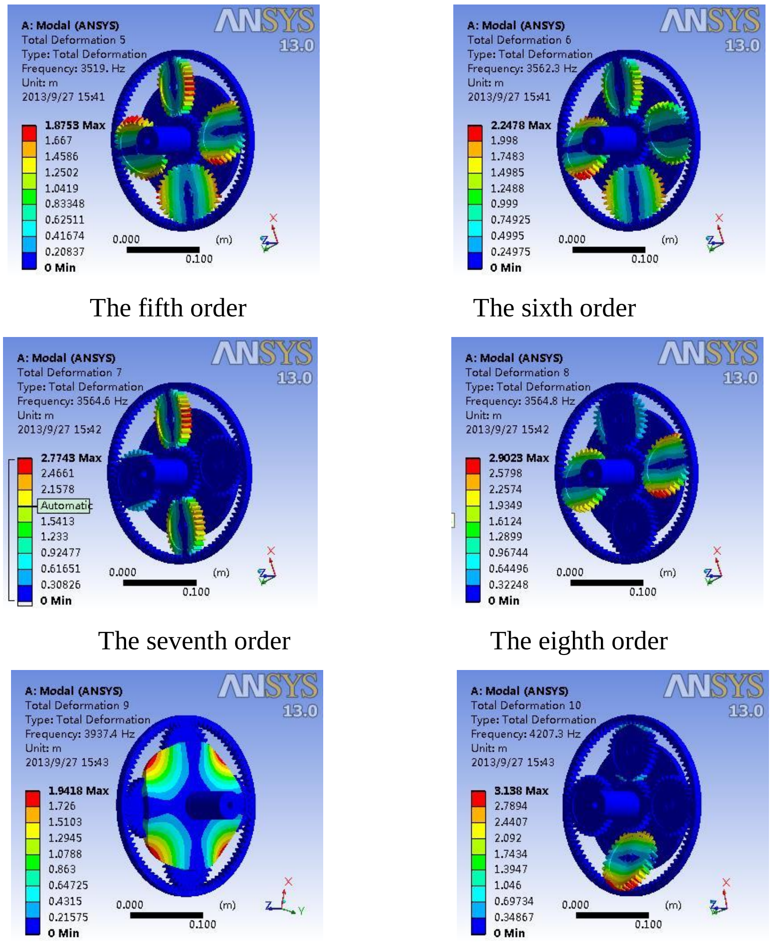
The second order



The third order



The fourth order



The fifth order The sixth order

The seventh order The eighth order

The ninth order The tenth order

Fig. 3 The first 10 vibration modes

and corresponding modes are obtained. In case of resonance, advancing to avoid these frequency region on design of the planetary gear train is indispensable. The quality of the planetary gear train is improved, at the same time, the other dynamics analysis train (harmonic response analysis and transient dynamic analysis, etc.) are based on the result of modal analysis of planetary gear train.

IV. ACKNOWLEDGEMENTS

This work is supported by the National Natural Science Foundation of China (51575177), and the Outstanding Young Program of Hunan Provincial Education Department (14B057).

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