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Research on Finite Element Model Generating Method of General Gear Based on Parametric Modelling

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Abstract. Aiming at the problems of low efficiency and poor quality of gear meshing in the current mainstream finite element software, through the establishment of universal gear three-dimensional model, and explore the rules of unit and node arrangement. In this paper, a finite element model generation method of universal gear based on parameterization is proposed. Visual Basic program is used to realize the finite element meshing, give the material properties, and set the boundary / load conditions and other pre-processing work. The dynamic meshing analysis of the gears is carried out with the method proposed in this pape, and compared with the calculated values to verify the correctness of the method. The method greatly shortens the workload of gear finite element pre-processing, improves the quality of gear mesh, and provides a new idea for the FEM pre-processing.

1. Introduction

At present, in view of the problems such as NVH, lightweight, structural strength checking and so on, the traditional tedious and complicated analytical calculation method cannot meet the requirement of Engineering problems. With the development of computer simulation technology, the design and check of the finite element method has been widely used in automotive transmission, but the process in finite element calculations, with extremely tedious become the main problem in engineering and technical personnel .

In the finite element software, the finite element modeling of the gear and the application of the pretreatment conditions also depend on the manual operation. ANSYS, Hyper mesh, Abacus and other mainstream commercial finite element analysis software for the finite element analysis of the gear, and there is no better solution.

This paper first establish general gear tooth profile curve equation of the unified coordinate system, and then follow the INP file rule generating gear unit node coordinates and the corresponding arrangement of law, impose conditions with material properties and the boundary are given at the same time, finally compile executable program in the Visual Basic 6 environment .

2. Establishment of gear tooth profile equation

Taking the circle center of the gear as the coordinate origin, the gear tooth profile curve coordinate system is set up with the single tooth face as the left and right symmetry, and the gear tooth profile coordinate system is shown in figure 1. In the tooth profile curve coordinate system, the tooth profile involute (2-3) equation and the tooth root transition curve (3-4) equation of a single gear are deduced theoretically.

2.1 gear tooth profile involute equation

The polar coordinate equation of involute gear tooth profile is shown in figure 2.

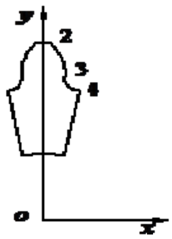

Fig.1 Coordinate of gear tooth profile curve

From the graphical parameters:

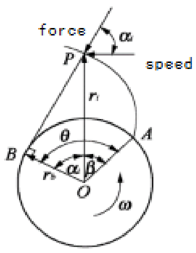

Fig.2 Polar coordinates of gear involute curve

$$\tan\alpha = \frac{\overline{BP}}{\overline{OB}} = \frac{\widehat{AB}}{r_b} = \frac{r_b(\alpha+\beta)}{r_b} = \theta \tag{1}$$

In the formula: ri is the radius of any point; rb is the radius of the base circle; α is the pressure angle at any point; θ is AB segment angle.α+β=θ.

The gear involute polar coordinate system is converted into a rectangular coordinate system, as shown in figure 3.

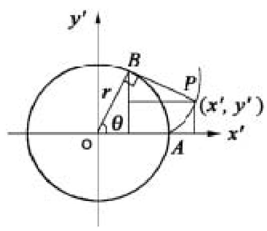

Fig.3 Rectangular coordinate system

In the xoy coordinate system, the coordinates of any point P (x, y) can be expressed as:

$$\begin{cases} x = x'\cos\delta + y'\sin\delta \\ y = -x'\sin\delta + y'\cos\delta \end{cases} \tag{2}$$

δ is the rotation angle.

Thus, the expression of P at any point on the involute gear tooth profile in xoy coordinate system can be obtained:

$$\begin{cases} x = (r_b \sin\theta - \tan\alpha_k \cdot r_b \cdot \cos\theta)\cos\delta - \\ (r_b \cos\theta + \tan\alpha_k \cdot r_b \cdot \sin\theta)\sin\delta \\ y = (r_b \sin\theta - \tan\alpha_k \cdot r_b \cdot \cos\theta)\sin\delta + \\ (r_b \cos\theta + \tan\alpha_k \cdot r_b \cdot \sin\theta)\cos\delta \end{cases} \tag{3}$$

2.2 dedendum transition curve equation

The gear machining process, gear cutter fillet processing gear root transition curve should be established, as shown in Figure 1 of the gear tooth profile curve coordinate system, get the right gear tooth root transition curve of the equation (3-4).

The schematic diagram of the tooth profile of the cutter is shown in figure 4.

The following parameters are shown in the diagram:

$$\begin{cases} a = h_a^* m + c^* m - r_\rho \\ b = \dfrac{\pi m}{4} + h_a^* m \times \tan\alpha + r_\rho \cos\alpha \\ r_\rho = \dfrac{c^* m}{1 - \sin\alpha} \end{cases} \tag{4}$$

Using the rack type cutter to process the gear, the gear tooth profile is the cutting tool processing line and the gear processing pitch circle (graduation circle) is tangent to the pure rolling to form, as shown in figure 5. P is a node, NN is the normal line of the contact point between the fillet of the tool and the transition curve, and the angle between the NN and the cutting line of the cutter. If the coordinate system is shown in Figure 5, the involute equation can be:

$$\begin{cases} x_2 = r\sin\varphi - \left(\dfrac{a}{\sin a'} + r_\rho\right) \times \cos\left(a' - \varphi\right) \\ y_2 = r\cos\varphi - \left(\dfrac{a}{\sin a'} + r_\rho\right) \times \sin\left(a' - \varphi\right) \end{cases} \tag{5}$$

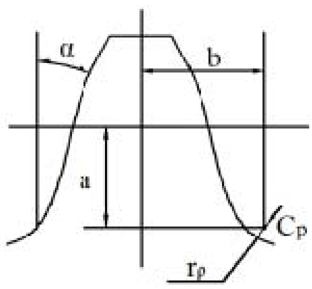

Fig.4 Schematic diagram of tool profile parameters

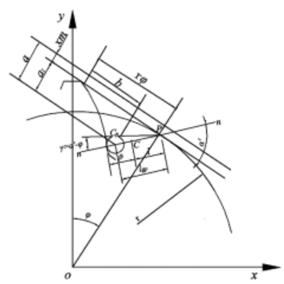

Fig.5 Schematic diagram

3. INP file unit and node writing rules

INP file is a text file, which contains a complete description of the model, in the preprocessor (such as ABAQUS/CAE) and Solver (ABAQUS/Standard or ABAQUS/Explicit) establishes a data transfer bridge [9]. At present, most of the former processors (such as MSC.PATRAN, FEMAP, and Hyper Mesh) are mostly supported in INP file format to output the model.

The INP file consists of a series of data blocks, each of which represents a particular part of the model. A data block is always started with a keyword with a “*”, followed by a corresponding parameter, and one or more data lines.

For the preparation of the pretreatment conditions INP file rules, refer to the fourth pretreatment conditions.

4. Programming

4.1 establish the form of gear mesh

This paper adopts the gear mesh arrangement form as shown in Figure 6, the right end face of single tooth mesh arrangement form as shown in Figure 7, the gear meshing gear form can satisfy the calculating accuracy in stress and bending stress, and can make the gear mesh reasonably, improve computational efficiency, but also for different requirements of precision, but also through the position adjusting control parameters in Figure 8 and 9 point 10 points, the number of grid is more reasonable.

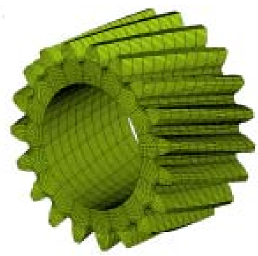

Fig.6 Overall arrangement form of gear mesh

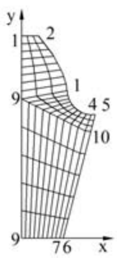

Fig.7 Right end of the single tooth mesh

4.2 gear unit node coordinate generation method

Firstly, on the basis of the element node coordinates of the second section is the gear tooth profile curve equation to generate a single tooth right end, because the tooth on the symmetry properties of Y axis, then the element node coordinates can generate a single tooth left end, through the acquisition of spiral angle and coordinate rotation transformation formula of element node coordinates a tooth is obtained, and then the rotation transformation can be obtained by all the nodes of the whole gear coordinate values, and finally explores node numbering rules, and give the corresponding coordinate value of node number .

4.3 node numbering and distribution

According to the INP rules, to the gear unit node coordinates generated number, in addition to as far as possible to meet each node is connected, continuous changes, but also try to make the node number rationalization, provide the corresponding rules for subsequent node key arrangement unit. If the node number is not regular, it is almost impossible to arrange the information model of a gear model which contains thousands of nodes and node numbers.

5. Pretreatment conditions (material, assembly, contact, load, etc.)

5.1 give gear material properties

Define the gear material properties, the default material name is: elastic modulus of 210000 MPa, Poisson's ratio of 0.3, density of 7.8 x t/, and finally define the section properties.

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5.2 analysis step definition

In the analysis step, we used 0.1s to display the dynamic analysis, and the time of the preset analysis is chosen. An explicit algorithm is used to determine the solution without any iteration, and the computational resources are less implicit than the previous incremental step.

5.3 field variables and historical variables

The contact pressure, contact force, stress, displacement and so on are the output variables of the field variables.

5.4 define contact and contact properties

(1) Create gear on contact properties.

(2) The selected contact involute tooth surface and fillet surface, tooth top surface node driven gear, which were placed into the unit set M_SURF-1, S_SURF-1.

(3) The creation of face-to-face contact and choose the calculation method of contact method, the finite slip formula.

5.5 set reference point

The main axis of the driven gear is taken as the reference point, and the coupling rigid constraint is established between the reference point and the inner ring and the profile.

6. Example

The preparation of gear finite element mesh generation based on parametric modeling program, GUI interface as shown in Figure 8, a calculation of dynamic stress of gear meshing gear meshing, the basic parameters of the large number of gear teeth was 24, the number of gear teeth was 20, 3mm module and pressure angle of 20 degrees addendum, 3mm, tooth width is 40mm, the large gear resistance moment is 100Nm.

The compiler generated INP file, the mesh as shown in Figure 9, the grid quality inspection shows that the finite element model of a total of 145920 units, of which the minimum Jacobian is 0.79, the mesh quality is good.

The INP file is imported into ABAQUS submitted by operation, the finite element calculation of stress nephogram and gear contact pressure contours are shown in Figure 10 and Figure 11, get the maximum contact stress is 591MPa, the maximum bending stress is 128.6MPa.

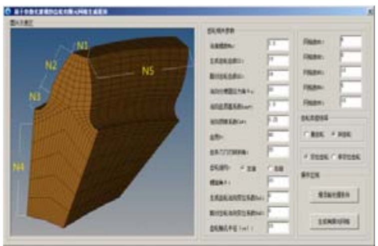

Fig.8 gear parameter input GUI

Fig.9 numerical example

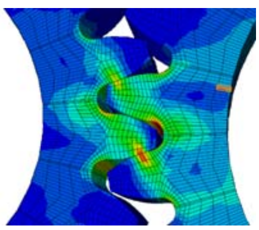

Fig.10 finite element calculation results

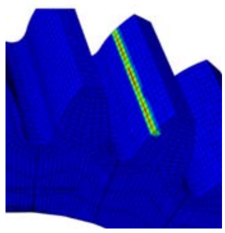

Fig.11 gear contact

Contact stress:

$$\sigma_{Hi} = Z_H Z_E Z_\varepsilon Z_\beta Z_{BD} \sqrt{\frac{2000 T_i}{d_1^2 b} \frac{u+1}{u} K_{Vi} K_{H\beta i} K_{H\alpha i}} \tag{6}$$

Bending stress:

$$\sigma_{Fi} = \frac{2000 T_i}{d_1^2 b} Y_F Y_s Y_\beta K_{Vi} K_{F\beta i} K_{F\alpha ii} \tag{7}$$

By theoretical calculation, the contact stress Hi is 573.1MPa, the bending stress Fi is 120.5MPa.

According to the calculation results, the tooth surface contact stress, finite element calculation results and theoretical calculation results by 3.29%, bending stress, finite element calculation results and theoretical calculation results is 6.72%, due to the application of the penalty function in the finite element model, the differences in the reasonable range, which verified the validity of the established model, and verified the correctness of the proposed modeling based on parameterized finite element model of gear generating method.

7. Conclusion

(1)The gear tooth surface equation of general unified coordinates are deduced according to INP file rule generation gear mesh node coordinates, grid node distribution inquiry unit, thus obtained gear finite element mesh node information.

(2)We propose a method to generate value coordinate numerical iterative linear equation based on the method of obtaining the gear generation node finite element mesh information. The method of arranging the nodes of the mesh based on the meshing parameters is given.

(3)The INP file to add gear contact stress and bending stress for pretreatment conditions, such as material properties, boundary conditions and loads.

(4)Finally through a pair of gear case is verified by the program to calculate the gear contact stress and bending stress is consistent with the ISO, to verify the feasibility of the method.

(5)For the involute tooth root transition curve fitting is good, can be used for precise gear calculation.

Acknowledgment

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