Analysis of four-edge mill modality and stress deformation based on ANSYS

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Abstract: In mechanical design, we often need to use CNC machining center, in which milling cutters are our indispensable and most common processing tools, milling machines. We often use two-edged milling cutters, three-edged milling cutters, four-edged milling cutters. In order to analyze the milling cutter, we need to draw the 3D modeling of the milling cutter in UG, import the 3D model into the workbench to analyze the tool finite meta, analyze a four-edged mill, analyze whether the natural frequency will resonate with the machine tool. Find 10th-order modes, stress analysis of tools, deformation analysis. Topology optimization is carried out to enhance existing effects, reduce costs and improve efficiency.

1. Introduction
Milling cutters are cutting tools commonly used in milling machines or machining machines to perform milling operations. They remove the material by fixing the yield within the machine. Although there are many different types of milling cutters, understanding the formation of chips is essential for using them. When the milling cutter rotates, the material to be cut is fed into it, and each tooth of the cutter cuts off a small piece of material. Achieving the correct fragment size is critical. In metalworking, milling accounts for the largest proportion, and analyzing the milling process and running smoothness of milling cutters is of great significance to ensure the quality of milling. CAD and CAE techniques can be applied to milling tool design and analysis, which can be replaced by various simulations and simulations of virtual milling tool models instead of traditional physical experiments. Through the interface between Pro/E and finite element analysis software ANSYS, the 3D model is imported into ANSYS, the modal analysis of the milling cutter is carried out, and its inherent vibration frequency and vibration type are obtained, which provides a basis for further dynamic simulation and structural analysis.

2. 3D solid model of the mill
Before you optimize your design, the first thing you need to do is draw a 3D model of the mill in UG. In order to import 3D entities into finite meta-analysis software, 3D solid files must be saved to IBES format when drawing, so that they can be import entities in the file of ANSYS, and be meshed and loaded to solve. The mill's 3D solid model, as shown in Figure 1, figure 2, is imported in an ANSYS analysis.
3. **Ansys analysis of the milling cutters**
Select the milling cutter material to enter the engineering data, add the material directly click on density, add the density 15000kg/m3 click on the isotropic elasticity, enter the elastic module: 6e11 pa. Poisson ratio: 0.3 as shown in Figure 3

![Figure 3 Mill properties](image)

Enter finite meta-analysis, a four-edged milling cutter, to analyze whether the natural frequency will resonate with the machine tool. Click on A4 to select the model and select the newly created alloy material. Set the grid size of the model size by 1mm. Build a grid.

The clamping surface of the tool in practice is the cylindrical part. As shown in Figure 4

Click on the A5 support fixed support to select the mounting surface. Find the 10th order mode. As shown in Figure 5
Solve the speed of the machining center 0 to 10000r/min. So the maximum frequency of the machining center is 166.7hz due to the multi-edged tool, multi-frequency effect, and 166.7 multiples: 333.3hz, 500.hz, 666.8hz. Results show that the natural frequency is much greater than the possible resonance frequency, the machining center has no effect on the tool. [3]

4. Calculation of cutting force
Through the experimental method, the cutting force data when various influence factors change, and the expression that reflects the relationship between the factor and the cutting force is processed, which is called the experimental formula of cutting force calculation.

At present, people have accumulated a large number of cutting force experimental data, for general machining methods, such as turning, hole machining and milling has established a direct use of the experience formula. The commonly used experience formula can be divided into two categories: one is the exponential formula, the other is calculated by unit cutting force. [4]

Practice has proved that there are many factors affecting cutting force, such as workware material, cutting amount, tool geometry parameters, tool material tool wear state and cutting fluid. In this paper, the exponential formula is used for easy calculation.

Main cutting force:
\[
F_c = C_{FC} \cdot A_p \cdot f_{yc} \cdot V_c^{n_{fc}} \cdot K_{FC} \tag{1}
\]

Back force:
\[
F_p = C_{FP} \cdot A_p \cdot f_{yp} \cdot V_c^{n_{fp}} \cdot K_{FP} \tag{2}
\]

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\[
F_f = C_{FF} \cdot A_p \cdot f_{yf} \cdot V_c^{n_{ff}} \cdot K_{FC} \tag{3}
\]

medium \(F_c\) - -------- main cutting force (N); medium \(F_p\) -------- back force (N); medium \(F_f\) -------- in-force (N); In the style: \(x_{fc}, y_{fc}, n_{fc}, x_{fp}, y_{fp}, n_{fp}, x_{ff}, y_{ff}, n_{ff}, C_{FC}, C_{FP}, \) \(C_{FF}\) factor check table is available

| Main cutting force (N) | \(F_c = 9.81 \cdot C_{FC} A_p x_{fc} y_{fc} V_c^{n_{fc}} K_{FC}\) |
Back force (N): \[ F_p = 9.81C_{fp}A_p^{x_{fp}} f_{y_{fp}} V_{c}^{n_{fp}} K_{fp} \]

In se-force (N): \[ F_f = 9.81C_{ff}A_p^{x_{ff}} f_{y_{ff}} V_{c}^{n_{ff}} K_{ff} \]

The power consumed during cutting: \[ P = F \times V \times 10^{-3}/60 \]

Figure 5 Cutting force calculation formula

The parameter check table in the method (1-1) can determine the parameters \( C_{fc} = 3600 \) in turn, \( x_{fc} = 0.9, y_{fc} = 0.9 \), \( n_{fc} = 0 \), the cutting amount is, in turn \( a_p = 2\, \text{mm}, f = 0.6\, \text{mm/r} \) and \( v_c = 150\, \text{m/min} \) the available cutting force is calculated to be 2333N.

According to the calculation can be known CNC processing center high-speed steel milling force size of 2333 N, where the allowed deformation range is up to 0.02mm from figure 7 below can be known that the tool deformation range is 0, 0.0042288mm can be to meet tool requirements.

Figure 6 Total deformation of the mill stress

5. Conclusion

(1) By using UG 3D drawing software, using equivalent stiffness replacement theory, to find out the structure of CNC four-edge milling cutter, to establish a three-dimensional model of milling cutter, using ANSYS simulation software to perform static analysis and modal analysis of the axle, to obtain the total response of the axle force, total strain cloud map, get the maximum value of simulation, and then compare with the theoretical value, get that the deviation between the numerical simulation results of the axle and the theoretical results is very small, using the modules in ANSYS Workbench to simulate the engineering problem modal simulation, to obtain the numerical simulation results of finite meta-analysis is reliable. The static simulation results are less than the stress value, indicating that the axle meets the design requirements.

(2) The Static Structural module in the ANSYS Workbench environment simulates small deformations that are not visible to the naked eye, allowing for more intuitive observation of loaded deformations of the axles. In fact, when doing finite meta-analysis, you can make a pre-calculation or judgment based on the existing knowledge of magic. This paper is to solve the problem first by means of the method in materials aesthetics, and then use finite meta-analysis software to verify the calculation, which improves the accuracy of the calculation.[5]

(3) This paper makes full use of the advantages of the two kinds of software, the real number of
model/simulation and optimization calculation, by the computer instead of designers to complete a large number of repeated modeling, simulation work, effectively improve the efficiency of work.

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