Mechanical Characteristics Analysis of Grinding Plate of Food Waste Grinding Mill Based on ANSYS Workbench

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Abstract. Food waste accounts for 30% - 50% of domestic waste, and its centralized treatment is difficult. For commercial places with large production of food waste, it is a better way to use grinding mill to crush food waste and then discharge it into sewer. The mechanical properties of grinding plate are the decisive factors affecting the performance of grinding mill. In this paper, the static analysis and modal analysis of the grinding plate of commercial grinding mill are carried out. The results show that: under the rated load, the maximum equivalent stress of grinding hammer is 83.4mpa, the maximum equivalent stress of cutter head is 77.6mpa, which meets the design requirements, but the stress is relatively concentrated. The lowest modal vibration frequency of the lapping plate is 456.2hz, and the lapping plate will not have resonance damage under normal conditions.

Keywords: Food Waste, Grinding, Grinding Plate.

1. Introduction
Food waste accounts for 30-50% of domestic waste [1]. Due to the scattered sources of food waste, easy to rot, easy to spread diseases and high water content [2], food waste is difficult to be treated centrally with high cost [3]. Especially in commercial places such as canteens, hotels and restaurants, the output of food waste is very large [4]. It is a better treatment method for these commercial places to crush the food waste to 3mm size and then discharge it into the sewer. The grinder used is generally grinding type, and the grinding plate is the main crushing mechanism [5].

Because there are a certain amount of bones, shells and other hard objects in kitchen waste, the structural strength of grinding plate is one of the important factors to determine the performance and safety of grinding grinder [6]. In this paper, the mechanical properties of the grinding plate of the grinding mill used in commercial places such as canteens, hotels and restaurants are studied to provide a theoretical basis for the subsequent optimization design.
2. Analysis Model

The grinding disc analyzed in this paper mainly consists of three parts: cutter head, triangular cutter and grinding hammer. Each grinding disc contains six triangular cutters and three grinding hammers. The cutter head is equipped with installation holes. The triangular cutter and grinding hammer are installed on the cutter head and fixed on the cutter head by welding process. The diameter of the cutter head is 219mm, the thickness of the cutter head is 6mm, and a hexagon hole is set in the center of the cutter head, which is used for the motor to drive the grinding plate to rotate. The structure of the cutter head is shown in Figure 1. The material of grinding plate is qste420t, and its material parameters are shown in Table 1.

![Grinding plate model](image)

Figure 1. Grinding plate model

| Modulus of Elasticity/GPa | Poisson’s Ratio | Yield Strength/Mpa | Tensile Strength/Mpa | Density/(kg·m⁻³) |
|--------------------------|----------------|-------------------|---------------------|-----------------|
| 200                      | 0.3            | 420               | 480                 | 7.85x10³        |

3. Statics Analysis

Statics analysis is one of the most common methods to analyze the mechanical structure characteristics. In classical mechanics, the dynamic equation of an object is:

\[ M\ddot{x} + C\dot{x} + Kx = F(t) \]  \hspace{2cm} (1)

Where \([M]\) is the mass matrix, \([C]\) is the matrix damping, \([K]\) is the stiffness coefficient matrix, \([x]\) is the displacement vector and \([f]\) is the force loss. In linear static structural analysis, the force is independent of time, so the displacement \([x]\) can be obtained from the following equation [7][8].

\[ Kx = F(t) \]  \hspace{2cm} (2)

In statics analysis, the load types include external force and pressure, steady inertia force, displacement load, temperature load, etc.

3.1. Static Analysis Pretreatment

In the digital modeling software Creo, the three-dimensional model of the grinding disc is established and saved in STP format and imported into ANSYS Workbench, as shown in Figure 1. ANSYS Workbench not only provides common engineering materials, but also allows users to customize the analysis materials according to their own needs. After importing the grinding disc model into the analysis software, the materials shown in Table 1 are established and assigned to the cutter head, triangular cutter and grinding hammer respectively. In ANSYS Workbench, mesh generation methods
mainly include automatic mesh generation, tetrahedral mesh generation, hexahedral dominant mesh generation and sweeping method. In this paper, the method of hexahedron leading mesh generation is adopted, and some parameters are added to control the mesh generation [9].

According to the relationship between the force and the reaction force, a fixed constraint is applied on the inner side of the hexagon hole in the center of the cutter head, and then a load is applied according to the measured data. A force of 780N is applied on the grinding surface of each grinding hammer, and the direction of the force is perpendicular to the grinding surface; Then, a force of 120 n is applied on the side of each triangular knife, and the direction of the force is perpendicular to the side of the triangular knife; Then, a centrifugal force of 314rad / s was applied to the whole grinding plate. Through the above constraints and loads, the maximum load condition that the grinding cutter head may encounter is simulated. Constraints and loads are shown in Figure 2.

![Figure 2. Constraints and loads](image)

After the above pretreatment, the solution calculation is carried out. After the calculation, the results of grinding hammer and cutter head are processed respectively.

### 3.2. Static Analysis Results of Grinding Hammer

Figure 3 is the equivalent stress nephogram of the grinding hammer. It can be seen from the figure that there is a certain stress concentration at the bottom and step position of the grinding hammer under the set working conditions. The maximum stress appears at the bottom of the grinding hammer, and the maximum value is 83.4mpa, which is far less than the allowable stress of the material and meets the design requirements. Later, the welding area can be increased and the stress concentration can be reduced.

![Figure 3. Equivalent stress nephogram of grinding hammer](image)

Figure 4 is the total deformation nephogram of the grinding hammer. It can be seen from the nephogram that in the set working condition, through the superposition of equivalent strains, the
maximum deformation position is the step part of the grinding hammer, and the maximum deformation is 0.04mm, which is small and meets the design requirements.

**Figure 4.** Total deformation nephogram of grinding hammer

### 3.3. Static Analysis Results of Cutterhead

Figure 5 is the cloud diagram of equivalent stress of the cutter head. It can be seen from the figure that in the set working condition, a certain stress appears on the whole tool disc, and the stress is mainly distributed in the position of the grinding hammer. The maximum stress appears in the hexagon hole in the center of the cutter head, the maximum value is 77.6mpa, which is far less than the required stress of the material, which meets the design requirements.

**Figure 5.** Equivalent stress nephogram of cutter head

Figure 6 is the total deformation nephogram of the cutterhead. It can be seen from the nephogram that the maximum deformation occurs at the edge of the cutterhead due to the accumulation of equivalent strain under the set working condition, which corresponds to the position of the grinding hammer, and the position of the maximum deformation also presents a certain periodicity. The maximum deformation value is 0.3mm, which meets the design requirements.
Modal analysis is a common method to study the dynamic characteristics, vibration analysis and dynamic optimization design of mechanical structures. Mode is the inherent characteristic of mechanical structure, each structure has multiple modes, and each mode has corresponding vibration frequency and mode [10].

4.1. Modal Analysis Preprocessing
The results of static analysis and the prestress of elements and nodes are considered in the prestressed modal analysis, which is closer to the actual working state of the grinding plate, so that the results of modal analysis are more accurate and the reflected modal shape is more real. In this study, the loads and constraints used in static analysis and the results of static analysis are used as the analysis conditions of prestressed modal analysis.

4.2. Modal Analysis Results
There are some errors in modal analysis, and with the increase of order, the analysis error increases. According to the actual situation, this paper extracts the first four modes of the grinding plate, as shown in Table 2. The vibration frequency range is 465.2-1335.6Hz, and 465.2Hz is far higher than the frequency provided by the external excitation of the grinding plate, so the grinding plate will not have resonance damage under normal conditions.

Table 2. Vibration frequency of grinding plate

| Modal order | Vibration frequency /Hz |
|-------------|-------------------------|
| 1           | 465.2                   |
| 2           | 529.6                   |
| 3           | 688.3                   |
| 4           | 1335.6                  |

5. Conclusion
Grinding disk is one of the important factors that determine the working and safety performance of the grinder. This paper takes the grinder used in the canteen, hotel and restaurant as the object, and analyzes the mechanical properties of the grinding plate. The results are as follows.

(1) Under the rated load, the maximum equivalent stress of the grinding hammer is 83.4mpa, which meets the design requirements, but the stress is concentrated, which can increase the welding range and reduce the stress concentration.

(2) Under the rated load, the maximum equivalent stress of the cutter head is 77.6mpa, which meets the design requirements, but the stress is concentrated.
The lowest mode vibration frequency of the grinding disk is 456.2 hz, which is far beyond the frequency provided by the external excitation of the grinding disk, so the grinding disk will not be damaged by resonance under normal conditions.

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