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Stress Analysis and Optimization Design & Research of the Large Ball Mill Cylinder

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To carry out stress analysis of the large ball mill cylinder, and discuss the optimization design plan. The stress values under working state and full-load prohibited state of the large-scale ball mill cylinder were analyzed, and the finite element was used to optimize the design. It found in recent research and analysis that, the relevant parameters of the large-scale ball mill's cylinder were in line with the equipment design requirements and the equipment was safe and stable. Finite element model analysis is an effective method to optimize the barrel of large ball mills, which is worthy of research and reference.

1. Introduction

The cylinder is one of the application equipment in the mechanical processing production, and it needs to carry a certain dynamic load during the application process. Due to the poor working conditions of the cylinder, the life and reliability of the equipment itself is relatively low, which may cause unfavorable effects on the processing and production of the enterprise. The large ball mill cylinder is a kind of equipment with relatively simple design structure and relatively reliable working performance. It has certain application value in raw material production and processing. Compared with the general cylinder, the large-scale ball mill cylinder has a good automation control effect, which is beneficial for enterprises to reduce the manpower costs. Therefore, the large ball mill cylinder is one of the common raw material grinding equipment, which has wide application space in the field of raw material processing and production. To promote the processing of raw materials, more and more companies begin to conduct application research and analysis of the large-scale ball mill cylinder, especially in the field of mineral resources development, etc., which has high quality requirements for raw material processing equipment.

In case that the large ball mill cylinder may be damaged due to excessive stress in raw materials processing, equipment stress must be explored. Based on this, in this paper, it mainly analyzes the stress of large-scale ball mill cylinder, and provides reference for the optimal design of the cylinder through exploration of the application effects of finite element analysis methods of the three-dimensional model of the ball mill cylinder, meshing and load constraints analysis, etc.

2. Literature review

Since the reform and opening-up, China has paid more attention to the development of large heavy industry, but it has been greatly influenced by the introduction of the technology and machinery of the former Soviet Union. In grinding operations, the crushing equipment is mainly ball mill. In addition to a small number of mines to protect the rare metals with low hardness, most of the mining and production manufacturers, whether they need coarse grinding or fine grinding, are preferred to use ball mills. Using steel ball to ground mineral medium is the main working principle of grinding equipment of ball mill. It has many advantages such as simple design structure, stable operation performance and high crushing degree. When dealing with all kinds of production materials, the ball mill is considered first; the degree of mechanical automation control is also high and reduced. A lot of manual operations have been widely concerned by manufacturers in various industries.

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The technical strength and quality of ball mill equipment in our country are not very mature at present, and there is a big gap compared with the equipment in the advanced countries. Therefore, the manufacturers of various mineral processing equipment should learn more advanced technology and experience abroad, improve their R & D ability and R & D strength, improve the overall technical level and operation performance of the ball mill equipment, and realize the sustainable and sustainable development of the ball mill industry. Statistics show that, after the rotary body of large ball mill produced in China is put into production, because the mill working environment mill is not sufficient, the wall of the cylinder is too large to produce cracks and expands constantly. If it is not found in time, the rotary body part of the ball mill will break suddenly and the processing operation is interrupted suddenly, which will make the enterprise make the enterprise. A major production accident will not only cause great economic losses, but also lead to casualties. The actual production phenomenon shows that the traditional design method cannot meet the needs of production requirements. The design of ball mill needs to use more advanced design methods to get more specific and detailed design simulation and strict structural parameters. In view of the large ball mill and some related materials, the production principle of the ball mill, the development at home and abroad as well as the research status of the rotary motion of the ball mill barrel are summarized, and the composition of the cylinder structure and the stress situation in the working production are analysed in detail and the force load of the cylinder in normal work is calculated. By using the computer finite element software, the force distribution of the cylinder in normal working state is obtained, and the two sides cover which is easy to occur stress concentration is analysed in detail.

After several years of development, not only the different forms of different application methods are quite rich, the theoretical basis is quite perfect, but also a batch of effective general software has been developed. At present, it has been widely applied in engineering. Giagopoulos and Arailopoulos use a large general finite element software to calculate the stress of a ton ball mill. The deformation and stress distribution of the ball mill are obtained. The risk section and the stress size are pointed out. The analysis results show that the strength analysis of the ball mill cannot be used simply by the beam model; at the same time, it has rich function of back and back treatment. Especially in the post-processing, the results can be visualized, and the colour cloud images of the deformation and displacement can be observed directly. Once the model is established, the local structure can be easily modified so that the structure can be reached to the optimum step by step (Giagopoulos and Arailopoulos, 2017). Takashima and others applied the three-dimensional finite element analysis of the cylinder stress to the ball mill and predicted the residual life by combining the theory of fracture mechanics (Takashima et al., 2016). Hassanzadeh analyses and studies the measurement and modelling of residence time distribution of ball mill (Hassanzadeh, 2017). Loncarevic and others applied the check of static and fatigue strength for the stress and strain of the ton ceramic ball mill (Loncarevic et al., 2016). Kuznetsov and Morozov develop the crackle of the mill in view of the great development of the ball mill. From the practice, through the analysis of the lubrication principle of the ball mill and the welding process of the mill, the corresponding technical measures are taken. At the same time, it also provides a good reference for the design and manufacture of the mill. When the mill runs normally, the grinding ball is thrown down to a certain height and pulverized the material at a certain speed. At the same time, the material is crushed by the grinding ball and the lining plate itself, which may cause the crushing and cracking of the grinding ball and the lining plate. Therefore, the impact stress of the grinding ball is of two importance, on the one hand, grinding from the angle of breakage. The size of the ball impact determines the crushing efficiency on the other hand, in terms of the reduction of the crushing rate of the grinding ball and the liner in use, the size of the impact stress of the ball is an important basis for the material selection of the grinding ball and the lining plate (Kuznetsov and Morozov, 2016). Burek and others believe that the impact of the impact stress on the structure strength of the ball mill barrel must be considered, and some measures to prevent the stress damage of the cylinder are put forward. However, there is always a lack of accurate understanding of the impact stress of the ball mill, which is because it is difficult to measure the impact stress of a ball mill from the actual running ball mill, because it can hardly be recorded accurately (Burek et al., 2016). Yan proposes a simple and easy method of stress measurement. It does not require special instruments and is not limited by the impact velocity. The impact stress of different diameter ball mills in different sizes and diameters can be determined (Yan et al., 2016). When calculating the stress of a ball mill, the traditional method is to use the analogy method or by experience. Brecher simplifies it as a simple supported beam in the calculation of the strength of the cylinder body. It is calculated according to the combined deformation of plane bending and torsion. It is obvious that this method is very rough. This is because the difference between the diameter and length of ball mill is not large, which is not consistent with the assumption of simply supported beam, and the shell is a plate and shell structure, and its stress and strain behaviour is more complicated (Brecher et al., 2017).

To sum up, the above research work is mainly to study the concept of the ball mill cylinder and the stress application, but the stress analysis and optimization design are very little. Therefore, based on the above research status, through the analysis of the force state of the ball mill barrel at work, we can find that it is mainly affected by the impact force of the tube, the driving load of the large gear and the external force of its own gravity. Using the finite element software, the three-dimensional simplified model of the cylinder is set up, the element mesh is divided, the surface effect unit is covered, the force external load is applied, and the stress distribution and the displacement change of the cylinder are obtained through the analysis and calculation. As the end cover of the cylinder is a part of stress concentration easily, the contact force between the cylinder and the sliding bearing is analysed, the maximum stress and the position are obtained. Then the analysis is summarized, and the possible development direction of the ball mill is put forward.

3. Methods

3.1 Construction of three-dimensional model of ball mill cylinder

The physical structure of the ball mill cylinder is complex. When building a three-dimensional model, it is not necessary to model exactly according to the actual production structure. Through the structural analysis, some minor components that have weak effects on the force result are simplified, saving computing time and resources. Moreover, the cylinder of the ball mill belongs to the symmetrical structure, and half of the geometric model can be established for analysis. The structure of the ball mill cylinder mainly consists of inlet and outlet end caps, hollow cylinders, large gears, and liners and bushings of the corresponding structures. The inner liner of the cylinder is to reduce the impact on the wall of the cylinder when the material and the medium release in the cylinder. It has little influence on the stress analysis of the structure. Its structure can be ignored during modeling, but the weight effect is equivalently imposed on the cylinder. The equivalent application of gravity means that the actual weight and volume of the modeled structure are kept unchanged, and its density is increased so that the gravity effect of the omitted parts does not disappear. When manufacturing the cylinder, some structures are connected together by means of welding. In the three-dimensional modeling, they are built according to a continuous whole, and the welding places are all transitioned according to the extension of the structure curve. For example, the hollow shaft and the end cap are connected by welding. In the modeling, the two parts can be regarded as one part, and the connection part is transitioned by the arc. In the analysis of force, the gearwheel only plays a role of gravity and has no structural influence. Therefore, when establishing a large gear model, its gear teeth and hollow brackets can be omitted and simplified into a solid ring structure with constant material density. (The three-dimensional solid model of the cylinder is shown in Figure 1)

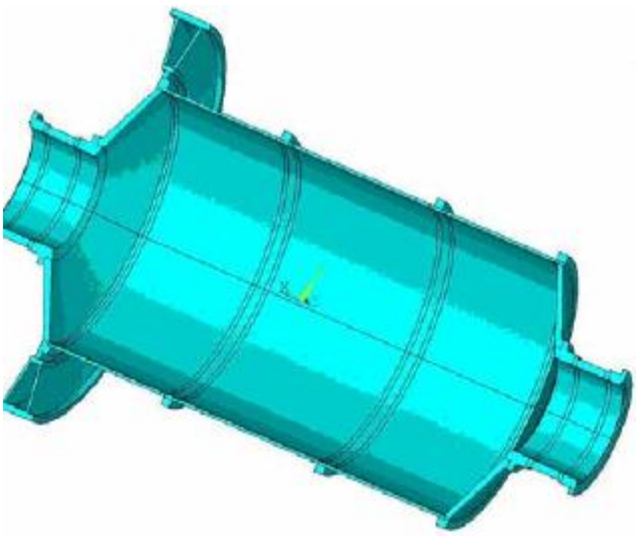

Figure 1: Three-dimensional solid model of cylinder

3.2 Division of the grid

Dividing the analysis system into several units is an important step in the finite element analysis. Grid division is to divide the three-dimensional model into several units. The performance of unit division has a great influence on the accuracy of the analysis results and the calculation scale. Sometimes the results of the calculation of the system are diverged because the grid division does not meet the analysis conditions. Therefore, when dividing the grid, we must divide the grid according to the model structure and analysis conditions, and ensure that the grid size and density meet the calculation requirements. The number of grids (also called grid density) depends on the size of the model being divided and the size of the partitioned cells. The number of grids directly affects the accuracy and calculation scale of the calculation results. As the number of grids increases, the calculation accuracy will improve, and the calculation scale will also expand; the number of grids will be too small and the calculation scale will decrease, but at the same time, the calculation results will be inaccurate. Therefore, when determining the number of grids, it is necessary to weigh the two factors for comprehensive consideration. Before dividing the grid, you have to choose the type of units. ANSYS software provides a variety of unit types to meet the needs of different research objects. The Solid45 hexahedron element is adopted in the analysis of ball mill barrel stress. This type of element is often used to construct three-dimensional solid structures. Each element is defined by eight nodes. Each node's initial settings contain degrees of freedom along the x, y, and z directions. Because Solid45 unit can meet the performance of plasticity, creep, expansion, stress strengthening, large deformation and large strain, it can meet the calculation requirements of this analysis. Due to the symmetry of the barrel structure of the ball mill, it is possible to use a body sweep method to divide the entire grid, ensuring the regularity of the grid size and the uniformity of the grid distribution. The material parameters of each part of the cylinder are shown in Table 1.

Table 1: Material parameters of cylinder

	Feed end	cylinder	Big gear
material	ZG20SiMn	16Mn	ZG42CrMo
Elastic modulus E/GPa	206	206	206
Poisson's ratio mu	0.3	0.3	0.3

3.3 Application of load and determination of restraint conditions

To save computing resources, when establishing the three-dimensional model, the structure of the cylinder is simplified, and the structure that has little effect on the result of the force is omitted. However, the effect of gravity cannot be ignored. Therefore, to approach the actual analysis as much as possible, the weight of the omitted part is equivalently applied to the corresponding structure. In the establishment of the cylinder model, considering that the structure of the liner, the bushing and the fixing ring are all secondary functions of the auxiliary function, the omission is performed. The weight of the cylinder liner is applied to the weight of the cylinder, and the weight of the liner is added to the total weight of the end cap. In this way, although the three-dimensional model is simplified, the overall system's structural weight does not change, which can reduce the workload when modeling, and ensure that the analysis results are close to the actual work situation, thus killing two birds with one stone. When the ball mill barrel is not started and the amount of injected medium is the largest, the filling rate in the barrel is 38%, the weight of the material is 88t, the steel ball weight is 492t, and the loose proportion is 4.6t/m3. From these data, the vertical distance from the upper surface of the drum to the bottom of the drum is h = 2.36 m. The size of the force acting on the area where the wall of the cylinder is in contact with the material and the steel ball gradually changes with the depth of the medium. To achieve this effect, a surface effect unit, surf154, is established on the acting surface, which is suitable for a variety of changing loads and surface effects. (Applied changing surface load to unit surf154 is shown in Figure 2)

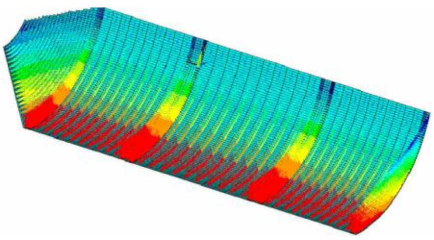

Figure 2: Applied changing surface load to unit surf154

The barrel of the ball mill is the most complex part of the force during the operation of the mill. Its stiffness and strength have a direct impact on the service life of other parts and the movement accuracy of the transmission part. Therefore, a more precise verification calculation must be performed on this part. The traditional calculation is to simplify the cylinder as simply supported beam, and to divide the cylinder into a plane by force, and calculate according to plane bending and torque twist of theoretical mechanics. However, the structure of the end cap at the inlet and outlet ends is relatively complex. It is difficult to divide the force into a plane, and the deformation of the force exerts great influence on the reliability of the cylinder. Therefore, the traditional simplified method cannot accurately and completely reflect the overall stress deformation. As a result, to improve the design quality of the ball mill, reduce the waste of manufacturing materials, and improve the stability of the structure, it uses the finite element method to analyze the stress and strain of the barrel of the ball mil in this paper, and it establishes the finite element model of the grinding machine barrel. Due to the force analysis of the ball mill rotor, a part of the structure is simplified without affecting the force analysis. On the one hand, the model can be simplified, calculations can be reduced, and resources can be saved; on the other hand, some of the results of the attention can be clearly seen. The liner in the cylinder is simplified and its weight is added to the cylinder; The chamfering and welding seams on the inlet and outlet end caps can be viewed as continuous; The inlet and outlet bushings in the end cap can also be omitted when modeling, but the structural weights are added to the two end caps.

4. Result and discussion

4.1 Analysis of the finite element calculation result of cylinder stress

After the calculation load is applied, the stress distribution of the cylinder is achieved through finite element software analysis, which is shown as Figure 3.

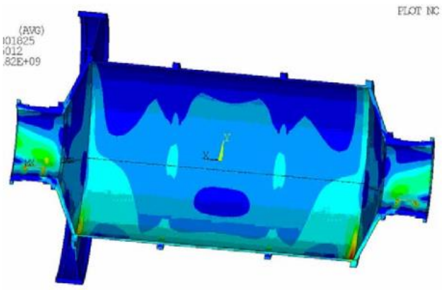

Figure 3: Distribution of stress distribution in cylinder

From the above figure, the connection between the hollow shaft and the end cap is the most stressed. In practical work, the constraint of the hollow shaft of the end cap is not as complete as it is in the modeling process. The material of the cylinder is selected as 16Mn. Referring to the related design manual, the yield limit of the material is 120MPa. Therefore, under the condition of full load and standstill, the maximum stress of the cylinder is far less than the yield limit of the cylinder material, which can meet the production requirements for production.

4.2 Stress analysis of hollow shaft and end cap fillet

To calculate more accurately the stress of the hollow shaft and the end cap fillet, it conducts constrains and loads again towards the above model in this paper. The bearing reaction force and the pressure of each unit are obtained through the relevant pressure calculation method, and the constraint and pressure are conducted again towards the ball mill cylinder. The force diagram is shown as Figure 4.

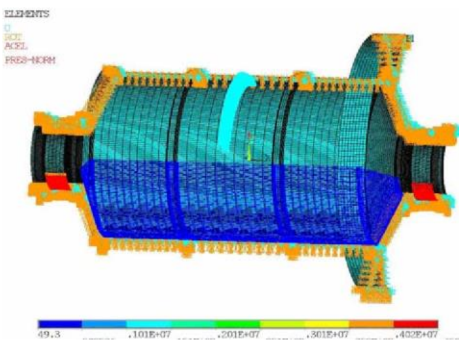

Figure 4: Bearing support and restraint

After applying equivalent stress, the maximum force occurs at both ends of the cylinder. The stress of other parts is not much different from the force analysis before the application of equivalent stress. It can be clearly seen where the stress is concentrated by magnifying the force distribution on both end caps.

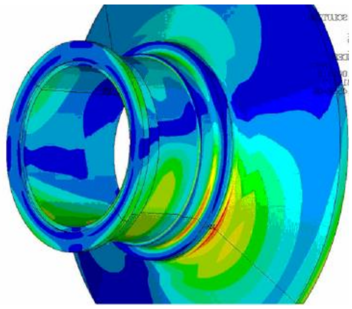

Figure 5: Stress amplification diagram of hollow shaft at mobile end

The maximum stress of the feed end cap occurs at the roundness of the connection between the hollow shaft and the end cap, and the maximum value is 52.8 MPa; The maximum stress at the discharge end section also occurs at the joint between the hollow shaft and the end cap. The maximum stress value is 45.6 MPa. According to the parameters of the material, it is within its allowable range. (The mobile hollow shaft stress magnification is shown in the above Figure 5.)

5. Conclusion

In this study, it mainly takes the large ball mill barrel as the research object, analyzes the cylinder stress, and uses the finite element analysis method to optimize the design. According to the calculation of the working state of the large ball mill cylinder, it is found that the stress is the same in both the working state and the stationary state. Under normal working conditions, the force of the large ball mill cylinder is greater than that under the full load static state. According to the analysis of the finite element model, the maximum load of the ball mill in the static state is 49.7 MPa, which can meet the production requirements of the cylinder. After re-applying the load analysis, the maximum stress at the fixed and free ends was 52.8 MPa and 42.6 MPa, respectively. The data results meet the design requirements, indicating that this study's optimal design method is feasible. Because the author's professional level is limited, it is difficult to fully grasp the state of stress in the force analysis of large-scale ball mill barrels. The reliability of the large-scale ball mill cylinder still needs to pass the practice test. In the practical application process, the optimization design parameters of the large ball mill cylinder must be simulated to ensure the design accuracy.

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