International Journal of Energy
ISSN: 2957-9473 | Vol. 3, No. 1, 2023

Statics Analysis and Modal Analysis of Copper Anode Plate Taking Robot

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Abstract: Taking the copper anode plate picking robot as the research object, the three-dimensional model of the robot was established by solidworks software, and combined with the actual working characteristics of the robot, the workbench software was used to analyze the static mechanics of the robot arm in the most dangerous working condition and the first six orders of modal analysis in three typical working conditions: picking position, putting position and starting position. The simulation results show that the strength and stiffness of the robot arm and the small arm are within the allowable range and meet the design requirements; it is necessary to avoid the low-order frequencies or to strengthen the rigidity of the overall structure of the robot.

Keywords: Copper Anode Plate; Robot; Static Analysis; Modal Analysis.

1. Introduction

In recent years the instability of copper price, people are more and more concerned about the technology of copper metallurgy industry, the pyrometallurgy copper production method as an important component of copper production methods and attention, copper anode plate casting belongs to the pyrometallurgy, pyrometallurgy is the main method of producing copper anode plate at present, accounting for 80% to 90% of copper production. Copper anode plate casting machine is the main equipment used in the process of pyrometallurgy in China, of which plate picking machine is a very important part. Compared with the traditional plate picking method, the copper anode plate picking robot has the advantages of improving the safety of the production process, increasing the labor productivity and improving the quality of copper anode plates. Through the function of the end-effector of the plate picker robot, it can complete the handling work of copper anode plate, which is widely used in copper anode plate production and other fields.

At present, most of the plate picking methods used in copper anode plate production line are hook type plate picker and waist type plate picker, which will make the plate lug of copper anode plate elongated and deformed, and break the connecting rod and eccentric disk, and the chain in the water tank is easy to wear and often fall off the plate, which affects the production efficiency. In order to solve the problems encountered in the actual production, a set of copper anode plate picking robot was developed. In order to make the picking robot pick the plate safely and reliably, a static analysis of the different working conditions of the copper anode plate picking robot is now available at [1].

2. Typical Working Conditions Selection

Static analysis is the basis for strength and stiffness analysis calculations [2]. The static stiffness of the robot is one of the necessary conditions for the overall design of the mechanism, so different working conditions of the mechanism should be analyzed. In this paper, three typical and representative working conditions are selected for analysis. The pick- up robot is in the starting position and the copper anode plate is at the highest position in the process [3]. When the robot is subjected to vertical downward force, the joints are balanced. As a representative position, it is necessary to analyze the displacement deformation and stress distribution of the pick-up robot. The pick-up robot is in the pick-up position. In this position, each arm of the robot is in a lower position, and the end-effector and the robot are subjected to abrupt changes in force when picking up the plate. When the end- effector of the pick-up robot is subjected to a vertical downward force, the pick-up robot and the end-effector will have a large deformation. Therefore, the analysis of this position is to calculate the maximum displacement deformation and stress distribution and stress concentration of the robot. The robot is located at the position of plate release, and the attitude of the end-effector remains unchanged at this time, and the robot rotates at a certain angle to reach the plate release position. It is also necessary to analyze the displacement deformation and stress distribution in this position.

3. Static Analysis of Plate Picking Robot

3.1. Finite Element Modeling

Based on the plate picking process of the copper anode plate picking robot, a model of the copper anode plate picking robot is established. The model simplifies the small structures such as threaded holes and chamfers on the picking robot and end-effectors, etc., which have a small impact on the stress-strain of the overall picking robot [4].

In order to verify the influence of copper anode plate on the deformation of the complete plate picking robot under the most dangerous working conditions, the simulation model of the plate picking robot needs to be further processed. For the selected working condition, the model is now constructed for the plate picking robot picking position, and then the material of each part is set for the picking position [5]. As shown in Table 1.

In order to achieve a reasonable simulation analysis, a good mesh quality is required, so the components of the copper anode plate picking robot are meshed separately.

Table 1. Materials and parameters of each part

Name	Materials	Modulus of elasticity (GPa)	Poisson's ratio	Yield limit (MPa)
Robotics	Q345	209	0.29	345
End-effector	1Cr18Ni9Ti	190	0.305	205

Because of the complexity of the copper anode plate picking robot model, the solution time and the accuracy of the solution should be considered in the meshing. In the simulation model of plate picking under hazardous conditions, the denser the mesh is, the more accurate the results are after solving, but considering the solving time, the mesh size of the plate picking robot under the final picking position is set to 100 mm.

The overall plate picking robot is a more regular entity, so hexahedral meshing is used to achieve a better mesh effect; the end-effector consists of several parts with more complex shapes and multiple features, so tetrahedral ten- node meshing is used to obtain a good mesh quality. The final mesh quality properties after the division show that there are 317469 nodes and 192,895 cells in the mesh division of the copper anode plate pickup robot. The mesh division is shown in Figure 1:



Figure 1. Mesh division of taking plate position

3.2. Analysis of Results

Since the 3D solid model of the overall copper anode plate picking robot is simplified, especially the motor, reducer and other components are simplified in the end axis, the mass is reduced by about 70 kg, so the 70 kg mass needs to be converted into load and reloaded onto the end axis of the picking robot during the analysis process; the mass of the copper anode plate is about 370 kg, which also needs to be converted into load and loaded onto converted into load on the end axis; and the end axis. The mass of the copper anode plate is about 370 kg, which also needs to be gravity load is loaded into the whole picking robot.

The load is applied at the picking position of the picking robot, and the load is applied to the jaws of the end-effector. The overall deformation and equivalent force clouds of the pick-up position were obtained by the calculation of finite element simulation software.

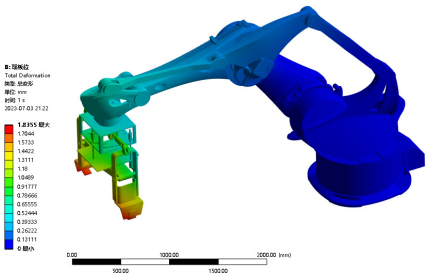


Figure 2. Cloud diagram of total deformation at the taking plate position

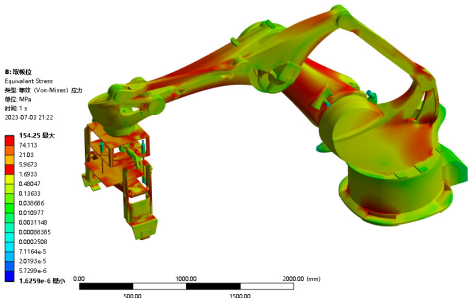


Figure 3. Cloud diagram of equivalent force at the taking plate position

The results of the static analysis of the taking plate position show that the maximum total deformation at the taking plate position is at the stopper shown in Figure 2, and its size is 1.8355mm as shown in Table 2; the maximum equivalent force position is at the fixed frame of the end-effector shown in Figure 3, and its size is 154.25MPa as shown in Table 2; the maximum strain is 7.9263e-002. Reaction unit as the output result, the maximum shear force is applied at the fixed frame of the end-effector at the position of picking up the plate, and the magnitude of the force is -2.5853e-005N in the X direction, 2.3129e-006N in the Y direction, and 72419N in the Z direction, the direction is consistent with the coordinates of the 3D modeling, and the combined force of the 2 directions is the shear force, the magnitude is 72419 N. Taking the whole The material safety factor of the robot is 1.2, and the allowable stress of the end-effector is 170.83 MPa, and the allowable stress of the robot is 287.5 MPa, and the maximum equivalent force is 154.25 MPa, which is much smaller than the allowable stress of the material. The total deformation and equivalent effect are not enough to cause the failure of the part, so the structure of the pick- up robot is safe and reliable in the pick-up position and meets the strength requirements of the part.

Table 2. Take plate position stress, strain

Target Name	Total deformation/mm	Equivalent force/MPa	Strain/mJ
Minimum value Maximum	0	1.6259e-006	1.2804e-010
value	1.8355	154.25	7.9263e-002
Average value	0.40093	1.1624	6.5055e-003

Table 3. Shear force of taking plate position

Time/s	X-direction/N	Y-direction/N	Z-direction/N	Combined force/N
1	-2.5853e-005	2.3129e-006	72419	72419

4. Modal Analysis of the Entire Machine

The common modal analysis methods are finite element analysis and vibration experiment method, and the finite element analysis method is used in this paper. The first 10-order inherent frequencies of the robot obtained from the modal analysis are shown in Table 4. The first-order inherent frequency of the robot in the three typical working conditions is relatively close, and the first-order inherent frequency in the starting position is 28.226 HZ, which is slightly higher than the other two working conditions, and the first- order

inherent frequency in the pickup position is the smallest, 21.603 HZ. The first-order inherent frequencies in the three working conditions are low, between 20 HZ -30 HZ, and it can be seen that the overall structure of the References robot has low stiffness, and if it is necessary to improve the If the low order inherent frequency of the robot needs to be improved, structural strengthening is needed later to improve the overall rigidity.

Table 4. Take plate position stress, strain

Modal order	Pick-up position	Placement position	Starting position
1	21.603	25.891	28.226
2	24.575	33.885	34.306
3	50.38	51.215	49.795
4	72.427	81.127	77.65
5	96.961	99.399	103.55
6	106.16	106.61	111.23

5. Conclusion

The static and modal analyses of the loading and unloading robot show that

(1) The robot meets the requirements at the pickup position.

(2) The inherent frequency of the robot is low, and it is necessary to avoid low-order vibration patterns in practice to prevent the harm caused by low-order vibration patterns or to strengthen the overall stiffness of the robot.

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