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Typical Structure Analysis of Chain Conveyor of Electrolytic Cathode Stripping Machine

Ouyang Tao

Jiangxi Nerin Equipment Co.,Ltd, Nanchang City ,China, 330013
Email: ouyangtao@nerin.com

Abstract: The electrolytic cathode stripping machine is the automatic special equipment for copper smelting. Taking the typical structure of chain conveyor of cathode stripping machine as an example, this paper uses finite element analysis software to analyze the force of the truss structure during operation, calculate the characteristic values of the stress distribution, deflection and stability of the structure, and obtains the weak link of the force. By changing the cross-section of the beam and column and different spans, the utilization rate of material can be improved and the production cost can be reduced.
Key words: Cathode stripping machine; structure optimization; truss structure.

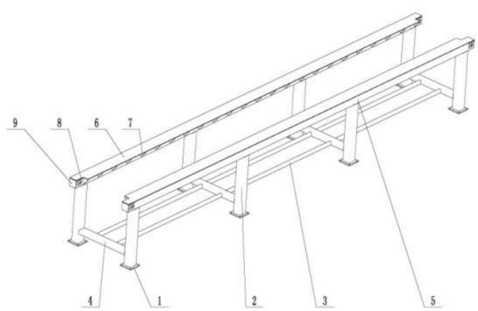
1 Introduction

Cathode stripping machine is the essential special equipment for large-scale copper electrolysis and electrowinning projects. It is widely used in the copper smelting industry and is essential large-scale automatic equipment for the production of cathode copper in the copper electrolysis process. Cathode copper is processed through a series of processes[1-2 such as washing, stripping, stacking, packaging, weighing and outputting with the help of a stripping machine. In 2001, China first introduced two sets of cathode stripping machines from Europe, which have been running well[3]. Since then, nearly 30 sets[4] have been introduced. Since 2012, many domestic companies have also completed the introduction and development of cathode stripping machine. However, the focus of the introduction and development is on the the adaptability of stripping principle, new product and new process.

With the gradual deepening of development, the stripping principle has become more mature, and further refinement of the structure has become necessary. Taking the typical structure of chain conveyor of cathode stripping machine as an example, this paper uses finite element analysis software to analyze the force of the truss structure during operation, calculate the characteristic values of the stress distribution, deflection and stability of the structure, and obtains the weak link of the force. By changing the cross-section of the beam and column and different spans, the utilization rate of material can be improved, providing reference for the rational arrangement of span and structural design[5.

2 Typical structure example of stripping machine

A special crane places a whole cell of materials on the plate receiving rack, and a trolley transfers the materials to the washing chain conveyor, or the special crane directly drops them on the washing chain conveyor. The 3D model of receiving plate rack is as follows:



Picture 2-1 Drawing of receiving plate rack
1- base plate 2-column 3-column 4- bottom cross beam 5-cross beam 6-upper cover plate 7-rib plate 8-side plate 9-end cover

Due to different processes and plant configurations, the washing chain conveyor usually receives a maximum of about 60-120 copper cathode plates, each of which weighs about 220kg. The material mainly acts on the inner side of upper cover plate, and upper cover plate is subjected to uniform force, which is calculated as follows:

$G = mg = 220 \times 120 \times 9.8 = 258720N$

3 Material properties

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The receiving plate rack is made of 304 stainless steel[6]. 304 stainless steel is a relatively common material. Since it has better performance than ordinary stainless steel in terms of rust prevention and high temperature resistance, 304 stainless steel is widely used in the metallurgical industry. At the same time, when copper is smelted by hydrometallurgy, corrosive substances will be produced, so the manufacturing material of the receiving plate rack should also have certain corrosion resistance. 304 stainless steel is American brand while the counterpart in China is 0Cr18Ni9. By checking the Mechanical Engineering Materials Manual[27], the chemical composition and mechanical properties of 304 stainless steel are shown in the table.

Table: main chemical composition of 304 stainless steel

Element	C	Si	Cr	Mn
Content	≤0.08	≤1.0	18.00-20.0	≤2.0
Element	Ni	P	S	
Content	8.00-11.00	≤0.045	≤0.03	

Table: Mechanical properties of 304 stainless steel

Brand	Yield strength σ_S (MPa)	Tensile strength σ_b (MPa)
304 stainless steel	205	520
Density g/cm3	Elastic modulus (GPa)	Poisson's ratio
7.9	195	0.247

When selecting material type and setting material parameter, select the stainless steel material in the material list and input the physical parameter corresponding to 304 stainless steel into the corresponding material.

4 Introduction of calculation

Under normal working conditions, the loads on the receiving plate rack include the gravity of the cathode plates and the gravity of the conveyor chain, and the loads are concentrated on a rectangular area within a certain width range of the beams on both sides of the rack.

(1) Cathode plate gravity

The cathode plate weighs about 200kg per piece. The maximum of 100 plates can be hung on the chain. The total weight of the cathode plates is:

G = mg = msg

G—The total gravity of the cathode plates

M—Total mass of cathode plates

m—The mass of a single cathode plate ×

s—Number of cathode plates during chain conveying

g—Gravitational acceleration, g= 9.8N/kg

(2) Chain gravity

The weight of a single chain is 500kg. When the receiving plate rack is working, there are two chains are conveying cathode plates. The total gravity of the chain is:

G=msg=220×100×9.8=215600 N

(3) Total gravity

The total gravity also considers the weight of the additional conveying chain, so the total weight is:

G=215600+9800=225400N

Due to the non-statically determinate structure of the beam, numerical calculations are more convenient[7-8]. Finite element analysis technology is a simulation calculation analysis method that approximates physical systems in real life using mathematical method, using finite elements to approximate real physical systems containing infinite unknowns[9-10]. The common calculation steps are as follows:

The first step is to create a model: According to the actual problem, build a mathematical model, use 3D modeling software to build the corresponding model, and prepare for importing finite element analysis software.

The second step is pre-treatment Define the solution model according to the actual problem, including the following aspects:

(1) Define the geometric region for solving the problem: Determine the geometric region for solving based on the physical properties of the actual problem.

(2) Define element type

(3) Define the material properties of the element

When selecting material type and setting material parameters in the finite element software model, select stainless steel in the material list and input the physical parameters corresponding to 304 stainless steel into the corresponding material.

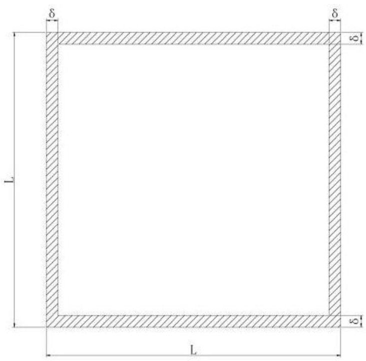
σ_s	σ_b	Elastic modulus	Poisson's ratio
205Mpa	520Mpa	195Gpa	0.247

(4) Define the geometric properties of the element etc
(5) Define the connectivity of the element
(6) Define the basis functions of the element
(7) Define boundary conditions
(8)Define Loads
(9) Refine element grid
After the grid division is completed, the constraint and load are applied. The total gravity is applied vertically and evenly to the 20×11530mm area on the upper surface of the rack, and a fixed constraint is applied to the bottom plate of the rack.
By observing the calculation results, it can be obtained that the larger deformation of the receiving plate rack is mainly concentrated in the upper plate and the square tube. The deformation of the bottom plate, column and bottom beam is less than 1mm. The largest deformation is in the middle of the upper plate between two adjacent columns. The maximum deformation is 2.8894mm. For a centerline beam with a span of 3500, the deformation is almost negligible.
Moreover, the stress of most structures of the rack is around 30Mpa, which is far less than the yield stress of the material. Although there is a stress concentration point at the junction of the square tube and the column, reaching 286.15Mpa, it is still less than the yield strength of the material.

5 Analysis of force state under different sections

Due to the influence of material state, the main body of the current chain conveyor is made of profile square tubes. The material is usually different such as 200×8mm, 150×8mm, 150×6mm, etc. Mechanical simulation analysis is carried out, and the results are as follows:
The statistical analysis under different combinations is as follows:

Column section	200×6	150×6	150×6
Beam cross section	200×8	150×8	150×6
Maximum deformation	3.6734	5.1643	5.9155
Maximum stress	399.45	408.34	545.47

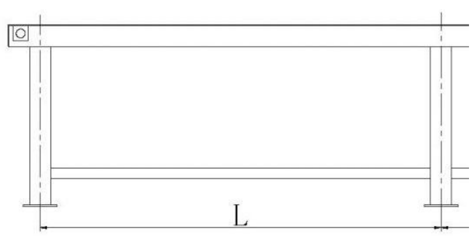


The unit of section size is mm, the unit of deformation is mm, and the unit of stress is MPa.
From the data in the table, it can be seen that when the section of the beam and the section of the column are changed, the change of the section of the beam has a greater impact on the entire force, especially when the wall thickness of the beam is changed, the local stress increases significantly, while the change of the column has a smaller corresponding impact; except for individual stress concentration points, its overall strength can meet the requirements; when the section of the beam is unchanged, only the column is modified, take 200×6 as an example, if adjusted to 150×6, a single column can save nearly 50% of material. Based on a double-span plant building, the whole set of chain conveyor can save about 1.7 tons of materials.

6 Force calculation of rack with different spans

Considering that most structure stress of rack is only about 30Mpa when the distance between two spans is 3500. Stress simulation calculations are performed for distance between two spans. Choose center distance of distance between two spans at 3000, 4000 and 4500 center distance for calculation. From the calculation results, it can be seen that when the distance reaches 4500, the maximum stress is 353.69Mpa, which is still less than the yield stress of the material. The calculation results are as follows:

Span	3000	3500	4000	4500
Deformation	2.0944	2.8894	3.2912	3.5863
Stress	224.56	286.15	313.3	353.69



The unit of section size is mm, the unit of deformation is mm, and the unit of stress is MPa.
At present, the distance between two spans between adjacent columns used in production is designed to be relatively small, generally 3000 to 3500. According to the calculation results, the distance between two spans can be appropriately enlarged to improve the utilization rate of materials and reduce manufacturing costs. Taking a double-span plant as an example, the receiving plate rack is always more than 30m. When the distance between two spans between two adjacent columns changes from 3000mm to 4500mm, the number of columns used changes from 11 to 7.6, and the column material is reduced by 30.9%.

7 Conclusion

The main purpose of structural statics analysis of receiving plate rack is to verify whether the deformation and stress of the rack structure meet the use and design requirements, and to improve the material utilization rate from different aspects such as sectional area optimization and column span distance optimization. This paper takes the typical structural form of the cathode stripping machine conveyor chain conveyor as an example, uses finite element analysis software as a calculation tool, analyzes the force of the typical rack structure during operation, calculates the characteristic values of the structure such as stress distribution, deflection and stability, and obtains the influence of different factors on the force of the entire rack by changing the section and span distance of the beam column to guide production design, improve material utilization and reduce production costs. It can be seen from the calculation that for the reasonable design of constrained load-bearing structural parts, the finite element analysis can be used to effectively avoid stress concentration. This method also provides a technical means for industry optimization design; at the same time, by comparing the force of the rack under different span distances and sections, the spacing is appropriately expanded and the column section is reduced, which can meet production needs and reduce production costs at the same time, and is also helpful to enhance the competitiveness of enterprise.

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