Thermo-mechanical coupling analysis of roll mandrel

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Abstract. First, the force model of roll is set up, and the temperature field is analyzed according to the properties of the processed material, which provides data support for the thermomechanical coupling analysis of roll. Then, The effect of the roll temperature field distribution, the equivalent stress distribution and the equivalent plastic strain distribution on the roll is analyzed by the sequential thermo mechanical coupling analysis of the roll. Finally, It provides theoretical support for studying the mechanism of roller damage and prolonging the life of rolls.

1. Introduction
China has been a big consumer of copper, especially copper consumption in recent years. Rolling technology, as the core technology of seamless copper tube production, determines the quality of copper tube production. The main production methods of seamless copper pipe are hot extrusion - cold rolling - cold drawing method, hot cross rolling piercing-cold rolling-cold drawing method, horizontal continuous casting and rolling method. The hot extrusion process has good quality and flexibility, but the geometric waste is high, the cost is high, and the investment of equipment is high [1-5]. The main technological process of horizontal continuous casting and rolling of seamless copper tube is generally as follows: continuous casting tube billet-three roll planetary rolling-drawing-finishing and annealing. It has the advantages of large flexibility, good product quality and low cost. The main rolling technology of the seamless copper tube rolling process is planetary rolling technology. In this paper, the three-roll planetary rolling technology is taken as an example to analyze the thermomechanical coupling of the roll mandrel [6-10].

2. Thermal analysis of copper tube rolling process
Thermal analysis of rolling process is the basis of thermo mechanical coupling analysis, and lays the foundation for subsequent analysis [11-12].

2.1. Modeling of rolling process
The core rolling mechanism of the three-roller planetary mill is roller and mandrel. The mandrel plays a guiding role and the mandrel plays a guiding role. The mandrel is rotating with the inner wall of the copper tube in the actual rolling production. In order to simplify the model, the mandrel is fixed to the rigidity, and the simulation model of the mandrel is set up as shown in Figure 1.
The copper tube material used in this study is phosphorus deoxy copper (TP1). Its chemical composition is shown in table 1. TP1 has good heat conduction and corrosion resistance.

Table 1. TP1 chemical composition table

|   | Cu     | P     | Ni  | Fe  | Bi | Zn   | Pb  | S   | As  | Sb | Sn   | O   |
|---|--------|-------|-----|-----|----|------|-----|-----|-----|----|------|-----|
|   | 99.90  | 0.005 | 0.01| 0.02| 0.05| 0.005| 0.005| 0.005| 0.002| 0.002| 0.002| 0.01 |

The mechanical properties of TP1 materials are shown in table 2.

Table 2. Performance parameters of TP1 copper basic materials at room temperature

| Material | Density(g/cm3) | Yield strength (Mpa) | Poisson ratio | Modulus of elasticity(Gpa) |
|----------|---------------|----------------------|---------------|----------------------------|
| TP1      | 8.75          | 245                  | 0.3           | 121                        |

Figure 2. The influence of thermal coefficient on TP1
The thermal conductivity, specific heat and thermal expansion coefficient of TP1 are greatly influenced by temperature, so the relationship between temperature and temperature is fully considered in the study, as shown in Figure 2.

2.2. Temperature analysis of copper tube rolling process

Thermal simulation analysis of copper tube rolling process using MSC. Marc.

The copper tube three roll rolling process is simulated to obtain the copper tube billet temperature and heat flux distribution cloud chart as shown in Figure 3. The overall temperature field distribution of the copper tube is shown in figure(a). It is shown from the diagram that the temperature of the copper tube billet rolling in the direction of rolling and rolling along the axis gradually rises from the initial temperature of 19°C, and the temperature of the reducing area rises to about 190°C. In the concentrated deformation area, the maximum value of the copper tube blank is raised to the maximum value of about 650°C, then to the finishing. The zone temperature is increased due to the increase of the rolling area, and the deformation of the copper tube blank decreases, and the temperature drops to about 190°C. Figure(b) in the heat flux distribution of copper tube, it is shown that the maximum heat flux on the surface of the copper tube is in the contact area between the copper tube billet and the roll. It shows that the main heat transfer path of the copper tube billet is passed through the contact area of the roll.

3. Thermal coupling analysis of copper tube rolling process

Thermal coupling analysis and transient dynamic analysis of rolls are carried out by ANSYS Workbench.

Figure 4 a, b, c and d are equivalent stress nephogram and deformation nephogram obtained by thermal-mechanical coupling analysis and transient dynamic analysis of the same load step roll, respectively. The roll's maximum stress is located in the contact area of the roll and copper tube billet, and the maximum deformation amount is 465.55MPa, and the maximum deformation is 0.043mm. The maximum stress of the roll is 148.15MPa and the maximum deformation amount is 0.035mm. The yield limit of roll is σ=720MPa, and the safety coefficient of the roll in the thermal coupling analysis and transient dynamic analysis is obtained respectively: nc=1.47, nt=3.86, the known safety factor of the roller is n=2.1. It can be seen that the roller has a low working safety factor in the actual rolling production of copper tube under the coupling effect of high temperature and rolling force, and it affects the roll of the service life.
In the high temperature environment, it can be found that the stress of the roll increases significantly in the high temperature environment and the amount of deformation increases. It can be seen that during the process of copper pipe rolling, high temperature is produced by the roll and copper tube billet and the severe deformation of the copper tube billet, which produces a great amount of stress, distribution and deformation of the roll. It can shorten the service life of the roller and increase the production cost of copper tube rolling. Therefore, effective measures can be taken to reduce roll temperature, and the parameters of copper tube rolling can be optimized to reduce the rolling force, thus reducing the stress of the roll and prolonging the service life of the roll.

4. Conclusion
(1) the temperature of the contact zone between the roller and the copper tube billet is much higher than that in the non-contact area. When the temperature of a node is in contact with the copper tube billet, the temperature of the node rises. When the node is separated from the copper tube billet, the temperature of the node decreases. With the increase of the contact number, the maximum temperature of the node increases gradually.

(2) through the transient temperature finite element analysis of roller, the heat flux distribution of copper tube billet and roller in the process of copper tube rolling is obtained.

(3) in the high temperature environment, the stress of the roll increases significantly and the amount of deformation increases. The work safety factor of the roll in the actual rolling of copper tube is low. It can be seen that during the process of copper tube rolling, the roll and the copper tube billet are working hard and the copper tube blank is deformed so that the roll and the copper pipe contact area will produce high temperature. The force, deformation and so on have great influence.
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