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ANALYSIS ON TEMPERATURE FIELD AFTER ANGLE STEEL'S CONTROLLED COOLING

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According to the theory of thermal analysis, the angle steel as the research object, was established as one finite element model in section steel and was taken the thermal analysis with the software ANSYS. Contrasting the natural cooling and controlled cooling, could get angle steel's each parts about the temperature changes and the angle section's temperature field in all directions. Analysis results show that: the control cooling could increase the cooling rate, making the temperature distribution of steel more uniform, improve the temperature field distribution, and even increase mechanical property and general performance, which have a good reference value for the study to angle steel's controlled cooling on temperature field.

Keywords: steel, thermal analysis, Finite element model, controlled cooling, temperature field

INTRODUCTION

In the field of steel rolling, controlled cooling belongs to the category of controlled rolling. It refers to a method that people purposefully control the cooling process of hot rolled products. To be exact, the so-called controlled cooling is a cooling method that uses the rolling waste heat after rolling to control the cooling rate with certain control means, so as to obtain the required microstructure and properties [1].

Controlled cooling technology can refine the microstructure and improve the toughness of steel, which has become an important technology in rolling production, and has been continuously developed and applied [2]. With the deepening of the understanding of controlled cooling technology, great progress has been made in cooling equipment, cooling methods and other controlled cooling technologies [3].

One of the important purposes of controlled cooling is to further improve the strength of materials without reducing the toughness of materials. The controlled cooling of angle steel after rolling is to make use of the fast cooling of the surface layer of angle steel directly in austenite state after final rolling to reduce the temperature of rolled piece. In order to ensure that the tempered structure after quenching does not appear in rolled piece, the final cooling temperature must be higher than the recrystallization temperature of rolled piece.

At the same time, it can also reduce the temperature of the cooling bed on the rolled piece, reduce the pressure of the cooling bed, reduce the thickness of the scale, improve the strength and plasticity of the rolled piece, and make the angle steel get good comprehensive properties. Spray cooling is adopted in the controlled cooling of the diagonal steel after rolling. The spray cooling method has the characteristics of good cooling uniformity, fast cooling speed and wide cooling capacity adjustment range [4].

Table 1 **The chemic composition of Q235/ wt. %**

C	Si	Mn	P	S	Cr	Ni	Cu
0,15	0,22	0,56	0,016	0,028	0,001	0,018	0,1

The equilateral angle steel with material of Q 235 and specification of 100 mm × 100 mm × 12 mm is selected as the research object, and its chemical composition is shown in Table 1.

ESTABLISH FINITE ELEMENT MODEL

It use the large-scale general finite element analysis software ANSYS for analysis, ANSYS thermal analysis involves about 40 kinds of elements, of which 14 are purely used for thermal analysis [5]. The plane77 element is used to solve the two-dimensional temperature field model of angle steel. The geometric model of plane77 element is shown in Figure 1. The element is used to model two-dimensional heat conduction problems. This element can be used to model problems with curved boundaries. Each node of the element has only one degree of freedom, which is temperature. The output data of the cell includes node temperature and cell data, such as thermal gradient and heat flux. The two-dimensional model of angle steel is shown in Figure 2.

The width of angle steel edge is 100 mm, the thickness of angle steel edge is 12 mm, the inner arc radius

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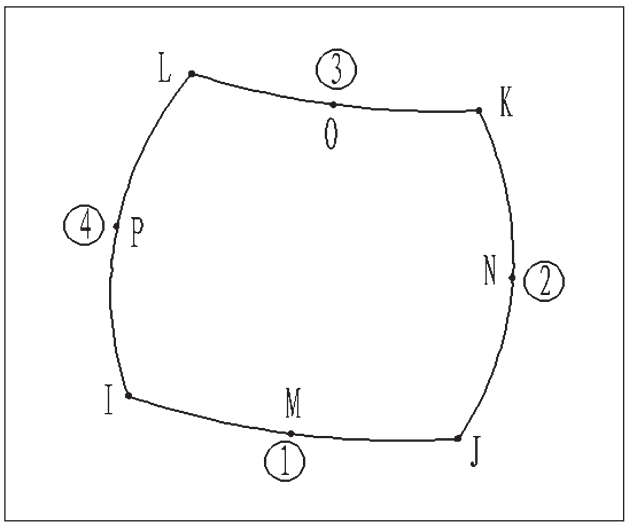

Figure 1 The geometry model of plane77

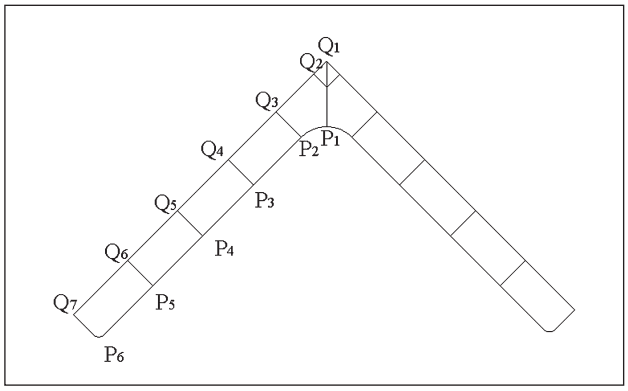

Figure 2 The planar model of angel steel

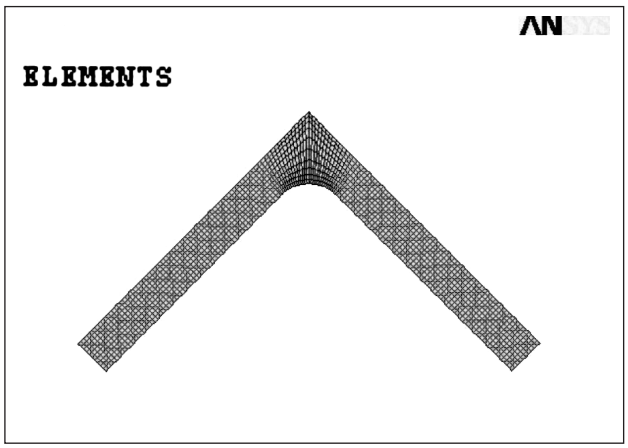

Figure 3 The grid of angel steel model after meshing

of angle steel is 12 mm. In order to ensure the authenticity of the simulation process and make the model intuitive and easy to understand, the whole section of angle steel is selected for modeling. Considering that the radius of the inner circle at the end of the angle steel is extremely small, the radius of the inner circle at the end of the angle steel is ignored in the process of ANSYS modeling, so that the model is appropriately simplified. Because the two-dimensional model of angle steel is relatively simple, in the process of ANSYS calculation, it will not occupy a lot of computer resources. In the degree of mesh density, this topic divides the two-dimensional model of angle steel mesh more carefully; in the mesh size, try to ensure that the length and width direction are consistent, in order to ensure the accuracy of calculation. After meshing, the model contains 1 600 elements and 5 132 nodes. The two-dimensional model after meshing of angle steel is shown in Figure 3.

ANALYSIS OF TEMPERATURE FIELD IN CONTROLLED COOLING PROCESS

Natural cooling

The initial temperature is 940 °C and the ambient temperature is 30 °C. The heat transfer coefficient of air cooling stage is determined by Table 2.

Figure 4 shows the temperature field distribution of angle steel after natural cooling for 300 S. As can be seen from Figure 3, after the angle steel is naturally cooled, the temperature field distribution is relatively uniform.

The red area means high temperature, and the blue area means low temperature. The high temperature area is distributed in the center of the combination of the two waists of the angle steel, and the maximum node temperature is 683,466 °C; the low temperature area is distributed in the outside of the end of the two waists of the angle steel, and the minimum node temperature is 632,496 °C, and the maximum temperature difference is 50,97 °C. The temperature distribution is more uniform, and the temperature difference of each node is relatively small, but the cooling rate of air cooling is very slow, and the cooling effect is not obvious, which is not conducive to the rapid transformation of austenite. We can see that the temperature of the inner part of the angle steel is the slowest in the cooling process.

Controlled cooling

After selecting a variety of different cooling schemes, we compare the results of controlled cooling calculation, and finally we choose a cooling scheme with the best controlled cooling effect: first air cooling for 3 seconds, then water cooling for 5 seconds, and finally air cooling for 5 seconds.

The flow density of Q_1Q_2 is 1 160/ $L \cdot m^{-2} \cdot min^{-1}$, that of Q_2Q_3 is 2 040/ $L \cdot m^{-2} \cdot min^{-1}$, that of Q_3Q_4 and P_2P_3 is 1 520/ $L \cdot m^{-2} \cdot min^{-1}$, that of Q_4Q_6 and P3P5 is 1 580/ $L \cdot m^{-2} \cdot min^{-1}$, and that of Q_6Q_7 and P_5P6 is 1 570/ $L \cdot m^{-2} \cdot min^{-1}$. The nodes location are shown in Figure 2.

Figure 5 shows the temperature field distribution of the angle steel after controlled cooling. At this time, the

Table 2 **The naturally heat transfer coefficient of angel steel**

temperature /°C	500	600	700
heat transfer coefficient /W.m^{-2}K^{-1}	44,62	57,22	72,44
temperature /°C	800	900	1 000
heat transfer coefficient /W.m^{-2}K^{-1}	90,58	111,92	136,15

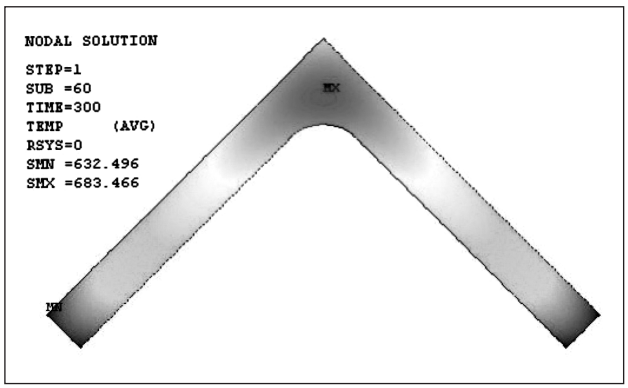

Figure 4 The temperature field after natural cooling

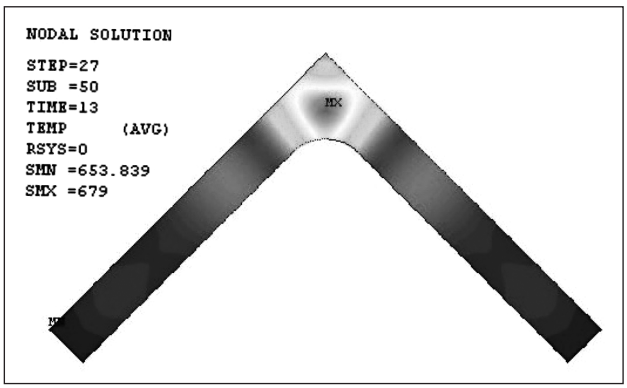

Figure 5 The temperature field after controlled cooling

temperature distribution of the whole section of the angle steel is very uniform. The maximum temperature of the joint is 679 °C, the minimum temperature of the joint is 653,839 °C, and the temperature difference is only 25,161 °C.

CONCLUSION

The temperature field distribution of angle steel under natural cooling and controlled cooling can be calculated accurately by ANSYS software. By comparing the calculation results of different controlled cooling schemes, the best cooling scheme can be selected: first air cooling for 3 seconds, then water cooling for 5 seconds, and finally air cooling for 5 seconds. This controlled cooling method can effectively improve the cooling rate of angle steel. The maximum temperature of the nodes is 679 °C, the minimum temperature of the nodes is 653,839 °C, and the temperature difference is only 25,161 °C, which is far lower than the maximum temperature difference of the natural cooling of 50,97 °C. The temperature distribution of the whole section of the angle steel is very uniform, which effectively improves the temperature field distribution of the angle steel section, and improves the mechanical properties and comprehensive performance of the angle steel.

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Note: The responsible translator for English language is L. Y. Huang, Anshan, China