Temperature Variation of Steel Plate with Different Thickness on Normalizing Process

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Abstract. By placing the thermocouples inside the steel plate and measuring the actual temperature in the normalizing process, combined with the numerical calculation, the temperature variation law of different thickness steel plate is simulated and calculated. The calculation shows that the core cooling rate is the lowest at the beginning of cooling. With the decrease of temperature, the cooling rate changes and then continues to decrease. The maximum cooling rate is $0.53^\circ$C/s-$0.35^\circ$C/s. When the plate surface temperature reaches $642^\circ$C-$673^\circ$C, the cooling rate of steel plate surface is consistent with that of core.

1. Introduction

According to the phenomenon that the core and edge properties of the container steel plate 12Cr2Mo1R are different\cite{1-3}, the way of drilling and placing thermocouple on the steel plate is designed, and the temperature course curve of the rolled steel plate during the normal heat treatment is obtained. In order to cooperate with the temperature measurement test, the finite element model was established to simulate the temperature field of the steel plate under the same environment as the normal heat treatment test, and the cooling rate of the core of the steel plate with different thickness specifications was obtained\cite{4}. The convection heat transfer and radiation boundary conditions of normalizing process are deduced.

2. Experimental methods

Temperature measurement test of steel plate thermocouple with thickness of 60 mm: drilling with 12 Cr2Mo1R of 60 mm thick steel plate with hole diameter of 5 mm, and then embedded in thermocouple. Experimental 60 mm thick steel plate data as numerical simulation reference value. The equipment for measuring steel plate temperature acquisition is Anbai-AT4204 multi-channel temperature acquisition instrument and matching nickel-chromium-nickel-silicon K thermocouple, as shown in the following figure.
The normalizing heating test was carried out, the set temperature was 970°C, the actual furnace temperature was 1000°C, and the furnace temperature was controlled to 970°C.

3. Building Models
A 1/4 model is established using steel plate specification, 60 ×235×360mm; that is 1/2 length \1/2 width\ full thickness. The schematic diagram of the geometric model is shown in figure 2. Four typical locations during the normalizing test A\B\C\D thermocouple embedded, A\B\C\D coordinates of the four points are: A(0.028, 0.0055, 0.03); B(0.028, 0.0125, 0.05); C(0.031, 0.0365, 0.01); D(0.170, 0.0135, 0.03).

4. Building Models
4.1. Calculation of surface heat transfer coefficient
CH01-CH04 represent the temperature of the four points of the B\A\C\D with the normal heat treatment time.

Fig .3 Normalizing temperature history of typical position measured by thermocouple
4.2. Prediction of plate core temperature and calculation of cooling rate
The temperature history curve and cooling rate of the normalizing process of the core of the steel plate can be obtained by using the reverse heat transfer method to obtain the comprehensive heat transfer coefficient and substitute the checked model, as shown figure 4.

![Temperature reduction and Cooling rate](image1)

Fig. 4 Temperature history curve and cooling rate curve of the core of normalizing process

4.3. Cooling rate of steel core with different thickness
As can be seen from figure 5, As the thickness increases, The cooling rate of steel plate core is reduced; The maximum value was 0.53°C/s (60mm), 0.42°C/s (50mm), 0.35°C/s (40mm). As the temperature drops, The cooling rate gradually decreased. For 60 mm thick plates, The average cooling rate in the 956°C-800°C range is 0.32°C/s, The average cooling rate in the range of 800°C-400°C is 0.19°C/s, and below 0.044 percent.

![Temperature reduction and Cooling rate](image2)

Fig. 5 Cooling process curve and cooling rate curve of core of steel plate with different thickness

4.4. Cooling rate of surface and core of steel plate
The cooling rate of the surface and core of the three thickness steel plates during air cooling is shown in Fig. 6, in which a) is the temperature drop process of 40 mm thick steel plate and b) the cooling rate of 40 thick steel plate.
4.5. Effect of normalizing heating temperature on cooling rate of steel plate after normalizing

Fig. 7 shows the cooling process curve and cooling rate curve of Cr-Mo steel with thickness of 60 mm at different heating temperatures. Above 700°C, the higher the heating temperature, the greater the cooling rate of the steel plate. But below 680°C, the heating temperature has little effect on the cooling rate.

5. Conclusion
1) 60 mm steel plate, the cooling rate of the center is low at the beginning of cooling. Between 0.05-0.35°C/ s, the maximum cooling rate is 0.38°C/ S, when the temperature decreases to 930.
2) The steel plates of different thickness, the maximum rate of normalizing air cooling is : 0.53°C/ s (40mm), 0.42°C/ s (50mm), 0.35°C/60mm).
3) The surface of steel plate with different thickness reached 642°C(40 mm), 660°C(50 mm), 673(60 mm), the cooling rate of steel plate surface was consistent with the core.

References
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