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STUDIED ON THE KINETICS OF AUSTENITIZING PHASE TRANSITION OF 1Cr13 STEEL

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The austenitizing of steel plays an important role in improving its properties. Studying the kinetics of austenitizing of steel has certain theoretical significance for practical production. In this article, the Differential scanning calorimetry(DSC) was used to measurement the enthalpy change for the austenitizing process of 1Cr13 steel at different heating rates. The kinetic parameters were obtained based on the data of the enthalpy change for the austenitizing process of 1Cr13 steel. The result is shown that the activation energy of austenitizing process of 1Cr13 steel is dependence of the phase transition fraction. The kinetics mechanism function of the austenitizing process is nucleation and growth model, $[-\ln(1-\alpha)]^{2/3}$. The value of the pre-exponential factors is $8{,}617*10^{80}s^{-1}$.

Keywords: 1Cr13 steel, austenitizing, differential scanning calorimetry, kinetics mechanism function, enthalpy, the activation energy

INTRODUCTION

The main purpose of the heating for the heat treatment of metal materials is to obtain all or part of the organization of austenite. So the supercooled austenite was transformed into the required organization and properties through different cooling methods[1,2]. As the meaning was expressed, the cooling organization was obtained from the supercooled austenite at the after heat treatment for the steel. The strength, plasticity and toughness were better if the finer the grain size of austenite and the finer the transition structure at the after cooling[3,4]. Especially the toughness of tempered steel has a great impact. Therefore, the study of austenitizing kinetics of metal materials is of great significance to improve the mechanical properties of metal materials.

In this paper, the austenitizing process of 1Cr13 steel at different heating rates was studied by thermal analysis technique. The activation energy and mechanism function of 1Cr13 steel during austenitizing process were studied by equal conversion method based on the enthalpy change during austenitizing process. It can be provided some theoretical support for revealing the complexity of 1Cr13 steel austenitizing process

EXPREIMENT AND RESULT

At the first, use the wire cutter to cut the sample into primary sheets with a thickness of early 2,5 mm, and grind them into sheets with a thickness of about 2 mm and a width of about 2,5 mm. Labsys synchronous DSC was used in the experiment. The temperature measurement range is from room temperature to 1 600 °C. The heating program is from 30 °C to 1 050 °C at different heating rate of 10 °C/min, 20 °C/min, 30 °C/min and 40 °C/min, then drops to room temperature at a cooling rate of 50 °C/ min^{-1}.

The phase transition fraction was calculated by the method in literature[5] based on the data of the enthalpy at different heating rates. The relationship between the phase transition fraction and temperature is shown in Figure 1.

KINETICS ANALYSIS

The activation energy

Flynn-Wall-Ozawa method is a commonly used method for determining the activation energy [5,6]. The formula is shown in the following.

$$\lg\beta = \lg\left(\frac{AE}{Rg(\alpha)}\right) - 2{,}315$$

$$-0{,}4567\frac{E}{RT} \qquad (1)$$

Where, A is the pre-exponential factors, T is temperature, $g(\alpha)$ is the kinetics mechanism function of the austenitizing process, α is phase transition fraction, E is activation energy, R is gas constant, and β is heating rate.

According to Eq.(1), when the α is selected, $-\ln(1-\alpha)$ is also a constant value. Therefore, by making $\lg\beta$–$1/T$

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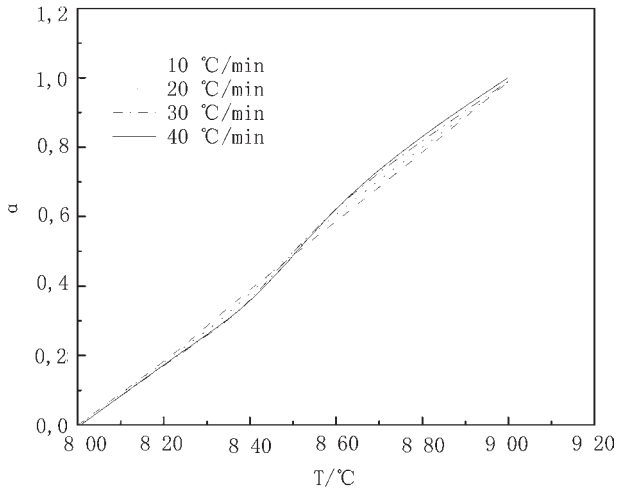

Figure 1 The relationship of the activation energy and Phase transition fraction

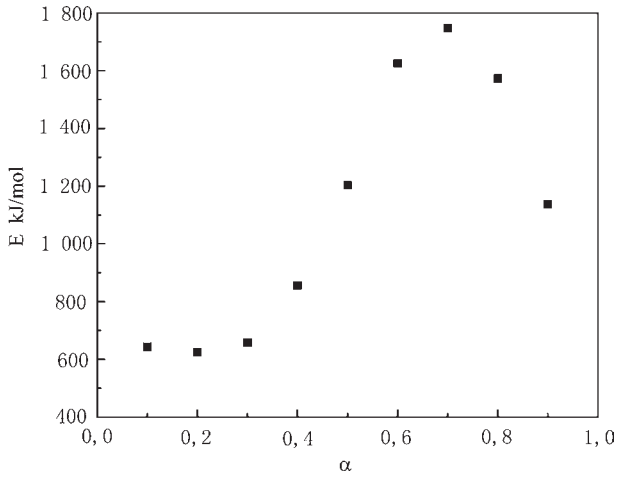

Figure 2 The relationship of the activation energy and phase transition fraction

curve, *E* under different Phase transition fraction could be determined according to the curve's slope. The relationship of the *E* and α calculated by the Eq.(1) with the Phase transition fraction is shown in Figure 2.

As seen from Figure 1, the activation energy varied with the Phase transition fraction. The activation energy changing can be divided into three stages. At the first stage, the activation energy is basically constant at the range of 0-0,2. At the second stage, the activation energy increases with the increase of the Phase transition fraction at the range of 0,3-0,7. At the three stage, the activation energy decreases with the increase of the Phase transition fraction at the range of 0,7-1,0. As can be seen from the above results, we can conclude that austenitizing process of 1Cr13 steel is a very complicated process.

MECHANISM FUNCTION

The austenitizing process of metal materials follows the mechanism of nucleation and growth, and the common mechanism functions are shown in Table 1.

Table 1 **The common mechanism functions**

Mechanism functions		Differential of mechanism functions
A_1	$-\ln(1-\alpha)$	$1-\alpha$
$A_{1.5}$	$[-\ln(1-\alpha)]^{2/3}$	$\frac{3}{2}(1-\alpha)\left[-\ln(1-\alpha)\right]^{\frac{1}{3}}$
A_2	$[-\ln(1-\alpha)]^{1/2}$	$2(1-\alpha)\left[-\ln(1-\alpha)\right]^{\frac{1}{2}}$
A_3	$[-\ln(1-\alpha)]^{1/3}$	$3(1-\alpha)\left[-\ln(1-\alpha)\right]^{\frac{2}{3}}$
A_4	$[-\ln(1-\alpha)]^{1/4}$	$4(1-\alpha)\left[-\ln(1-\alpha)\right]^{\frac{3}{4}}$

The mechanism function can be determined from the following equation [7].

$$\ln\left[\frac{\beta\frac{d\alpha}{dT}}{f(\alpha)}\right]=\ln A-\frac{E}{RT} \tag{2}$$

$$\ln\left[\frac{g(\alpha)}{T^2}\right]=\ln\frac{AR}{\beta E}-\frac{E}{RT} \tag{3}$$

Where $d\alpha/dT$ is the rate of phase transition.

Introducing the mechanism functions in the table 1 into the equation (2) and (3) , we can calculate the value *E* and the value *A*, according to the slope and intercept of $\lg\left[\beta(d\alpha/dT)\right]/f(\alpha)-1/T$ and $\lg g(\alpha)/T^2-1/T$. If the values obtained by the two methods are similar and the value of the correlation coefficient [r] is close to 1, we can judge the mechanism function. The result is shown in Table 2 and Table 3.

It can conclude that the $A_{1.5}$ is the mechanism function from the table 2 and table 3. On the one hand, the correlation coefficient [r] is close to 1. On the other hand, the value of the activation energy by the equation 2 and equation 3 are very close to the average value 1 118.72 kJ/mol^{-1} determined by the equation 1. Therefore, the pre-exponential factors *A* also can be calculated by the equation 2 and equation 3, the value of the *A* is 8,617*10^{80}s^{-1}.

Table 2 **The value of *E* determined by the equation (2)**

Mechanism function	*E* kJ/mol	[r]
A_1	1 717,79	0,51066
$A_{1.5}$	1 172,50	0,99257
A_2	1 375,35	0,80536
A_3	1 464,11	0,89257
A_4	726,13	0,78668

Table 3 **The value of *E* determined by the equation (3)**

Mechanism function	*E* kJ/mol	[r]
A_1	3 11,65	0,89342
$A_{1.5}$	1 127,32	0,99435
A_2	2 99,40	0,76412
A_3	8 6,65	0,86451
A_4	3 96,88	0,96342

CONCLUSION

The activation energy of the 1Cr13 steel austenitizing process is not a constant. The activation energy varied with the phase transition fraction. The mechanism function of the 1Cr13 steel austenitizing process is nucleation and growth mode, $[-\ln(1-\alpha)]^{2/3}$. The value of the pre-exponential factors is $8{,}617*10^{80}s^{-1}$.

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Note: The responsible translator for language English is associate professor Y. H. Wang - Yingkou Institute of Technology, Liaoning, China.