

Research on Thermal Simulation Test Parameters of CGHAZ for 2.25Cr1Mo0.25V Steel

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Keywords: 2.25Cr1Mo0.25V; CGHAZ; thermal simulation process parameters

Abstract: The reheat cracking most commonly occurs in the welding coarse grained heat affected zones (CGHAZ) of 2.25Cr1Mo0.25V steels. Thermal simulation test is an effective method to obtain CGHAZ material. In this paper, based on practical welding process of 2.25Cr1Mo0.25V steel, a series of thermal simulation tests with different process parameters were carried out on Gleeble thermal-mechanical simulator. According to the comparison of hardness, grain size and microstructure between the simulated and actual CGHAZ, the suitable thermal simulation parameters of 2.25Cr1Mo0.25V steel CGHAZ were screened out.

1 Introduction

2.25Cr1Mo0.25V steel has higher high temperature strength, better creep resistance and hydrogen resistance than the traditional CrMo steel, and gradually become the preferred material for hydrogenation reactor steel^[1,2]. However, due to the addition of strong carbide forming elements such as V and Ti, the sensitivity of the welded joint to reheat cracking is greatly increased. Since 2007, there have been reheat cracks in many 2.25Cr1Mo0.25V steel hydrogenation reactors both at home and abroad^[3,4]. Reheat cracking has become one of the major problems in the manufacturing process of 2.25Cr1Mo0.25V steel hydrogenation reactor^[5,6].

The reheat cracking of 2.25Cr1Mo0.25V steel mainly occurs in the coarse grain heat-affected zone(CGHAZ) of welded joint^[7]. The heat-affected zone of the welded joint is only 2-3mm, and the CGHAZ is more narrow. It is difficult to obtain CGHAZ test material. For such problems, thermal simulation is generally used. By selecting the appropriate thermal simulation parameters^[8,9], the materials close to the actual welding structure are obtained. At present, the thermal simulation research on the heat affected zone of 2.25Cr1Mo0.25V steel is mainly focused on the influence of different welding thermal cycles to the microstructure and properties of the heat affected zone^[10]. But about the simulation of actual 2.25Cr1Mo0.25V steel CGHAZ material, the thermal simulation process parameters have not been reported.

Therefore, the thermal simulation process parameter research and Gleeble thermal simulation test are carried out in this paper. The thermal simulation process parameters of 2.25Cr1Mo0.25V steel CGHAZ material were studied by comparing the microstructure and properties of the thermal simulation material with the actual welding joint CGHAZ material.

2 Test Material

In order to obtain the actual welding joint CGHAZ material of 2.25Cr1Mo0.25V steel, the 2.25Cr1Mo0.25V steel plate produced by Wuyang steel mill of China is used for welding. The size of the steel plate is 1000×250×88mm and the chemical composition is shown in Table 1. According to the same narrow gap submerged arc welding process of hydrogenation reactor, the welding voltage is 32V, the speed is 20m/h, and the current is 580A. Welding material is Japan's Kobelco production: US-512H welding wire, flux is PF-50 and electrode is CM-A106HD. The welding work was done by Lanshi Heavy Equipment Co., Ltd. and the actual welding joint CGHAZ material was obtained from the weld by machining method after welding.

The test device used in thermal simulation test is Gleeble3180 test machine. Thermal simulation specimens were prepared from 2.25Cr1Mo0.25V steel base material and the sample size is shown in Figure 1

Table 1 Chemical composition of parent metal (%)

Element	C	S	P	Si	Mn	Cr	Mo	V
Requirement	0.11~0.15	≤0.005	≤0.010	≤0.10	0.27~0.63	1.95~2.60	0.87~1.13	0.25~0.35
Wuyang Steel	0.14	0.002	0.006	0.07	0.60	2.48	1.00	0.33

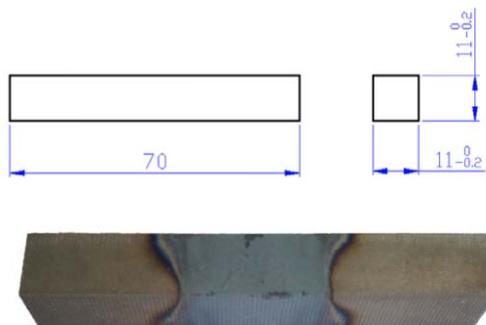


Figure 1 Dimensions of thermal simulation specimens

3 Test Method

(1) According to the actual welding process of the hydrogenation reactor and the experience of the welding heat transfer process, the range of the main influence parameters such as the peak temperature T_p , the peak temperature residence time t_p , the heat input Q , the heating rate ω_H , the preheating temperature T_0 were determined. The preliminary screening scheme of 9 sets of thermal simulation test parameters is shown in Table 2. Among them, according to the actual measured temperature of welding peak temperature and heating rate of 2.25Cr1Mo0.25V hydrogenation reactor, the peak temperature of T_p is 1320 °C and the heating rate ω_H is 1000 °C/s. 2.25Cr1Mo0.25V steel welding generally adopts narrow gap submerged arc automatic welding. According to its welding process calculation, the heat input Q is about 25~35kJ/cm, and the preheating temperature T_0 is between 180~220°C. According to the welding speed and measured experience, the peak temperature residence time t_p is about 0.5 ~ 2s. The HAZ module in the Gleeble thermal simulator has a mature weld cooling model that calculates the cooling times $\Delta t_{8/5}$ and $\Delta t_{p/8}$ based on the heat input and peak temperature.

(2) According to the thermal simulation test parameters of Table 2, nine sets of thermal simulation test materials were obtained.

(3) By comparing the hardness, microstructure and grain size of the experimental material obtained by thermal simulation with the actual CGHAZ material, the thermal simulation material which is closest to the actual CGHAZ is screened out, and the appropriate thermal simulation parameters are obtained.

Table 2 Screening Scheme of CGHAZ Thermal Simulation Test Parameters for 2.25Cr1Mo0.25V Steel

Sample number	1	2	3	4	5	6	7	8	9
t_p (s)	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0
Q (kJ/cm)	25	25	25	30	30	30	35	35	35
$\Delta t_{8/5}$ (s)	18.3	18.3	18.3	21.9	21.9	21.9	25.6	25.6	25.6
$\Delta t_{p/8}$ (s)	10.6	10.6	10.6	12.7	12.7	12.7	14.8	14.8	14.8

4 Test Results and Analysis

4.1 Hardness screening

The actual welding CGHAZ hardness was measured with Vickers hardness tester, and the measurement points were 5. The measurement results are shown in Table 3.

Table 3 Actual welding CGHAZ material hardness

CGHAZ hardness (HV10)					Average value	Variance
402	395	410	387	411	401	9.10

The hardness values of the 9 sets of thermal simulated samples were measured. Each sample selected three different positions, the measurement results shown in Table 4. It can be seen from Table 4 that the variance of the hardness values of samples 1, 4 and 7 is close to 15, which is much larger than the variance of the actual welding CGHAZ hardness 9.1. Therefore, these three sets of samples were excluded. And then according to the average hardness value of screening, screening results shown in Figure 2. The line indicates the actual hardness range of the welding CGHAZ. The point indicates the average hardness value of the heat simulated sample. The average hardness values falls within the actual range of CGHAZ hardness are 5, 6, 8 and 9 samples. The hardness of these four groups of specimens is more close to the actual welding CGHAZ.

Table 4 Hardness values of 9 sets of thermal simulation materials

Number	Hardness (HV10)			Average	Variance
1	385	421	403	403.0	14.70
2	397	425	407	413.0	11.59
3	418	423	427	422.7	3.68
4	362	385	396	381.0	14.17
5	387	412	405	401.3	10.53
6	403	398	387	396.0	6.68
7	390	401	365	385.3	15.06
8	402	389	402	397.7	6.13
9	385	385	401	390.3	7.54

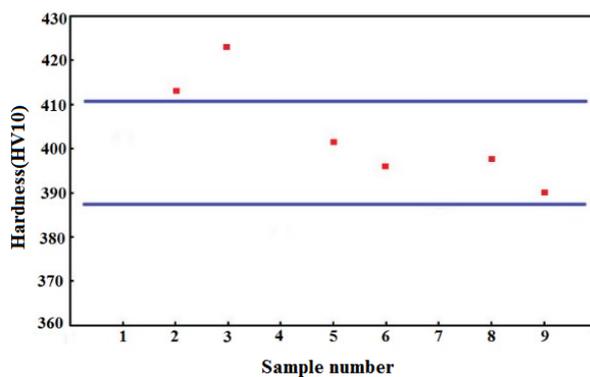


Figure 2 Hardness screening results

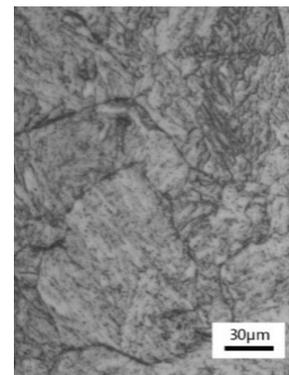


Figure 3 Actual CGHAZ metallographic diagram

4.2 Microstructure and grain size screening

The microstructure of the actual welded joint CGHAZ of 2.25Cr1Mo0.25V steel is shown in Figure 3, the grain size is about 4.5 degree, and the microstructure is lath bainite structure.

The metallographic graphs of the 9 groups of thermal simulations are shown in Fig. 4 and the grain size grades are shown in Table 5. It is found from Table 5 that the grain size of samples No.1, No.4 and No.7 is very uneven. From the grain size, the grain size of samples No.2 and No.3 are 1 degree smaller than the actual CGHAZ, and the grain size of No.8 and No.9 samples are 1 degree

larger than the actual CGHAZ. Only No.5 and No.6 samples are closer to the actual welding CGHAZ, but the No.6 test specimen strip bainite is larger than the actual joint, and the No.5 sample is closest to the actual joint in the microstructure and grain size. The results of comprehensive hardness, microstructure and grain size show that No. 5 is relatively closer to the actual welding CGHAZ

The hardness and microstructure of 9 sets of thermal simulation materials and the actual welding joints CGHAZ were compared comprehensively. The results showed that the sample material No. 5 was the closest to the actual welding joint CGHAZ. The corresponding thermal simulation parameter is that the peak temperature is 1320°C, the heating rate is 1000°C/s, the peak residence time is 1s, the welding heat input is 30kJ/cm, the preheating temperature is 200°C and the thermal cycling curve is shown in figure 5.

Table 5 Grain size grade of 9 sets of thermal simulation material

Number	1	2	3	4	5	6	7	8	9
Grain size	3.0-5.	3.5-4.	3.5-4.	3.0-5.	4.0-4.	4.0-4.	4.0-5.	5.0-5.	5.0-5.
	5	0	0	5	5	5	5	5	5

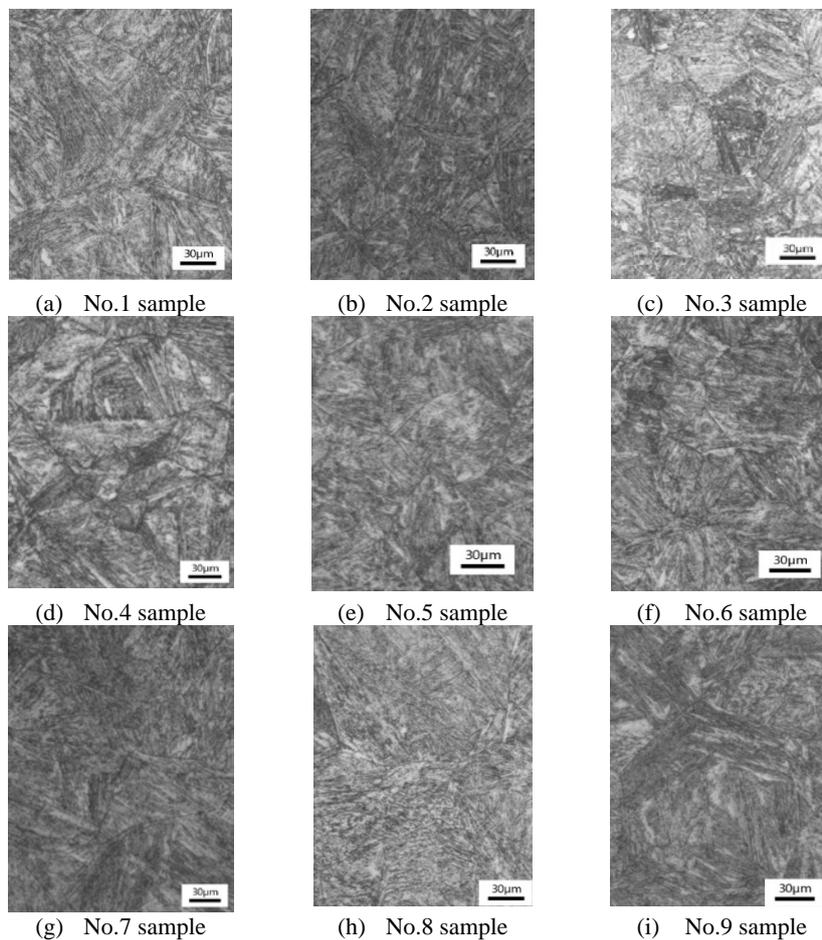


Figure 4 Metallographic diagram of thermal simulation material

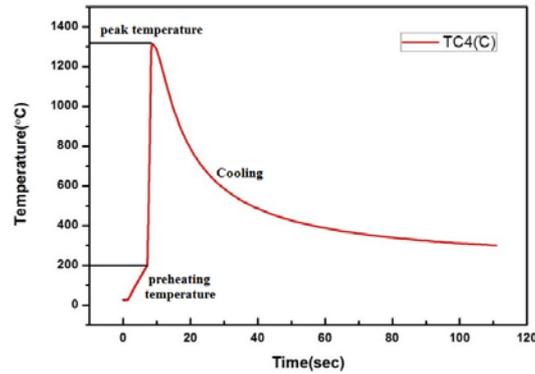


Figure 5 Thermal cycling curve

5 Conclusions

The suitable for 2.25Cr1Mo0.25V steel CGHAZ is screened by comparing the hardness and metallographic structure of the material obtained from the different thermal simulation process parameters with the actual welding CGHAZ material. The suitable thermal simulation process is that the peak temperature is 1320°C, the heating rate is 1000°C/s, the peak residence time is 1s, the welding heat input is 30kJ/cm, the preheating temperature is 200°C. The material obtained under this thermal simulation process is closest to the actual welding CGHAZ of 2.25Cr1Mo0.25V steel.

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