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SIMULATION ANALYSIS OF X80 PIPELINE STEEL WELDING

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In order to improve the quality of welded joints and increase the service life of pipelines, ABAQUS finite element software was used to simulate the temperature field of 18,4 mm thick X80 pipeline steel in multi-layer and multi pass welding. The peak temperature of different passes was compared, and the change trend of temperature field in the welding process was obtained,. The results show that the peak temperature of the weld and its adjacent areas is higher, and the peak temperature of the weld center is the highest. Due to the fast welding speed, the heat cannot be transferred to other areas in time, resulting in uneven heating of the entire test panel.

Keywords: pipeline steel, X80, welded joint, welding simulation, temperature field

INTRODUCTION

As a low-carbon low-alloy steel, X80 pipeline steel has good strength and toughness, welding performance, crack arrest performance and corrosion resistance, and is widely used in the West East Gas Pipeline[1]. Welding is the most important way to connect pipelines, and the quality of welded joints directly affects the service life of pipelines. Welding parameters, such as preheating temperature, interpass temperature, heat input and plate thickness, will affect the welding thermal cycle, thus changing the microstructure and mechanical properties of the weld metal [2, 3]. However, the traditional methods for measuring the quality of welded joints (such as mechanical measurement and physical measurement) are expensive and have certain requirements on the sample size [4]. Therefore, based on ABAQUS software, this paper analyzes the welding process of X80 pipeline steel by finite element simulation, analyzes and compares the changes of residual stress and temperature field, and determines the quality of welded joints.

TEST MATERIALS AND PROCESS

The base metal is X80 pipeline steel plate, and its chemical composition and content are shown in Table 1. The plate is welded by multi-layer welding. The size of a single test panel is 50 mm × 25 mm × 18.4 mm, the welding groove form and welding sequence are shown in Figure 1.

Table 1 **Chemical composition of X80 pipeline steel /wt.%**

C	Si	Mn	P	S
0,0062	0,28	1,85	0,011	0,0006
Cr	Mo	V	Ni	Nb
0,03	0,022	0,059	0,016	0,1

The X groove is made with the groove angle of 60°and 70°respectively.

During welding, first conduct gas shielded welding on the external welding side, then conduct internal welding double wire submerged arc welding, and finally conduct external welding double wire submerged arc welding. The welding process is simulated by finite element software ABAQUS. The heat input is determined by the main welding parameters, namely welding cur-

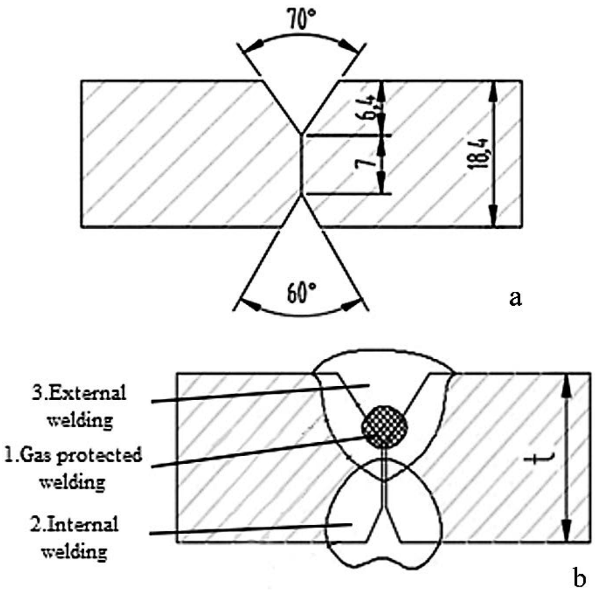

Figure 1 Butt groove drawing and welding sequence: a - welding joints; b - welding sequence

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Table 2 **Welding parameters**

Weld layer	Electrode sequence	Electric current /A	Voltage /V	Welding speed /m/min
Backing weld (GMAW)		220	25	0,50
Internal welding (SAW)	1#	700	33	0,80
	2#	450	37	
External welding (SAW)	1#	850	33	0,80
	2#	450	37	

rent, arc voltage and welding speed. The welding parameters are shown in Table 2.

SIMULATION RESULTS AND ANALYSIS

After using the finite element software ABAQUS to simulate the welding process of X80 pipeline steel, the temperature field distribution of different passes and different times is obtained, as shown in Figure 2.

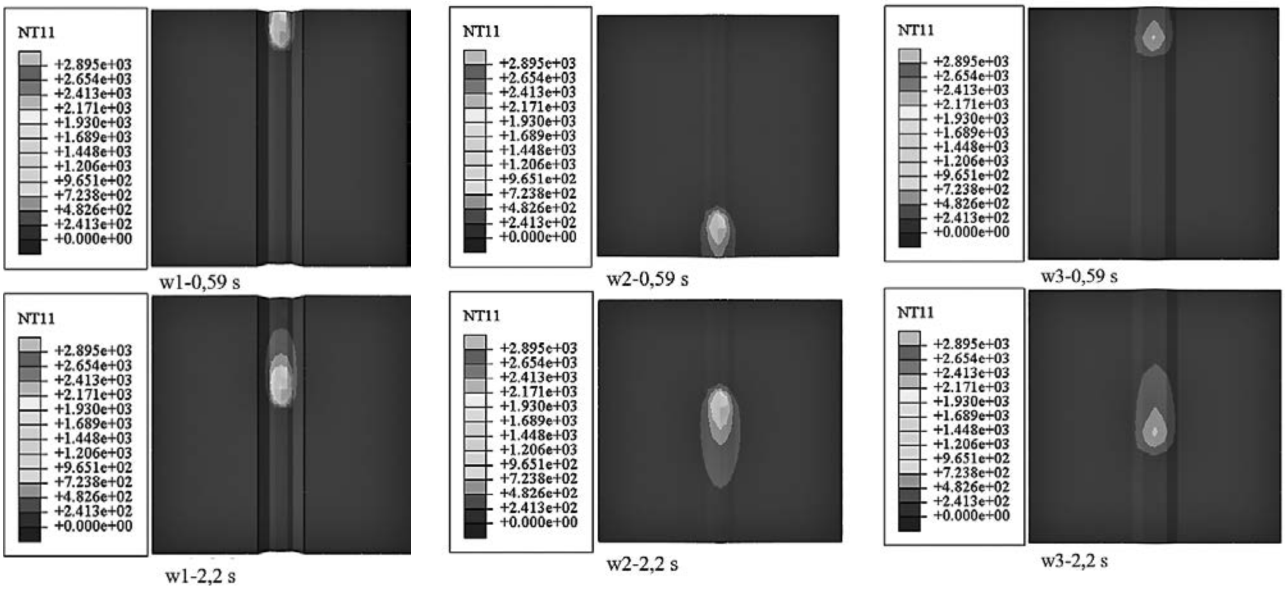

Figure 2 Temperature field distribution in different passes at different times

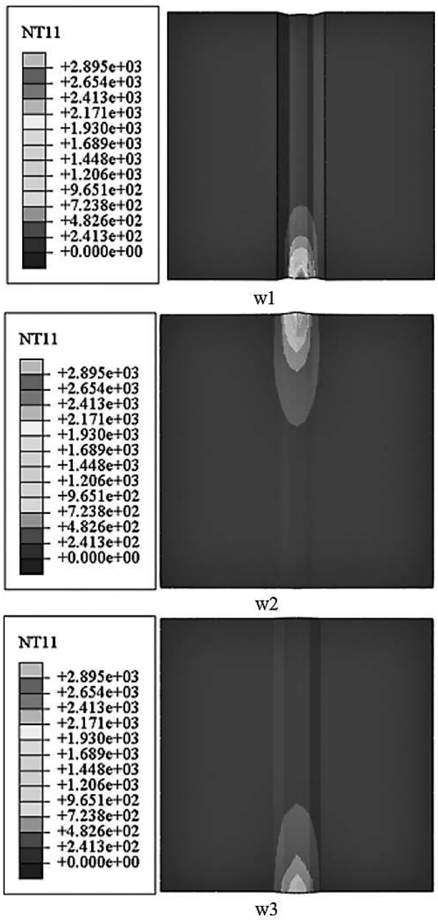

Figure 3 Temperature field distribution in different passes at different times

Wherein, w1~w3 represents the analysis step of 1~3 welding passes. It can be seen from the figure that in the first pass of welding, under the influence of heat source, the heat distribution in the weld area presents an oval shape with concentrated front and scattered rear. There is a relatively large temperature gradient around the weld. As the welding ends, the temperature begins to cool, and the temperature gradually diffuses from the end of welding to the surrounding. In the second and third pass of welding, the whole temperature field transformation process is basically similar to the first pass.

At the same time, when the welding of each weld is adjacent to the edge of the weldment, the temperature in the center area of the weld will increase, as shown in Figure 3.

Nine points are selected for three passes of weldment as shown in Figure 4. It can be seen from the figure that during the welding process of the pipeline, the temperature rises rapidly with the approach of the heat source and cools rapidly with the distance from the heat source. Because of the fast welding speed, the temperature gradient near the weld is very large, and the heat cannot be transferred to other areas in time, resulting in uneven heating of the entire test plate and the highest temperature in the weld center.

As shown in Figure 5, the calculation point 1 is located in the center of the heat source. When the welding time reaches 4.3s, the peak temperature is the highest, reaching 2200 °C; The farther the calculation points 2

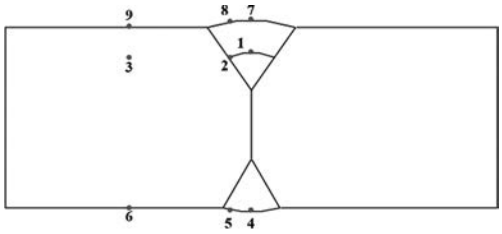

Figure 4 Calculation point distribution

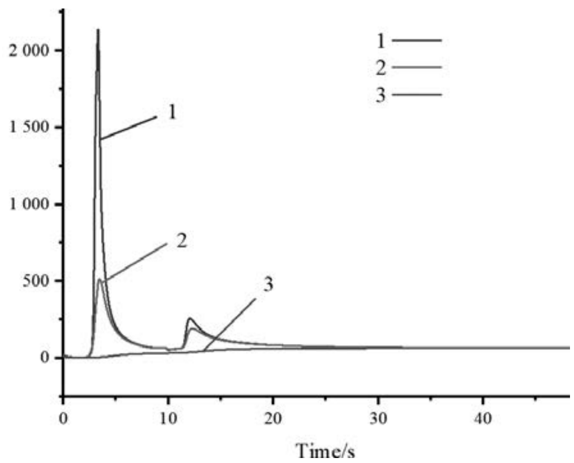

Figure 5 Temperature change curve of gas shielded welding

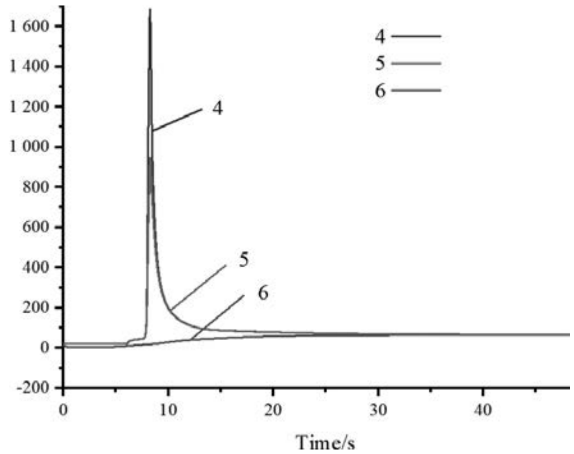

Figure 6 Temperature change curve of internal welding

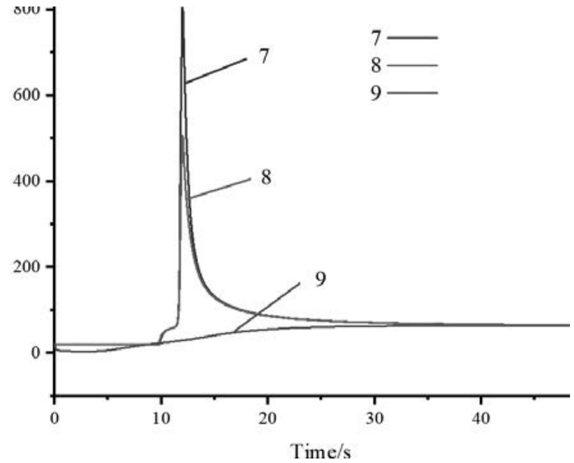

Figure 7 Temperature change curve of external welding

and 3 are from the heat source, the less heat they receive and the lower the peak temperature. As shown in Figures 6 and 7, calculation points 4 and 7 are located in the center of the heat source, with the highest temperature; The calculation point 5 is close to the heat source, and the peak temperature is high. The temperature gradient between calculation points 4 and 5 reaches 600 °C.

However, calculation points 6 and 9 are far from the heat source and have low temperature. With the increase of time, the temperature of the whole weldment decreases rapidly under the effect of heat conduction and convection until the third pass of welding, and the temperature decreases significantly compared with the first two passes.

CONCLUSION

By determining the thermophysical property parameters and mechanical property parameters of the material, including temperature, specific heat, Young's modulus, Poisson's ratio, thermal conductivity, yield strength and thermal expansion coefficient, the finite element simulation of multi-layer and multipass welding of X80 pipeline steel is carried out based on ABAQUS. The results of temperature field agree with the actual test. The results show that the temperature in the weld center is the highest during the welding process, and the temperature gradient near the weld is very large due to the fast welding speed, so the heat cannot be transferred in time, resulting in uneven heating of the whole weldment. After welding, the temperature will diffuse from the end position to the surrounding until it is cooled to room temperature.

Acknowledgments

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REFERENCES

[1]. M. X. Zhang, G. J. Chen, Z. P. Ma, et al. Study on joint microstructure and mechanical properties of X80 pipeline steel [J] Welding technology 49 (2020) 04, 20-5+1

[2]. Y. J. Wang, Y. Wang, Q. X. Cao. Effect of welding process on microstructure and mechanical properties of 2205 duplex stainless steel joint [J] Welding Technology 51 (2022) 10, 21-26

[3]. Bonmatin M, Chabert F, Bernhart G, et al. Ultrasonic welding of CF/PEEK composites: Influence of welding parameters on interfacial temperature profiles and mechanical properties [J]. Composites Part A: Applied Science and Manufacturing 2022, 162: 107074.

[4]. W. Z. Jiang. Welding quality control of 14Cr1MoR (H)+S32168 clad plate [J] Welding technology 51 (2022) 02, 84-87

Note: The responsible translator for English language is M.M. LI -North China University of Science and Technology, China