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EFFECT OF PREHEATING TEMPERATURE ON POST-WELD RESIDUAL STRESS OF DISSIMILAR STEEL PLATES

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Based on the numerical simulation software Visual-Environment, the numerical calculation and analysis of residual stress field under different preheating temperatures for Q345/2Cr13 dissimilar plate welding were carried out in this paper. The effects of different preheating temperatures on post-weld residual stress were mainly studied. The results showed that different preheating temperatures have little effect on the lateral residual stress, while the longitudinal residual stress and the initial and end of the weld have greater impacts. For residual stress difference between the two base metals should not be too high, the dissimilar plate welding should adopt a moderate preheating temperature.

Keywords: steel plates, dissimilar welding, preheating temperature, numerical simulation, residual stress

INTRODUCTION

Heating during the welding process and subsequent rapid cooling are prone to residual stresses and deformations in the joint weld and its vicinity [1]. The residual stress generated can reach the yield strength of the base metal, which deteriorates the mechanical properties and corrosion resistance of the material during service, such as stress corrosion cracking (SCC), fatigue and brittle failure in the weld zone [2]. The residual stress of the weldment can be reduced or eliminated by a number of thermodynamic methods, and the residual stress can be reduced by preheating, suitable welding sequence[3], et al. Research [4-6] found that preheating can improve the welding performance of materials, on the one hand, preheating delays the cooling rate of the weld and the base metal and increases the stiffness of the material at low temperatures; on the other hand, the magnitude of the shrinkage stress is reduced, so preheating is one of the effective ways to reduce the cracking of the base metal and the weld metal. However, preheating can also have adverse effects [7,8], grain boundaries are prone to embrittlement due to long periods of high temperature, grains in the melting zone and heat affected zone are easily roughened, and the grain boundary liquefaction area is widened, the ductility of the joint is deteriorated and the crack sensitivity is enhanced. Therefore, the study of welding residual stress field has important practical significance in welding mechanics, and the development of numerical simulation technology makes the research of residual stress after welding more efficient [9].

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There are studies having shown that proper preheating temperature can reduce residual stress and improve the safety of welded components [5,6]. Martensitic stainless steel is prone to cold cracking during welding. In order to prevent the occurrence of joint cracks and maintain good mechanical properties, martensitic stainless steel needs to be pre-heat treated before welding, but the preheating temperature should not be too high, which should be below the martensite start transition temperature (450 °C) generally [9-11].

In order to clarify the influence of preheating temperature on residual stress field of Q345/2Cr13 dissimilar steel, this paper analyses the post-weld residual stress of Q345/2Cr13 dissimilar steel at different preheating temperatures by numerical simulation, which provides a reference for the actual welding work.

Experimental process

In this paper, the model-based meshing software Visual-Mesh in Visual-Environment is used to establish the model and mesh. The paired plate welding model was established by drawing two pieces of 50 mm × 200 mm × 4 mm plates. The schematic diagram of the model is shown in Figure 1, wherein the weld width is set to 5 mm. In the meshing, considering the extreme uneven distribution of heat during the welding process, the linear meshing method is adopted, that is, the mesh of the area near the weld is denser than the edge. Plate 1 is low alloy steel Q345, plate

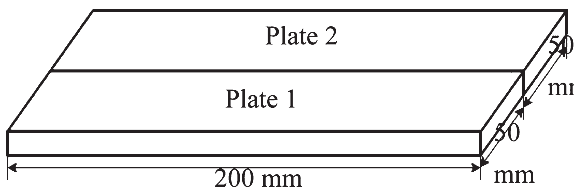

Figure 1 Model of simulation

2 is martensitic stainless steel 2Cr13, and the filling material of the weld is Q345. The chemical composition of the two materials is shown in Table 1.

Table 1 **Chemical composition of Q345 and 2Cr13 /wt, %**

	C	Si	Mn	Cr
Q345	0,12 - 0,18	0,5	1,7	0,30
2Cr13	0,16 - 0,25	1,0	0,43	0,12 - 0,14
Mo	V	Ni	S	P
0,10	0,15	0,5	0,045	0,050
-	-	0,60	0,030	0,010

In order to study the influence of preheating temperature on the welding residual stress field of Q345/2Cr13 dissimilar steel, the numerical simulation analysis of Q345/2Cr13 dissimilar steel welding was carried out with different preheating temperatures. The specific welding experiment scheme is shown in Table 2.

Table 2 **Numerical simulation projects**

Computing scheme	Amp / A	Vol / V	Temperature / °C
Case 1	140	15	100
Case 2	140	15	200
Case 3	140	15	300

The welding process during arc motion involves complex physical, chemical, and metallurgical phenomena such as heat conduction, convection, radiation, evaporation, and melt solidification [12,13]. Therefore, the following assumptions are made during the numerical simulation [14]:

a) It is assumed that the surface deformation does not change the heat transfer and mass transfer between the welding arc and the workpiece;
b) Ignore the blurred area where the solid-liquid two phases coexist in the molten pool.

Simulation results and analysis

Figure 2 shows the lateral residual stress distribution of three different preheating temperatures. The direction is selected from the center point of the outer edge of the plate 1, along the vertical weld direction, to the center point of the outer edge of the plate 2. It is observed that the longitudinal residual stress amplitude of the 2Cr13 side (plate 2) in the weld and its vicinity is much larger than that of the Q345 side (plate 1), and the distribution of high residual stress is narrower than that of the Q345 side. Due to Q345 has higher thermal conductivity and specific heat capacity than 2Cr13, the temperature distribution is uniform during the welding process, and the temperature gradient is small, so that the heat affected zone is wider and the stress field gradient is smaller than the 2Cr13 side, resulting in a wider residual stress region. Similarly, due to the difference in thermal conductivity, the influence of different preheating temperatures on the residual stress on the Q345 side is more obvious. As the temperature increases, the residual stress increases near the edge and decreases in the weld area. On the 2Cr13 side, the effect of preheating temperature is not obvious in the area close to the weld due to the slow heat conduction, and the preheating temperature in the edge area reduces the residual stress.

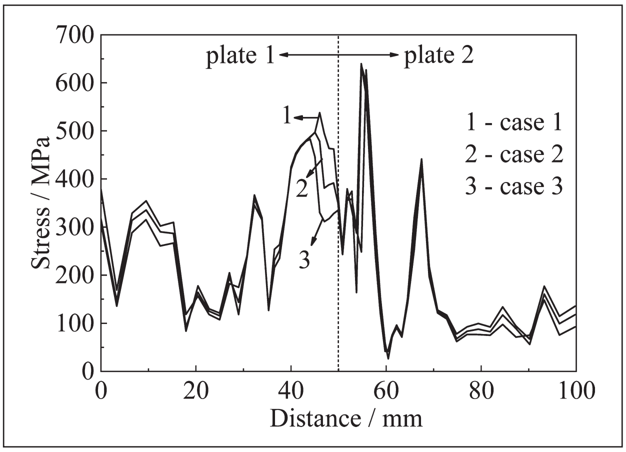

Figure 2 Lateral residual stresses

Figure 3 shows the residual stress distribution curve on the weld line. It can be seen from the comparison that there is a large fluctuation in the residual stress at the both end positions, which is caused by fluctuations in the arc unstable welding energy at the start and end of the welding. The residual stress curve is smoother throughout the length of the weld, indicating that the heat source reaches steady state arc stability. At the same time, with the increase of preheating temperature, the residual stress at the weld is more obvious. The average residual stress at 100 °C is 360,25 MPa, the average residual stress at 200 °C is 345,59 MPa, which is 4,16 % lower than that at 100 °C, and the average residual stress at 300 °C is 325,26 MPa, which is 9,72 % lower than at 100 °C. So, increasing the preheating temperature can reduce the residual stress at the weld seam of the dissimilar plate.

Figure 4 is a longitudinal residual stress distribution curve of the heat affected zone of the two plates at three preheating temperatures. As a whole, it can be seen that the residual stress on the Q345 side is less than the residual stress on the 2Cr13 side. This is also due to the fact that the Q345 thermal conductivity and specific heat capacity are larger than 2Cr13, resulting in uneven heat distribution during the welding process. At the same time, it can be seen that there is a phenomenon that the residual stress decreases with the increase of temperature in both kinds of

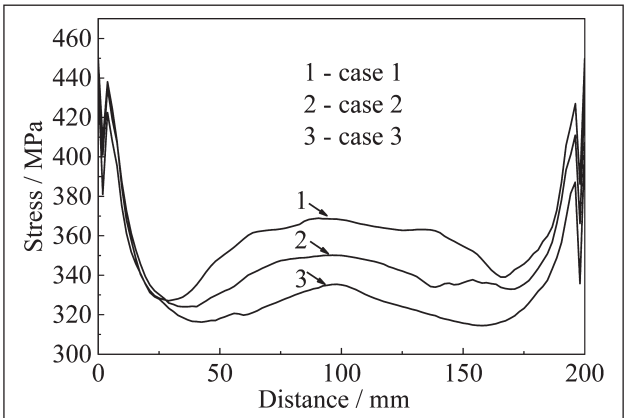

Figure 3 Residual stress distribution curve on the weld line

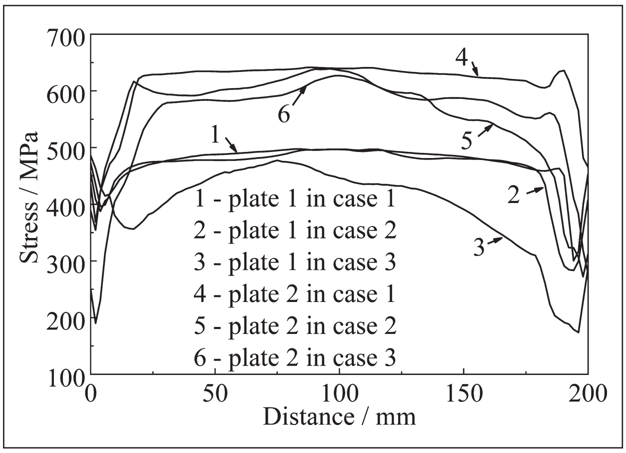

Figure 4 Residual stress distribution in heat affected zone of two plates in different preheating temperature

plates, which indicates that increasing the preheating temperature can reduce the residual stress after welding of the dissimilar plates to some extent. Considering the characteristics of dissimilar plate welding, the residual stress in the heat affected zone of the two materials should not be too large, and excessive compressive stress and tensile stress are avoided in the weld zone. The average residual stress of the plates 1 and 2 in each case was taken in the arc phase of the welding midsection. Where: the residual stress of plate 1 in case1 is 487,93 MPa, and the residual stress of plate 2 is 637,61 MPa, the difference between the two is 149,68 MPa; the residual stress of plate 1 in case2 is 482,51 MPa, and the residual stress of plate 2 is 607,56 MPa, the difference between the two is 125,05 MPa; the residual stress of plate 1 in case3 is 432,26 MPa, and the residual stress of plate 2 is 604,58 MPa, which is 172,32 MPa. It can be known from the above data analysis that the residual stress difference between the plate 1 and the plate 2 is the smallest when the preheating temperature is 200 °C. Therefore, the preheating temperature should not be too high for dissimilar plate welding, and proper preheating can reduce the residual stress of the welded joint.

SUMMARY

In the dissimilar plate welding, the increase of preheating temperature has little effect on the lateral residual stress, but the residual stress distribution on the Q345 base material side is wider than the residual stress distribution of the 2Cr13 base metal, which is due to the difference between the thermal conductivity of the material and the specific heat capacity.

By comparing the residual stress distribution at the weld and the longitudinal residual stress distribution in the heat affected zone of the two plates in each case, it can be seen that a certain preheating temperature can reduce the residual stress. However, the temperature should not be too high, so that the residual stress difference between the two base metals is too large, and the most preheating temperature is 200 °C.

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Note: Q. H. XIAO is responsible for English language, Liaoning, China