ATLANTIS PRESS
Advances in Engineering Research (AER), volume 143
6th International Conference on Energy and Environmental Protection (ICEEP 2017)

Study on the Influence of Tack Welding on Residual Stress of Overlap Joint

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Keywords: Tack welding; overlap joint; residual stress; finite element method

Abstract. Taking overlap joint as the object, it simulates welding process. And it obtains residual stress and distribution curves. By simulating the equivalent form of tack welding, it discusses the influence of tack welding by XYZ displacement constraint, X displacement constraint, node matching and adhesive contact on stress distribution. It verifies the results. The results show that four sets of tack welding are designed, and it calculates stress distributions. By XYZ displacement constraint, X displacement constraint and node matching, the simulation results is not consistent with the classical longitudinal stress distribution. By adhesive contact, the stress distribution is consistent with the test results, and error is controlled within 12.9%. It verifies the equivalent form of tack welding. Without considering tack welding, error is 40.3% at the distance from arc building of 50 mm. It does not meet the application requirements. It suggests that tack welding influence on the welding residual stress should be considered in the small model, and it simulates tack welding by adhesive contact.

Introduction

Tack welding is a common method to ensure the relative position in construction machinery [1]. Weld shrinkage caused by welding cooling makes welding gap increase. Tack welding can prevent the gap increase, and ensure dimensional accuracy. By numerical simulation, tack welding is generally considered less, and its influence can be neglected[2]. For tack welding, the distance between arc building and extinction is small. The filler metal is small. The fusion zone of metallurgical reaction is not sufficient, and the center of seam is fast cool. So the seam will be under tensile stress, and occurs stress concentration. Although tack welding is smaller, it is part of the seam. Therefore, the location and length of tack welding[3] will directly affect quality.

To evaluate the influence of tack welding on welding quality, it is necessary to study the theory and experiment of tack welding. Many scholars have done some experimental research work. The reference [4] developed short pulse control heat input, and fixed welding parameters. The strength of tack welding is the same as the parent metal. It reduces welding deformation, and ensures no defect. In combination with the industry standards and tests, the reference [5] specifies the requirements and precautions for tack welding of the bogie. At the same time, tack welding position is well combined with the seam to avoid defects. The reference [6,7] simulated the influence of different equivalent methods and length and position on welding deformation and residual stress. The length of tack welding directly affects seam strength.

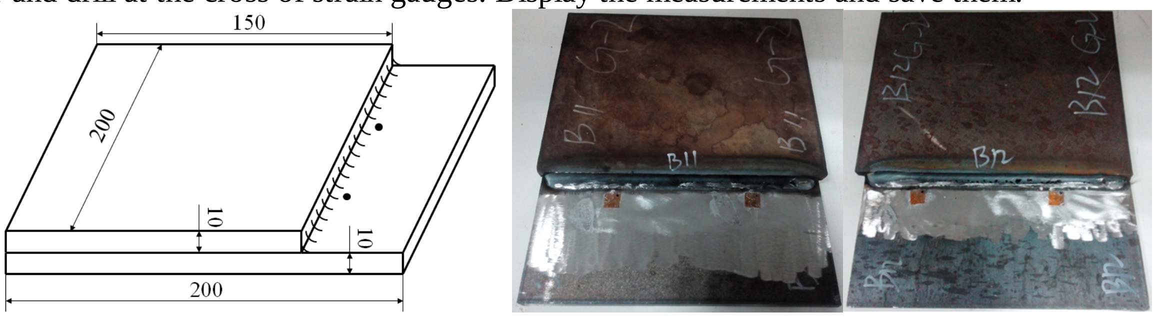
The literature shows that in the experimental research, research on tack welding is more to carry out basic research work based on the test and detection. Although it simulated the tack welding method, length, position and so on, the measurement result of residual stress is the second welding seam after two seams. Since the second seam has been treated by heat treatment, residual stress has been redistributed. It is more convincing to measure residual stress in the first seam.

In this research, for overlap joint, it establishes finite element model of tack welding, and simulates the different forms of tack welding. The results are compared with the experimental results.

Test preparation

The object is overlap joint. The length of plate is 200mm. The width of plate is respectively 200mm and 100mm. The height of plate is 10mm. The layer is single. The material is Q345. The wire uses ER50-6. The plate is no groove. Welding method is arc welding. Welding voltage is 24-26V. Welding current is 240-250A. Welding speed is 7 $mm \cdot s^{-1}$. Gas flow rate is 20 $L \cdot min^{-1}$.

In order to avoid the accident caused by experimental operation and other factors, it selects two groups of specimens. For stress measurement, it should be avoided in large stress gradient. Secondly, it should be possible to close the weld toe. Geometry model and measurements for residual stress are shown in Fig. 1. The test uses HK21A type residual stress tester [7]. Polish and treat the surface with anhydrous alcohol, and then paste strain sheets to make sure that there are no bubbles. Turn on the tester and drill at the cross of strain gauges. Display the measurements and save them.



(a) Geometry model of overlap joint (b) Measurements for residual stress

Fig. 1 Geometry model and measurements for residual stress

Establishment of finite element model

Physical and mechanical parameters change with temperature. The accuracy of the curves is directly related to the accuracy of simulation results. The material properties of Q345 are mature.

The ratio of overlap joint model is one equal to one. The discrete model all uses hexahedral. The minimum size is 1mm near the seam, and the minimum size of parent material is 15mm at the free end away from the seam. The minimum size of filled seam is 0.3mm, and the maximum is 1mm. The grid uses the transition. The total number of grid unit is 66309, and the number of node is 73594. FE model of overlap joint is shown in Fig. 2.

Heat source selects from the double ellipsoid heat source physical model proposed by Goldak. The static element is used to simulate filled metal, and adopts steady heat source loading method [5]. Convection and radiation exist between surface and environment temperature, so temperature coefficient is set at 0.02 and ambient temperature is 20 degrees.

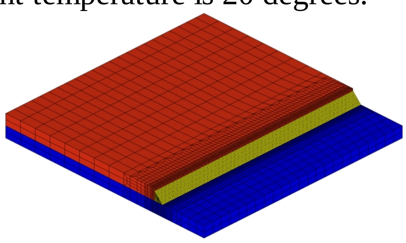
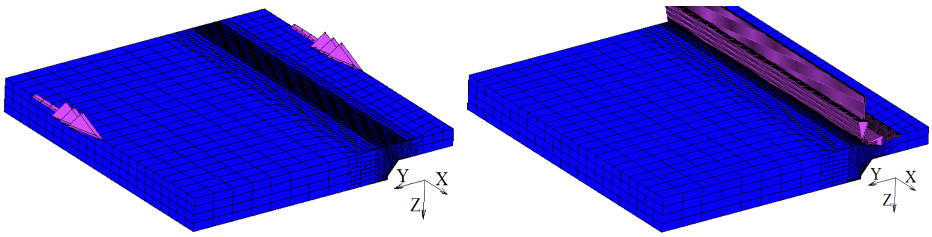


Fig. 2 FE model

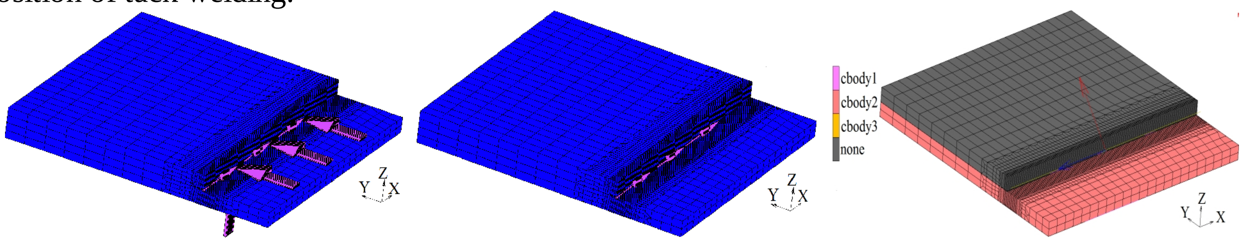
To prevent rigid-body displacement, it establishes mechanical constraints as shown in Fig. 3. Along the direction of the seam, it selects three positions at the lower surface of the cross section, and restrains X displacement. It chooses some nodes to restrict YZ displacement at the back of the seam. At the same time, simulate contact between the position of overlap joint and the welding platform.



(a) X direction constraint (b) YZ direction constraint

Fig. 3 Constraints of model

To evaluate the influence of stress on tack welding, it carries out at the four equal positions. It establishes the equivalent model of tack welding. It adopts the following four methods in this research. The model setting is shown in Fig. 4. Such as the influence of tack welding on the calculation results, without considering the influence of tack welding on the welding, and matched by the nodes at the position of tack welding.



(a) XYZ direction constraint (b) X direction constraint (c) Adhesive contact

Fig. 4 Different constraints set of model

The first scheme is that the node position of tack welding is not match, and uses the XYZ displacement constraints. It melts into the part of filed materials in the process of welding, and releases constraints in heat dissipation conditions. The second scheme is that the position of tack welding constrains X displacement, and releases X displacement constraint in heat dissipation conditions. The third scheme is that the position of tack welding uses node matching. The fourth scheme is that it applies adhesive contact, through applying great big force contact with the body between separated and no relative sliding speed, and bonds the two parts together.

Result analysis and discussion

Influence of different equivalent methods on residual stress distribution. By designing four sets of equivalent model, it calculates the residual stress distribution. The distance of measuring position is 3mm from the fusion line. It extracts longitudinal residual stress along the seam as shown in Fig. 5. It can be seen that different methods of tack welding have great differences between the results.

It can be seen from Fig. 5. The scheme one adopts XYZ displacement constraint to rigidly fix the position. The connection is not weakened or eliminated by welding and heat dissipation conditions. When the distance is 6mm from the arc building, residual stress is almost not changed. The position of arc building restrains small, so stress is small. The middle part of deformation cannot be released, and great constraint makes stress increase. It is tensile stress. The position of arc extinction due to cool, tensile stress increases first and then decreases. It does not meet the classical theory [1]. Similarly, the second scheme is not reasonable.

The third scheme is that the position of tack welding adopts node matching. Because of deformation and stress interaction, welding deformation could release through the position of node matching. The remaining positions of deformation are not release because there is no connection. In the corresponding position of tack welding, peak stress of simulation results in the extraction of the curve decreases. The stress near arc building should be small, and it is contrary [1], so the third scheme is not reasonable.

The fourth scheme is that it applies adhesive contact. It defines bonding contact between the two bonded contacts, and strain and stress are transferred between the two contacts. From the curve, it can be seen stress is smaller in the arc building and extinction position. Stress is larger in the middle part of the curve. It coincides with the trend of longitudinal stress distribution in the classical joint. Peak stress is 299.03MPa in the distance of 40mm from extinction position. After welding, stress occurs sudden change near tack welding in the cooling stage. Compared with the results of four schemes, the fourth scheme is more consistent with the theoretical results [1].

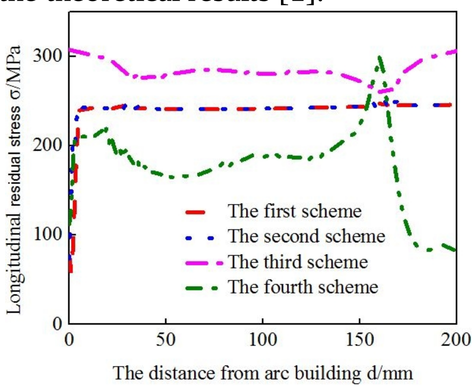


Fig. 5 Longitudinal residual stress distribution of different equivalent model

Test verification. It designs two groups of stress test, and obtains the results. At the same time, it extracts the stress simulation results of the fourth scheme as shown in figure 6. It can be seen that the simulation results are consistent with the measured residual stress distribution.

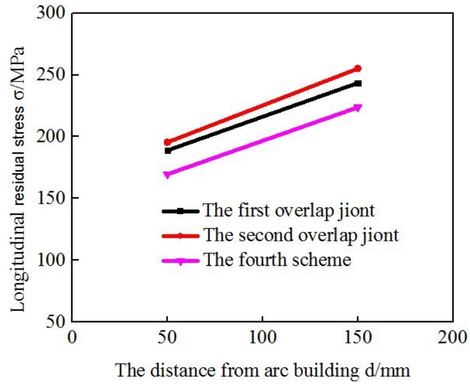


Fig. 6 Compared with simulation and test results

From Figure 6, we can see that the measured results are greater than the simulation results using the adhesive contact. The stress measurement results of two joint are close to each other, and the deviations are relatively small. It verifies the accuracy of the results. Compared with simulation and experimental results, errors are separate 10.3% and 12.9%, when the distance is 50mm from arc building. Errors are separate 8.1% and 12.3%, when the distance is 150mm from arc building. The error results meet the requirements of engineering application.

Tack welding on the distribution of residual stress and verification. It designs two groups of stress test, and obtains and extracts the results. To verify that tack welding have a certain effect on the residual stress distribution, it compares simulation results with considering or not of tack welding. Test results are average. It obtains longitudinal stress distribution results as shown in Fig. 7.

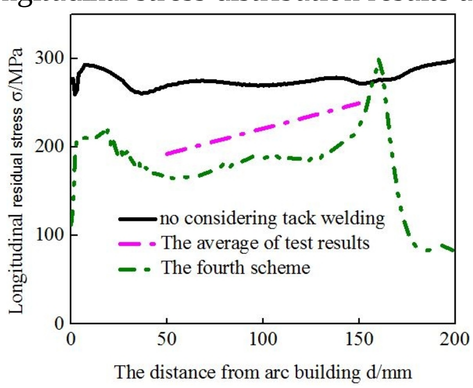


Fig. 7 Longitudinal residual stress distribution

Fig. 7 is the result of not considering tack welding. The distribution trend is relatively small at the arc building, and relative fluctuation of the remaining positions is relatively small, which is related to the structural form of the overlap joint. By comparing the curves, it can be seen that tack welding effects on the stress distribution. Error is 40.3%, when the distance is 50mm from arc building. Error is 9.1%, when the distance is 150mm from arc building. There is great deviation at the distance 50mm from arc building. It is suggested that the influence of tack welding on residual stress should be considered in the small model calculation, and adopts adhesive contact to simulate tack welding.

Conclusions

Through the simulation of tack welding, it designs four groups of equivalent models that are XYZ displacement constraints, X displacement constraint, node matching and adhesive contact. They calculate stress distribution curves. Comparing with measurement results, it verifies the equivalent form of tack welding. At the same time, consider the influence of tack welding on the simulation accuracy. The following conclusions are drawn in the research:

(1) By XYZ displacement constraint, X displacement constraint and node matching, simulation results is not consistent with the classical longitudinal stress distribution. By adhesive contact, stress distribution is consistent with test results. It verifies the equivalent form of tack welding.

(2) Considering tack welding, the error between the test results and the simulation results is small, which meets the requirements of engineering application. Without considering tack welding, one of the test measurement results has large errors and does not meet the application requirements.

(3) It is suggested that the influence of tack welding on residual stress should be considered in the small model calculation, and adopts adhesive contact to simulate tack welding.

In this study, there is not enough measurement value for detailed analysis and verification, which may lead to fail to convince simulation results. The model can be further adjusted by increasing the length of the seam or increasing the number of tests to verify the finite element model.

Acknowledgements

This work was financially supported by the Jiangsu Natural Science Foundation (BK20140229), and National Science and Technology Support Program (2015BAF07B02).

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