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The influence of process support on welding deformation of large-scale structure

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Abstract. For large-scale structure, it simulates welding deformation of the floor. It analyses the influence of different process support forms on welding deformation of the floor, and verifies the simulation results. The results show that the predicted results of no process support are consistent with the experimental results, and error is 8.5%. Two kinds of process support forms can control welding deformation of the floor. The simulation results of process support are consistent with the experimental results, and error is less than 14%, which proves the correctness of the finite element model. With the increase of process support, the maximum effect of controlling deformation is 32.8%.

1. Introduction

Welding deformation of large-scale structure is usual. Many means solve welding assembly dimension deviation, such as allowance by the orthopedic machining, milling flat, hammer method, flame shape-righting and so on. Residual strain causes harmful components not to be orthopedic, even to be scrapped. Therefore, it becomes an urgent problem to be solved welding deformation of large-scale structural. For different forms of large-scale structure, the method and effect of controlling deformation are different. Welding sequence optimization, process support application, anti-deformation tooling, and positioning welding equipment are commonly used [1]. Welding sequence optimization needs more experience. When it achieves a desired value, it is no longer experimental, which will make the results not optimal. And there requires many tests. Numerical simulation of welding provides an effective prediction method, and its development is limited by no depth in academic field. In application field, its prediction accuracy and computation efficiency need experience. Anti-deformation tooling and positioning welding equipment need to be designed. They are direct and effective methods, but it affects production time and input, and cannot be applied to upgrade the structure form. Process support can be effectively positioned, and controlled welding deformation. However, to ensure the robot welding rate and the convenience of manual welding, it is necessary to effectively exert the number of process support. To predict accurately, simulation becomes an effective means. The position of deformation is restrained by process support [2].

To study the influence of process support on welding deformation, many scholars have done many jobs. The reference [3] designed different forms of process support by finite element method. It got the rules of controlling deformation, and the influence of different forms on deformation. But it did not verify. The reference [4] analyzed the influence of bead reduction on the residual stress. The tooling and fixture are restrained on the side of the steel tube, and the tensile stress is greater. The reference [5] established the fixture constraint in accurate model of welding process, and various mechanical constraint boundary conditions were thought about to establish the relationships of the normal and tangential mechanical interactions between welded panel and fixture. The reference [6] simulated high-tensile steel sheets welding, and rational boundary conditions were chosen and an assembly-and-welding fixture is designed. From the above literature, the research of process support has been carried out. But process support is applied more to the stiffened parts with large cross sections.

In this paper, it takes large-scale structure as the object. It is equivalent to smaller and simpler section of process support, and establishes the finite element model. The welding deformation simulation results are obtained, and they are compared with the experimental results.

2. Establishment of finite element model

Material of large-scale structure is Q460, and welding wire is SLD-60 wire. Welding method is arc welding. Welding voltage is 27-29V. Welding current is 280-290A. Welding speed is 7 mm·s^{-1}. To avoid the accident of experimental results, it selects two groups of specimens.

The mechanical properties and parameters of Q460 change with temperature, and the accuracy is directly related to the simulation results. The properties of Q460 are shown in figure 1.

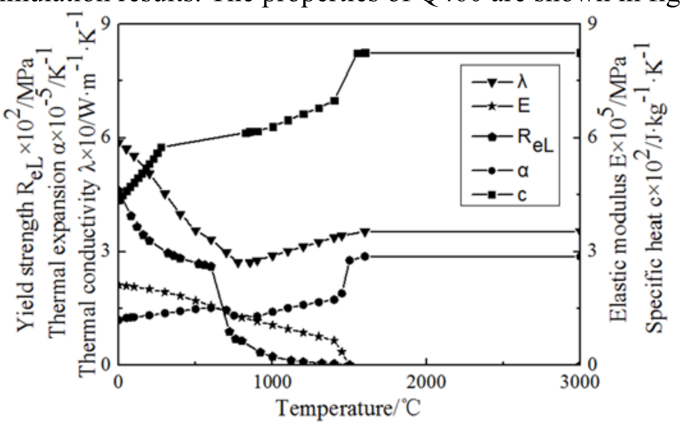


Figure 1. Relationship between mechanical parameters and temperature of Q460

The thickness of the floor is 25 mm, and the thickness of the ear plate is 16mm. The rest is 10mm. The structure is symmetrical, and the half is analyzed. To verify the influence of process support on deformation of the floor, it measures the distance between point A and point B. The mesh is hexahedral. The maximum size is 30mm, and the minimum size is 0.5mm. To ensure uniform in the weld seam and heat affected zone, it obtains 376675 grids and 459279 nodes shown in figure 2.

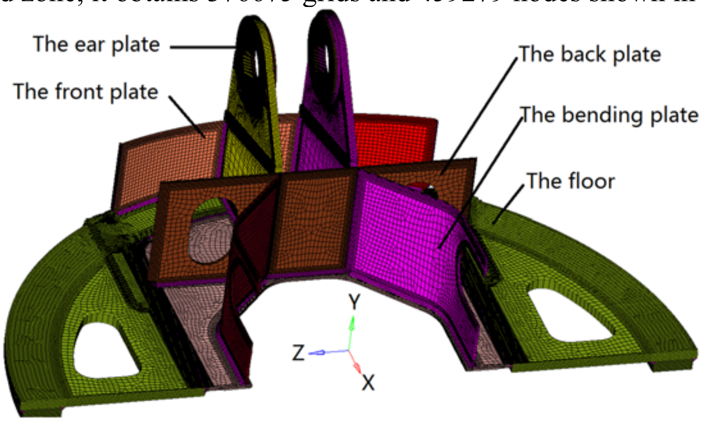
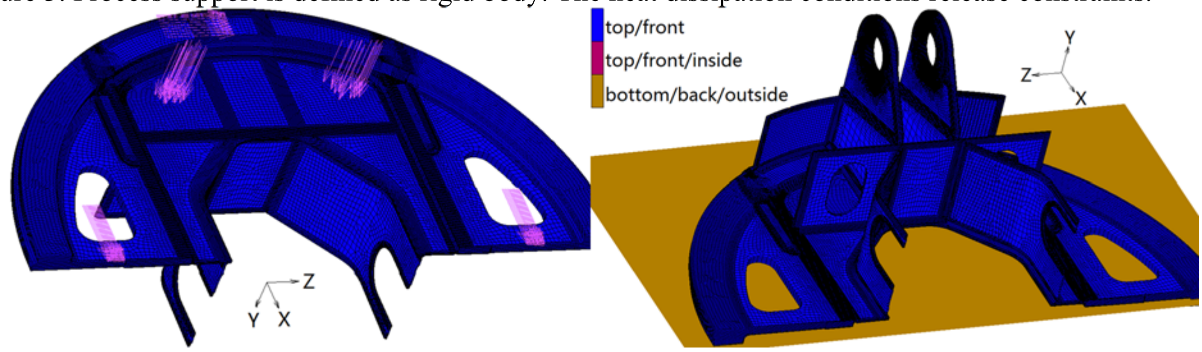


Figure 2. FE model

Heat source selects the double ellipsoid heat source model by Goldak, and adopts steady heat loading. Weld seam adopts preset filled. The convection and radiation of the parts and external environment are considered respectively by Newton's law and Pohl Weitzman's law. The boundary condition of temperature field is equivalent, and the coefficient of heat dissipation is 0.02. The ambient temperature is set at a constant value of 20 degrees.

It selects the position of big rigid as the constraint. The constraint defines in the position of contact plane. Select some nodes in the symmetrical free-end to limit the X displacement. Select some nodes between the front and back plates to limit the Y direction. Select some nodes from the free-end of the floor in the symmetry of the ear plate to limit the Z direction. The position between the floor and the plate is equivalent to contact constraint. Establish the mechanical constraint conditionas shown in figure 3. Process support is defined as rigid body. The heat dissipation conditions release constraints.



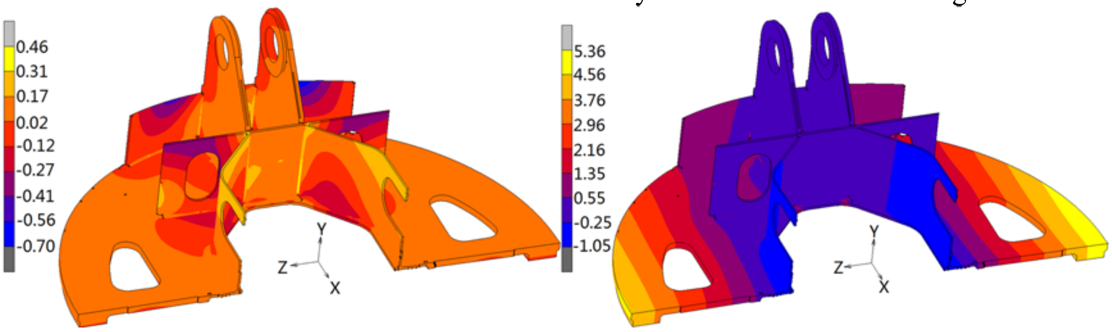
(a) Displacement constraints (b) Contact

Figure 3. Constraints set of the model

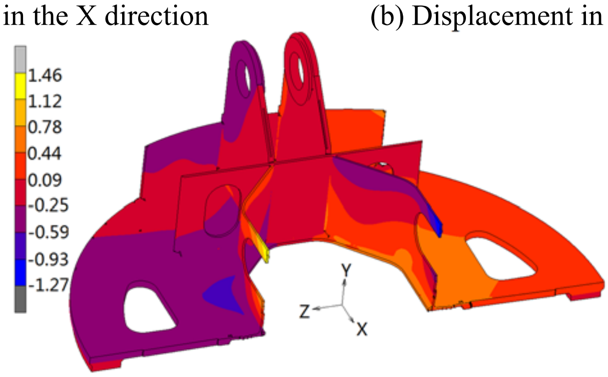
3. Result analysis and discussion

3.1. *Simulation results analysis of welding deformation.*

Deformation counters of the XYZ direction are obtained by simulation as shown in figure 4.



(a) Displacement in the X direction (b) Displacement in the Y direction



(c) Displacement in the Z direction

Figure 4. Deformation counters of the XYZ direction

From figure 4, the maximum deformation occurs at the Y direction, and the peak value is 5.36mm. The minimum deformation is in the X direction. Weld seams are arranged in the middle of the structure, and the shrinkage leads to deform at the free-end of the floor.The floor hardly deforms in the X direction. The maximum position appears at the upper end of the front plate, and the value is 0.7mm. The shrinkage force cannot be released through the joint position, only at the upper free-end of the model. Deformation in the Z direction dues tobe upward at the two free-ends of the floor. The maximum deformation occurs at the free-end of the bending plate, and the value is 1.46mm.

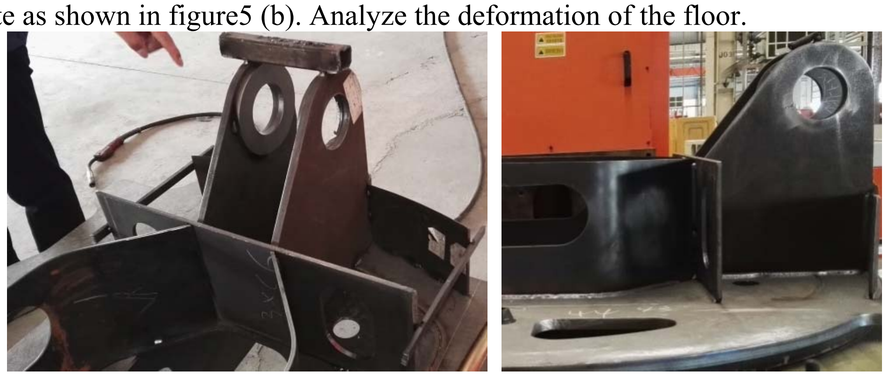
3.2. *Test verification*
Measure the peak value of deformation between point A and B. Record two groups of results and calculates average value of the peak difference. It extracts the deformation peak of simulation results as shown in table 1.

Table 1. Deformation measurement of the floor.

	Maximum value (mm)	Minimum value (mm)	Difference value (mm)
Test1	7.2	3.5	3.7
Test2	6.5	3.4	3.1
Simulation	12.9	10	2.9

From table 1, it shows that the flatness average value of the floor is 6.4mm. It is proved by experiment that the maximum deformation occurs at the A end of the floor, and the minimum deformation is near the end of the back plate. Compared with the measured results, the simulation results are coincident with the actual situation, and error is 8.5%. The accuracy is mainly for several reasons, such as stable work environment, good ventilation and close to assuming equivalent heat transfer coefficient, stable welding speed and parameters, no complicated boundary conditions, good uniformity grids near weld seams, and so on.

3.3. *The influence on welding deformation of the floor in different forms of process support.*
In the next step, the floor is welded together with two vertical plates. The gap between the floor and the vertical plate is small, and repair welding reduces. Both sides of the vertical plate are connected with the front and back plates, so the front and backplates deform in the X direction. The ear plates are connected with the booming. To guarantee the assembly size, it needs to control deformation of the ear plate in the Z direction. To ensure the dimensional positioning requirements, design two kinds of process support. Process support are outside the free-end of the front and back plate, and the free-end of the upper ear plate as shown in figure 5(a). To minimize the number, apply only in the upper free-end of the ear plate as shown in figure5 (b). Analyze the deformation of the floor.



(a) The first scheme (b) The second scheme

Figure 5. Experimental verification of process support

On the FEA model, increase equivalent process support as the schemes. Obtain the simulation results, and extract the simulation results as shown in figure 6.

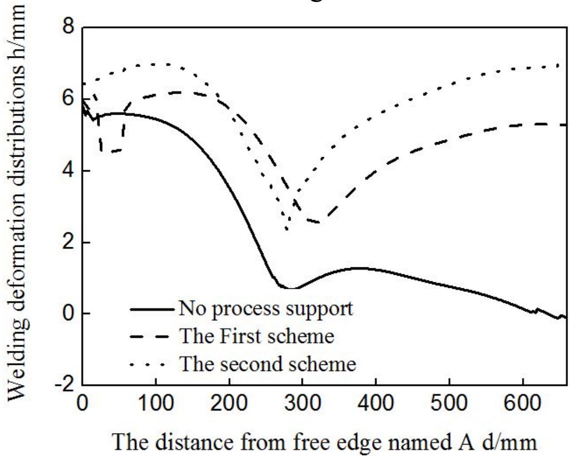


Figure 6. Welding deformation distributions

From figure 6, deformation of the first scheme is the same trend as that of the second scheme. The second scheme of process support has an influence on deformation of the floor. Process support increases the stiffness of the front and back plates, which makes the floor deformation larger. This restraint will cause a certain moment effect on the floor deformation, so the floor deformation is relatively large. The second scheme applying process support at the free-end away from the floor has not an influence on deformation obviously. The restraint hinders the upward deformation of the floor. Two groups of tests are carried out, and calculatethe average value.It obtains and records two groups of welding deformation. Extract the simulation results of the two schemes as shown in table 2.

Table 2. Deformation measurement of the floor.

	Maximum value (mm)	Minimum value (mm)	Difference value (mm)
A_1	7.2	3.5	3.7
A_2	6.5	3.4	3.1
B_1	12.9	10	2.9
B_2	7.5	2.5	5.0
The first scheme	6.2	2.5	3.7
The second scheme	7.0	2.4	4.6

From table 2, the average flatness of the floor is 4.3mm in the first scheme, and the average value is 5.1mm in the second scheme. The simulation results are more consistent with the measured results. Error is less than 14%. The two schemes on the floor deformation control are 20.3% and 32.8% respectively. The maximum deformation occurs at both ends of A and B, and the minimum deformation is near the end of the back plate. The floor deformation has a downward trend in the position of 300mm from the free-end. This is contraction effect of the bending plate, which makes the floor deformation along the negative Y direction. Therefore, process support can control welding deformation to a certain extent, which is related to the applied position and quantity.

4. Conclusions

Through the establishment of large-scale structure model, design and calculate different process support forms influence on floor deformation. It measures deformation results, and verifies the correctness of finite element model. The following conclusions are drawn in the research:

(1) Establish finite element model of large-scale structural without process support, which can be applied to the analysis of process support.

(2) The simulation results of process support are coincident with the actual situation. Process support can control welding deformation. Increase the amount of process support, which can further control the floor deformation.

The influence of different process support forms on large-scale structure deformation. Process support is not obvious on the control deformation. Due to materials, the quality of personnel, process control and other factors, suggest small contact surface of process support only as positioning, not as effective control deformation.

Acknowledgments
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