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Research on the Residual Stress and Influence Factors of Butt Welding Channel Section of BS700 High Strength Steel

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Abstract. Taking the butting weld structure of channel which was fabricated by BS700 as study object, the residual stress and influence factors of welding box section which was butted by two channel section were studied. The study results show that the main welding residual stress of butt weld channel steel is longitudinal residual tension stress, and it affect the stability and fatigue performance. Longitudinal residual distribution of two pieces of weld are located at the district of tension stress, the residual stress of welding foot in the second weld have bigger peak value. The varieties of section length have influence on transverse residual stress, but have little influence on longitudinal residual distribution. Changes of thickness of wall in channel section have marked influence on residual stress value of transverse and longitudinal weld. So it is necessary to choose appropriate thickness of channel for reducing the influence of residual stress on channel steel structure.

1. Introduction

The use of high-strength steel instead of the traditional steel structures can effectively achieve the purpose of improving the overall property of the structure, saving steel and reducing the cost of the project [1-2]. In the past decades, China has developed rapidly in designing the steel structures, and the high-strength steel commonly used in China is the material of Q460 steel [3], but the application of higher grade steel is still lack. So the steel structures of high-strength steel, especially for high strength steel products, still have many problems to be solved in China [4-5]. In recent years, BS700 high-strength steel have been independently developed and produced by China and have been successfully applied [6-8]. In this paper, BS700 butt welding channel steel structure was taken as the research object, and the welding residual stress and its influence factors of the structure was studied in order to promote the application of BS700 high strength steel in the steel structure engineering of China.

The finite element simulation software ANSYS was used to simulate the welding process of butt welded channel steel structure with different dimensions. In the model, the von Mises yield criterion and the thermo-mechanical coupled finite element simulation technique were used. The corresponding conclusions were obtained by comparing the calculation results of each plan. The parametric modelling method is adopted for the model size, which can easily modify the computational model.

In the process of designing the dimensional parameters of channel steel specimens, the spans of the influencing factors are equal: the length of the section of side channel steel with equal section length is taken as 70mm, 1000mm, and 130mm, respectively, and the length-width ratio of the section of side channel steel with non-equal-section length is respectively taken as 1:1.2, 1:1.4, and 1:1.6. The wall thickness of channel steel is 4mm, 6mm, and 8mm, respectively. To reduce the number of calculations and time, different pipe sizes are combined into eight model solutions. The design plans of the butt welding channel steel dimensions are shown in table 1.

Table 1. The design plans of the butt welding channel steel size parameters.

Plan number	1	2	3	4	5	6	7	8
The length of section/h	70	100	100	100	100	130	100	100
The thickness of section/b	70	100	100	100	120	130	140	160
The wall thickness Of channel steel/d	6	4	6	8	6	6	6	6

2. The numerical analysis model

The finite element model uses eight-node three-dimensional solid elements SOLID70, SOLID90, and surface effect element SURF152, with a weld width of 10 mm and a transition area width of 10 mm. In order to increase calculation accuracy, the weld seam is divided into denser meshes and the unit width is 1mm. The width of the transition area is 2mm, and the width of the remaining area is 4mm. The welding finite element model (such as plan 3) is shown in figure 1.

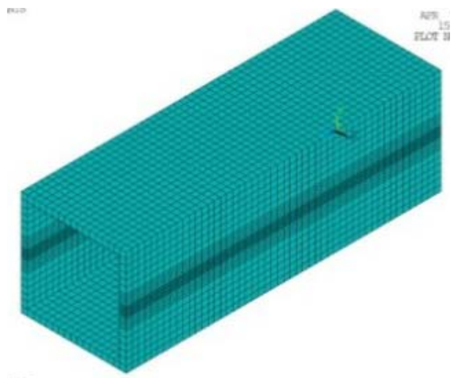


Figure 1. The finite element model.

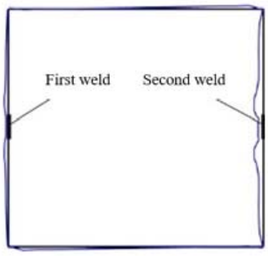
The finite element model which is established in the course of research is a thin-walled structure with a wall thickness changing from 4mm to 8mm [10]. A Gaussian heat source model is used for the Gaussian distribution model in the welding finite element simulation. When simulating, the heat source is applied to the weld surface in the form of heat flux which is calculated by equation (1).

$$q(r) = \frac{3Q}{\pi R^2} e^{-\frac{3r^2}{R^2}} \tag{1}$$

In the equation: $e = 2.71828$, Q is input heat, $Q = \eta UI$, η is efficiency, U is welding voltage, I is welding current, R is arc effective heating radius. The initial environment temperature is 20 °C. While loading the temperature field, the convection density is loaded on the surfaces of SOLID70 and SOLID90, and the heat flux density is loaded through the SURF152.

3. Butt welding channel residual stress distribution

The transverse and longitudinal residual stress distributions are shown in figure 2 and figure 3.



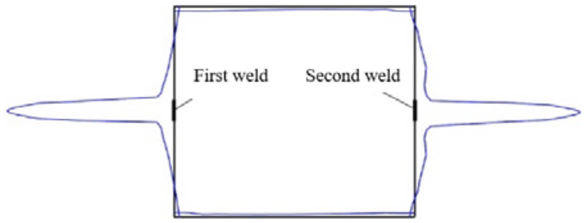
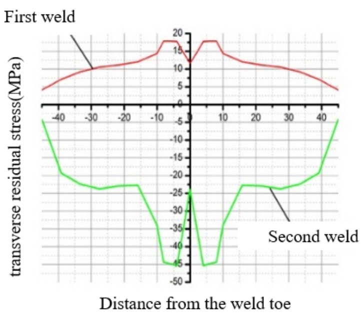


Figure 2. Transverse residual stress distribution. **Figure 3.** Longitudinal residual stress distribution.

It can be seen from figure 2 and figure 3 that the level of residual tensile stress of the welding channel steel is much higher than the residual compressive stress. The peak value of the welding residual stress on the long side of the steel channel section is located at the weld toe position. The peaks of the residual stress on the upper and lower edges of the channel steel section are mainly concentrated in the corners of the channel steel section. The transverse and longitudinal residual stress comparison curves of the first and second weld seams are shown in figure 4 and figure 5.



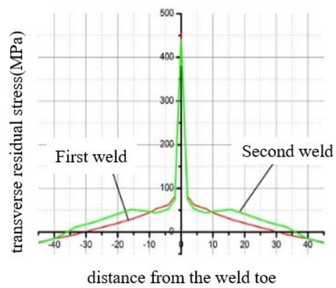


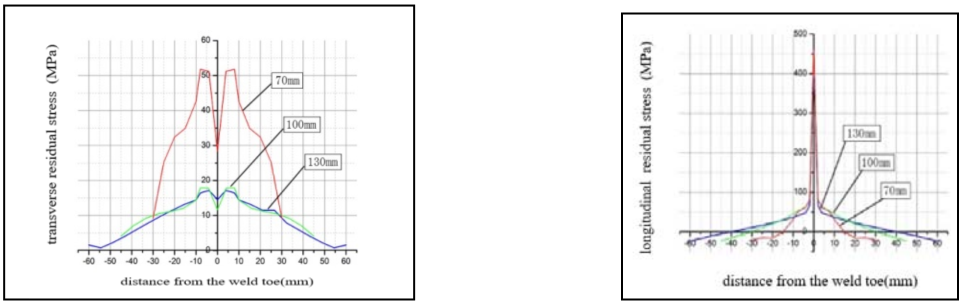
Figure 4. transverse residual stress comparison. **Figure 5.** longitudinal residual stress comparison.

From figure 4, it can be seen that the peak position of the residual stress at the weld position of the butt welded channel steel structure is not the weld toe, but about 5mm away from the weld toe, and as the distance from the weld toe increases, the transverse residual stress shows the trend of increasing first and then decreasing. It can be seen from figure 5 that the peak position of the longitudinal welding residual stress is at the weld toe position, and the peak value of the residual stress at the weld toe of the second weld is higher than the first weld. With the increase of the distance from the weld toe, the longitudinal residual stress near the weld seam gradually decreases. When the distance from the weld toe exceeds 10mm, the longitudinal residual tensile stress value near the first weld slightly increases and higher than the second.

4. The influence factors on welding residual stress of welded channel steel

4.1. Influence law of section length of butt welded channel steel on structural residual stress distribution

In this paper, the influence of the section length of welded channel steel on the structural residual stress is studied through plan 1, 3 and 6. The variation of the side length of each plan is equal: 70mm, 100mm and 130mm respectively. Except for the side length, other parameters of the finite element model are the same, aiming to eliminate the influence of other factors on the analysis result. The transverse and longitudinal residual stress curves calculated by different models are shown in figure 6.



(a) (b)

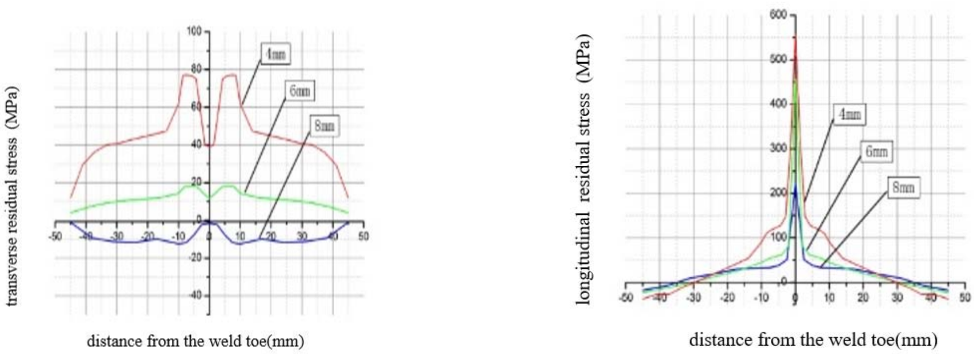
Figure 6. comparison curves of transverse and longitudinal residual stress of different side lengths.

As can be seen from figure 6(a), the transverse residual stress near the weld seam is always presents as tensile stress, and the peak location of transverse residual stress is 8mm away from the weld toe. The peak of transverse residual stress decreases with the increase of section length of channel steel. When the section length of the channel steel is reduced from 100mm to 70mm, the peak value of transverse residual stress increases by 33.877MPa, which is much higher than the increment of peak.

As can be seen from figure 7(b), the longitudinal residual stress near the weld seam is tensile stress, and its peak is mainly concentrated near the weld seam. With the increase of the section length of the channel steel, the peak of the longitudinal residual tensile stress at the near weld decreases gradually: 458.36MPa, 456.50MPa and 429.57MPa respectively. The longitudinal residual stress in plan 1 shows a significant drop down process.

4.2. The influence law of thickness of channel steel on structural residual stress distribution

The influence law of the thickness of butt welded channel steel on the structural residual stress was studied. The thickness of channel steel was changed by 4mm, 6mm, and 8mm respectively. The transverse and longitudinal residual stress curves which were calculated by different models are shown in figure 7.



(a) (b)

Figure 7. comparison curves of transverse and longitudinal residual stress of different thickness

As can be seen from figure 7(a), with the increase of the thickness of the channel steel, the variation law of transverse residual stress in the calculation model of each plan is gentle, and when the thickness of the channel steel is 4mm, the transverse residual stress has the most changes with the increased distance from the weld toe. With the increase of the thickness of the channel steel, the transverse residual stress near the weld area changed from the tensile stress region to the compressive stress region, and when the thickness of the channel steel reaches 8mm, the transverse residual stress distribution is completely transformed into compressive stress. However, with the change of the thickness of channel steel, the peak position of the transverse residual stress remains unchanged at about 8mm to the weld toe.

As can be seen from figure 7(b), the peak value of the longitudinal residual stress decreases gradually with the increase of the thickness of channel steel: 537.36MPa, 439.72MPa and 232.81MPa in turn. Meanwhile, the smaller the thickness of the channel steel, the greater the gradient of the longitudinal residual stress with the increased distance from the weld toe. From the vibrational peak of residual stress at weld toe, we can see that the deviation of peak value of longitudinal residual stress in plan 2 and plan 3 is 97.64MPa, while the deviation of peak value of longitudinal residual stress in plan 3 and plan 4 is 206.91MPa, which indicates that the greater the thickness of the channel steel, the greater the reduction amplitude of the peak value of longitudinal residual stress with the increase of thickness.

5. Summarize

Through the above analysis, we can draw the following conclusions:

(1) The welding residual stress distribution in the butt welded channel steel structure is mainly longitudinal residual tensile stress, the peak position of tensile stress is weld toe, the peak of tensile stress can reach 537.36MPa, which seriously affects the stability and fatigue performance of the butt welded channel steel structure.

(2) The transverse and longitudinal residual stress distribution of butt welded channel steel structure is different between two weld seam because of the welding sequence, the transverse residual stress distribution in the vicinity of the first welding line is presented as compressive stress, and the transverse residual stress distribution near the second welding line is tensile stress. Although the longitudinal residual stress distribution of two welding lines is in the tensile stress region, the longitudinal residual stress at weld toe of the second welding line is higher.

(3) The variation of length in the constant-section side-length mainly influences the distribution of transverse residual stress in the butt welding channel steel structure, and has little influence on the longitudinal residual stress distribution in the structure. While in the structure of butt welding channel, the stress of the structure performance is mainly longitudinal residual stress.

(4) The change of the thickness of the channel steel will significantly affect the transverse and longitudinal welding residual stress value, the smaller the thickness of the channel steel, the higher the transverse and longitudinal welding residual stress in the structure. When the thickness of the channel steel reaches a certain value the transverse residual stress value near the weld area is converted to compressive stress and the peak value of longitudinal residual stress at the weld toe can be reduced remarkably.

Acknowledgments

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