Title	Prospective design of weld joint between first and side walls in the test blanket module for ITER
Author(s)	Nakamura, Shinichiro; Serizawa, Hisashi; Tanigawa, Hiroyasu et al.
Citation	Transactions of JWRI. 2010, 39(2), p. 235-237
Version Type	VoR
URL	https://doi.org/10.18910/7635
rights	
Note	

Prospective design of weld joint between first and side walls in the test blanket module for ITER†

NAKAMURA Shinichiro*, SERIZAWA Hisashi**, TANIGAWA Hiroyasu***, MURAKAWA Hidekazu**

KEY WORDS: (Welding residual stress) (Electron beam welding) (Hot isostatic pressing) (Finite element method) (Cooling channel) (Test blanket module)

1. Introduction

Recently, in the collaboration with seven members, the international thermonuclear experimental reactor (ITER) has been constructed at Cadarache in France as the world's largest experimental fusion facility [1]. In current design of the Japanese test blanket module for ITER, the water cooling channels have to be installed in the first and side walls and these walls are planned to be joined by electron beam (EB) welding.

The size of cooling channels is 8 mm square while the thickness of first wall is 25 mm in current design, and such first wall is planned to be fabricated by using hot isostatic pressing (HIP) method [2]. On the other hand, the cooling channels are planned to be located near the EB welding and it is considered that the EB welding would affect the deformation of cooling channels and the residual stress at the surface of cooling channels. Sometimes, there might be a risk of stress corrosion cracking (SCC) at the surface of cooling channels because of the tensile residual stress on the surface.

So, in this research, for the purpose of decreasing the risk of SCC, the modification of the current design based on the welding residual stress was studied by using thermal elastic–plastic finite element method (FEM). Also, the prospective design proposed by the above research was examined by comparison between current and prospective designs.

2. Analyses by Simplified Models

It is desirable to reduce the size of cooling channels for controlling the risk of SCC, but this cannot be realistic concerning the effect of cooling. On the other hand, a position of EB weld joint between the first and side walls seems to be slightly movable because the first wall is planned to be fabricated by HIP method. So, in this research, the modification of the current design was studied by focusing on the distance from weld line to cooling channels in the first wall. Then four simplified FEM models were employed for the analysis of EB welding. The size of plates was 200^{l} x 400^{w} x 45^{t} (mm), and the distance from weld line to cooling channels were varied from 10 to 16mm.

The welding conditions were basically decided from the experiment and other two parameters (heat source model and thermal efficiency), which cannot be directly determined in the experiment, were assumed according to our previous studies [3]. Namely, the homogeneous heat source model, whose shape was T-type, was employed and the thermal efficiency was set to 0.7. **Figure 1** shows the welding residual stress distribution parallel to the weld line at a cross sectional plane in the middle of the weld line, and the stress beside the cooling channels is also plotted as shown in **Fig. 2**. From these figures, it was found that large tensile residual stress over 500 MPa was generated on the surface of the cooling channels when the distance from weld line to cooling channels was 10 mm. On the other hand, the residual stress was changed to be compressive when that was 16 mm. So, in order to reduce the risk of SCC, it is desirable for the location of weld line to be more than 16 mm apart from the surface of cooling channels.

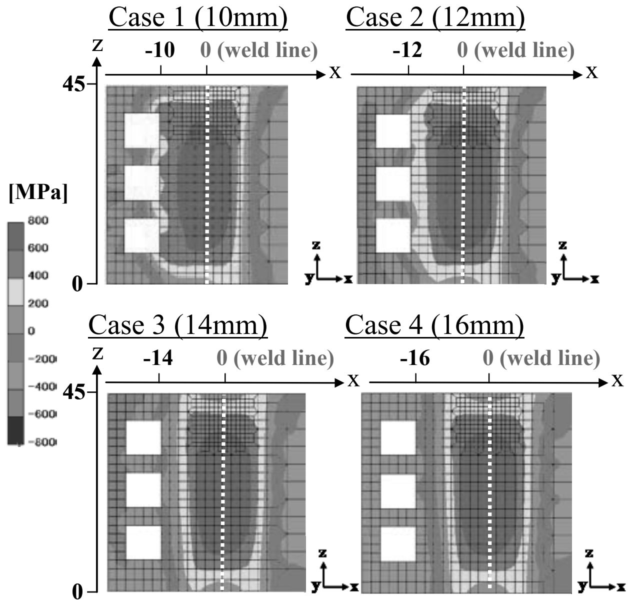

Fig. 1 Residual stress distributions parallel to weld line at cross sectional plane of middle of weld line.

† Received on 30 September 2010
* Graduate School, Osaka University, Japan
** JWRI, Osaka University, Japan
*** Japan Atomic Energy Agency, Japan

Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

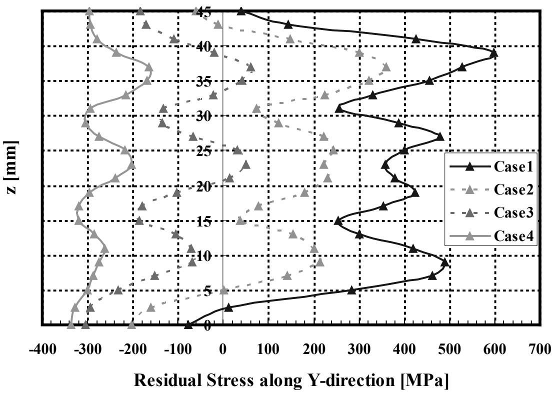

Fig. 2 Residual stress distributions parallel to weld line beside cooling channels.

3. Evaluation of Prospective Design

Figure 3 shows a schematic illustration of the box structure for Japanese TBM and FEM models for numerical analysis. As shown in this figure, a partial model was employed for this evaluation because of the limitation of computer resources. This figure also shows the FEM model with current and prospective designs obtained from the above studies. In prospective design, the width of backing was modified without changing the thickness of first wall. In the order to evaluate the residual stress in the prospective design, the thermal elastic-plastic analyses were conducted in two cases, which were Case-1 (current design) and Case-2 (prospective design), respectively.

In the elastic-plastic analyses, the mechanical boundary conditions were set as follows.

1) Displacement along y-direction was fixed at the cutting planes of the first and side walls perpendicular to the welding direction
2) Displacement along z-direction was fixed at the other cutting plane of the first wall
3) Displacement along x-direction was fixed at the other cutting plane of the side wall

The plastic strain distributions parallel to the weld line at center cross section were shown in **Fig. 4**. It can be found that the compressive plastic strain on the surface of cooling channels in Case 2 was much smaller than that in Case 1. Also, it was revealed that the distribution near the weld line became uniform by setting the weld line 16 mm away from the cooling channels.

Figure 5 shows the welding residual stress distributions parallel to the weld line at center cross section. From this figure, it was found that the residual stress on the surface of cooling channels in Case 2 was smaller than that in Case 1. However, tensile residual stress more than 200 MPa was generated beside channels in Case 2. Thus, it is necessary to conduct post weld heat treatment (PWHT) for decreasing the residual stress around channels. As for the appropriate condition of PWHT, it is revealed that the prospective design would be more suitable than the current design since the plastic strain beside channels was small and its distribution would be uniform as shown in Fig. 4.

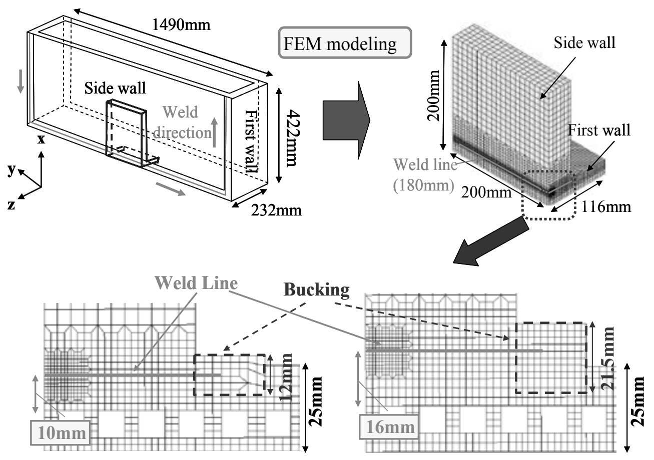

Fig. 3 Schematic illustration of box structure for TBM and FEM models with current and prospective design.

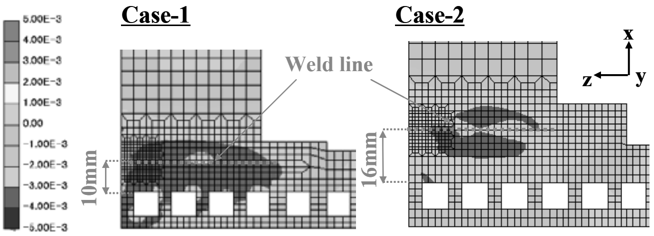

Fig. 4 Plastic strain distributions parallel to weld line at cross sectional plane of middle of weld line.

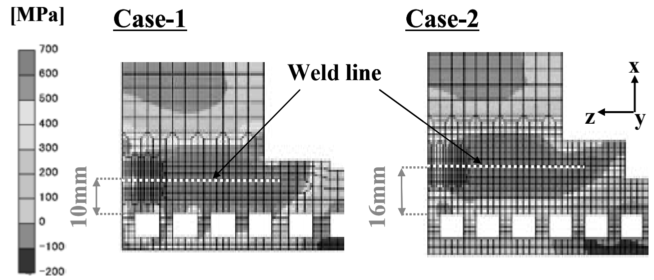

Fig. 5 Residual stress distributions parallel to weld line at cross sectional plane of middle of weld line.

4. Conclusions

In order to reduce the risk of stress corrosion cracking in the test blanket module for ITER, the modification of current designs was studied focusing on the location of the weld line by thermal elastic-plastic finite element analysis. Also, the prospective design was examined by using a partial FEM model of a box structure composed of the first and side walls.

(1) The change of distance between weld line and cooling channels from 10 to 16 mm would decrease the welding residual stress on the surface of channels and this decrement might lead to the reduction of risk for SCC.
(2) Residual stress on the surface of channels in the prospective design was smaller than that in current design, while tensile residual stress more than 200 MPa was generated. Thus, there is a need to conduct PWHT to reduce the residual stress, and the prospective design would be suitable for PWHT because the plastic strain

around cooling channels was small and its distribution was more uniform than that in current design.

References

[1] H. Tanigawa, T. Hirose, K. Shiba, R. Kasada, E. Wakai, H. Serizawa, Y. Kawahito, S. Jitsukawa, A. Kimura, Y. Kohno, A. Kohyama, S. Katayama, H. Mori, K. Nishimoto, R.L. Klueh, M.A. Sokolov, R.E. Stoller and S.J. Zinkle: Fusion Engineering and Design, 83, (2008), pp.1471-1476.
[2] T. Hirose, M. Enoeda, H. Ogiwara, H. Tanigawa and M. Akiba: Fusion Engineering and Design, 83, (2008), pp.1176–1180.
[3] H. Serizawa, S. Nakamura, M. Tanaka, Y. Kawahito, H. Tanigawa and S. Katayama: Journal of Nuclear Materials, to be published (2011).