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Prediction of welding deformation for double bottom structure in cargo hold of 50000 DWT multipurpose ship†

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1. Introduction

Double bottom is a typical unit of hull construction, and the prediction of its welding deformation is essential for hull structural design and accuracy control of shipbuilding. Three-dimensional thermal elastic-plastic FEM can simulate the whole welding process, but it takes huge calculation time and is only applicable to welding mechanics behavior analysis of welded joint or small structures. In this paper, through a large amount of computation and measurement, a simple calculation formula of inherent deformation which relies on thickness of plates is proposed. Based on the inherent deformation calculated by the simple formula [1][2], the deformations of the double bottom structure in NO.6 Cargo of 50000 DWT multipurpose ship are predicted by special software WSDP. The feasibility of inherent deformation database and simple formula is verified for the numerical results and agrees well with the experimental data.

2. Production Process of the Double Bottom Structure

The 50000 DWT multipurpose ship is a kind of welded steel ship with double shell structure. In this paper the block 1C14P/C/S has been taken as specimen of study. The specimen's width is 32250mm, length is 11860mm, and the height is 1750mm. The steel-type of inner bottom plate is GLDH32, and inner bottom longitudinal is GLAH32 while in other area is GL-A.

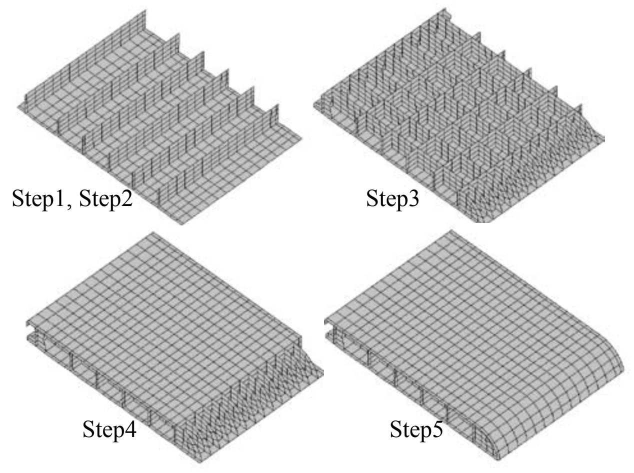

Fig. 1 Assembly and Welding Sequence

This double bottom block is divided into several components, such as the inner bottom plate, floor plates, shell plate, longitudinal girder, which are assembled separately at five steps as below, and shown in **Fig. 1**.
inner bottom plate => longitudinal structure => floor plate and stiffener => straight shell plate => curved shell plate.

3. The Finite Element Model

The finite element model is established by software HyperMesh. According to symmetry, a half of the block structure is meshed with quadrilateral elastic shell element [3]. There are 1730 model nodes and 2108 elements. **Figure 2** depicts the finite element model and constraints. X axis (longitudinal) is along the bow direction, Y axis (transverse) is along the port direction of the ship and Z axis (vertical) is along the upward direction to the shell plate. 151 fillet welded joints were employed.

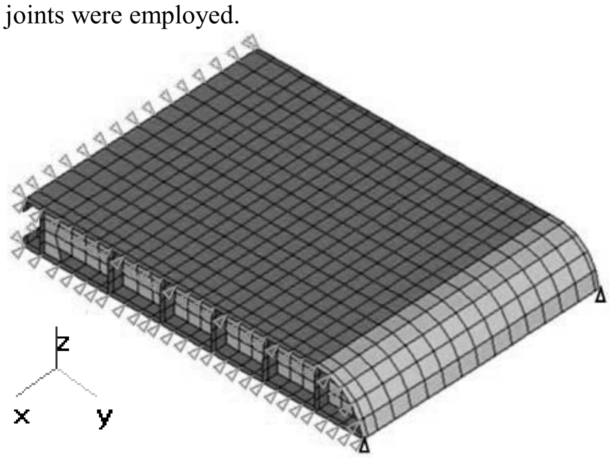

Fig. 2 Finite Element Model of Double Bottom and Constraints

4. Formula of Inherent deformation

The heat input is the main factor of inherent deformation. According to the welding technology used in hull, the total heat input is almost determined by the thickness of plates. Therefore, inherent deformation was considered as a function of the thickness of plates. The simplified inherent deformation formulas are proposed as:

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$$T_f = 0.016KEh^2 \ (N) \quad (1)$$

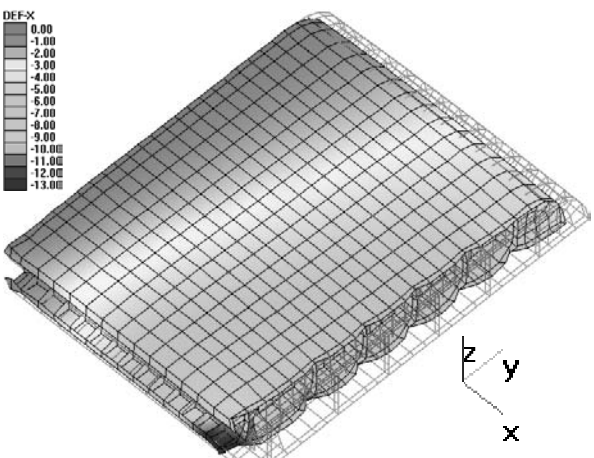
$$\delta = 0.006Kh \ (mm) \quad (2)$$

Where T_f is Tendon force, δ is the transversal shrinkage, E is the elastic modulus, h is the thickness of plates and K is the correction coefficient, its value is between 0.6~1.0. Since the main concern of shipyard is shrinkage of hull structure, in order to simplify the computation, the angular deformation has been neglected. The welding deformations of this block are predicted using the inherent deformation calculated by formula (1) and (2).

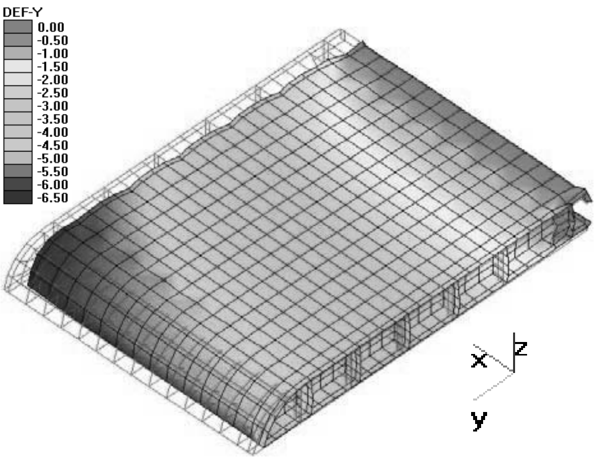
5. Calculated Results

Figure 3 displays the distribution of welding deformation along the longitudinal and transverse direction, and the deformation enlarged 100 times, the dashed line is the original contours of the structure.

Figure 4 expresses the shrinkage curve along the longitudinal and transverse direction at each step. The black curve depicts the actual displacement obtaining by measurement.

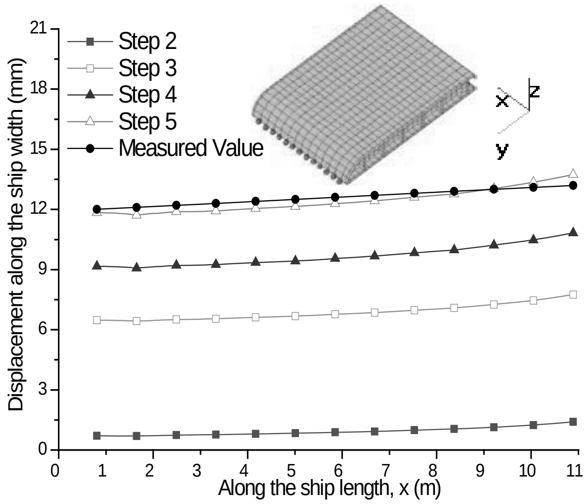


(a) Along the ship length

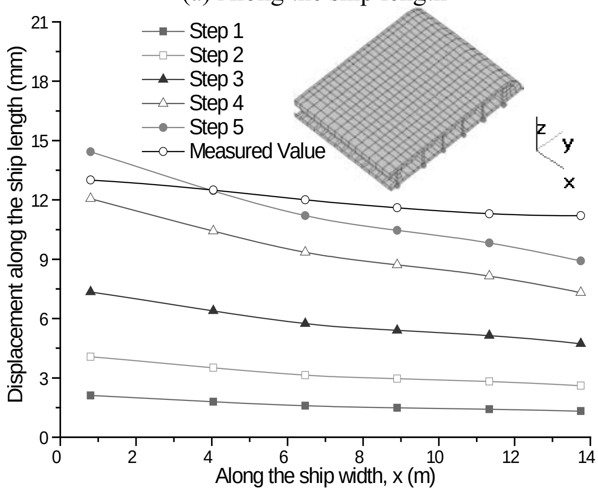


(b) Along the ship width

Fig. 3 Distribution of Welding Deformation



(a) Along the ship length



(b) Along the ship width

Fig. 4 Comparison of experimental and computational displacement by five steps

As Fig. 4 (a) reveals, the longitudinal shrinkage gradually increases with the welding sequences carrying on, and the maximum deformation is approximately 14.5mm occurring at the middle of the double bottom. It is indicated by comparison that the computational result agrees well with the experimental data. The similar conclusion can be acquired from Fig. 4 (b).

6. Conclusions

Based on the discussion above, we can conclude the following.

(1) The simple inherent deformation formulas for hull construction are obtained through a series of thermal elastic-plastic calculation and production experience:

$$T_f = 0.016KEh^2 \ (N)$$

$$\delta = 0.006Kh \ (mm)$$

Where T_f is the Tendon force, δ is the transversal shrinkage, E is elastic modulus, h is the thickness of plates and K is the correction coefficient, its value is between 0.6~1.0.

(2) The deformation of the whole structure along the longitudinal and transverse direction is 12mm and 13mm predicted by software WSDP based on the inherent strain method. This result agrees well with the measured value.
(3) The inherent strain method is practical, accurate and easy for calculation, so it can be a useful tool for prediction of welding deformation of hull construction.

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