2004년도 춘계 학술발표대회 발표논문, 2004년 5월, 제주

LNG선의 Deck Pillar부 이면의 보강재 용접 시의 변형 해석

Analysis of Deformation Induced by Fillet Welding of Stiffener on Back Side of Deck Pillar in LNG Carrier

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1. Background

This paper presents the analysis results of deformation induced by welding of stiffeners which will be attached for structural reinforcements of deck pillar support in LNG carrier. Because the deformation induced by welding of stiffeners may affect significantly to the strength of membrane in cargo tank, the welding deformation should be controlled in the range of 0.2-0.3mm in vertical deflection.

The analysis of welding deformation was performed by the simplified analysis method[1-4] using elastic analysis since it is very difficult to apply the direct three-dimensional transient thermal easto-plastic analysis in the calculation of the welding deformation.

2. Simplified method

Some analytical methods have been proposed to estimate the weld-induced deformation of steel structures. Meanwhile, by the assistance of computer program, FEA(finite element analysis) has become more practical and popular for this purpose.

Fig. 1 shows a thermal analysis diagram using FEM. At the first stage, the temperature distribution of each element at each time step is calculated using unsteady heat conduction analysis by heat input with the consideration of temperature-dependent physical properties. At the second stage, the deformation and stress of the structure at each time step are calculated using thermal elastio-plastic analysis by inputting the results of the first stage with the consideration of temperature-dependent mechanical properties.

As these calculations need a lot of time, labor and costs by repeating the calculations for each time step, a simplified analysis method is suggested in this paper. This method omits heat conduction analysis, while the inherent deformation is experimentally or analytically estimated, and the deformation can be calculated by elastic linear FEM using simplified models.

3. Formulae of welding deformation

Weld-induced deformations are usually classified as follows :

(1) angular distortio
(2) transverse shrinkage perpendicular to the weld line
(3) longitudinal bending distortion
(4) longitudinal shrinkage parallel to

the weld line

The formulae for the above deformation are well summarized in many references[1-3]. On the basis of the experimental results[4], the following formula was proposed as the angular distortion for FCAW(flux cored arc welding) as follows :

$$\phi_f = 1.243 \cdot p^{1.894} \cdot \exp(-0.165p)\ (\times 10^{-3} rad) \quad (1)$$

where, p is heat input parameter defined as

$$p = Q/t^{1.5} \quad (2)$$

with t and Q are plate thickness and heat input per unit length, respectively.

The formula for longitudinal bending distortion in one pass fillet welding is also proposed based on the experimental results[4] as follows :

$$1/r = 0.25(a/c\rho)(Q \cdot y_i/I_t)\ (mm^{-1}) \quad (3)$$

where, $1/r$: curvature

α, ρ, c : linear expansion coefficient, density, specific heat of material

y_i : distance between weld line and neutral axis

I_t : inertia moment about neutral axis of transverse section of T-bar.

4. Results of simplified analysis

The stiffeners for reinforcement of pillar will be attached by fillet welding having the weld throat thickness of 3.5mm. Therefore, throat thickness 3.5mm was adopted in the calculation of deformation by the simplified analysis method.

Two cases of welding method was investigated. One is continuous fillet welding[Fig. 1(a)], which is the way that attaches the flat bar(height 175mm, thickness 10mm) by continuous fillet welding on the back side of pillar supports. The other is partial fillet welding[Fig. 1(b)], which is suggested in order to minimize the welding deformation by the reduction of weld length itself. The flat bar will be attached only on the back side of pillar support contact point.

We obtained from the simplified analysis that the maximum deflection of pillar structure is less than 0.13mm. Fig. 2 and Fig. 3 show the deformed shape and deformation contour due to fillet welding of additional stiffener. We propose that although the deformation of partial fillet welding is less than that of continuous welding, the continuous welding can be adopted in the reinforcement method of pillar support since the absolute magnitude of deformation for both cases is very small and the fabrication method for partial welding is more difficult than that for continuous welding.

5. Conclusions

In this study, a simplified analysis method using elastic linear FEA to predict the residual deformation due to fillet welding was proposed.

From the results of simplified analysis, we propose that although the deformation of partial fillet welding is less than that of continuous welding, the continuous welding can be adopted in the reinforcement method of pillar support since the absolute magnitude of deformation for both cases is very small and the fabrication method for partial welding is more difficult than that for continuous welding.

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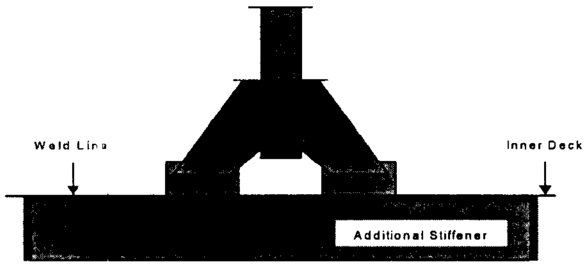
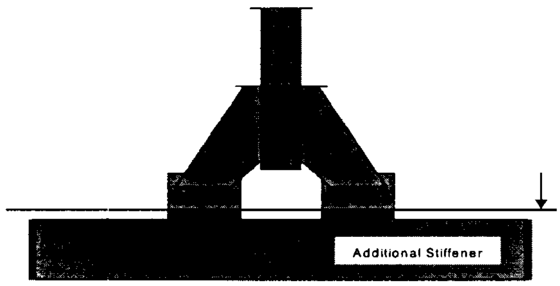
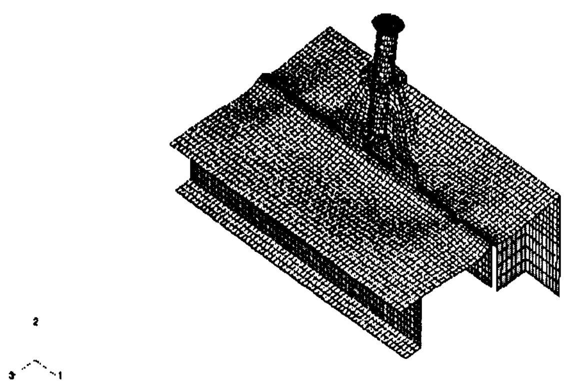


(a) continuous fillet welding

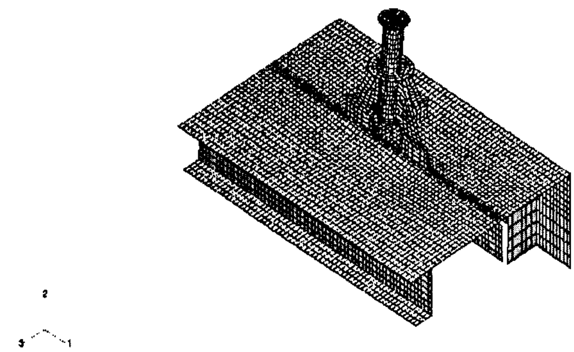


(b) partial fillet welding

Fig. 1 Welding method of additional stiffener

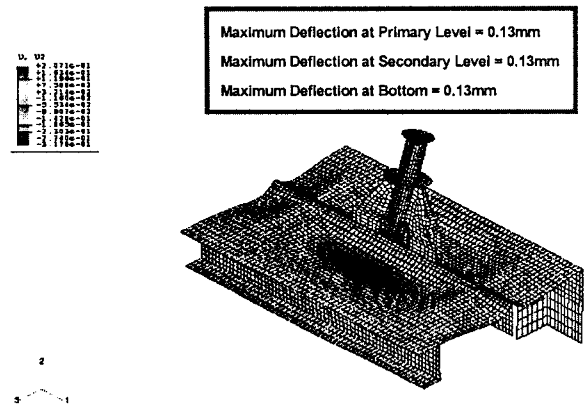


(a) continuous fillet welding

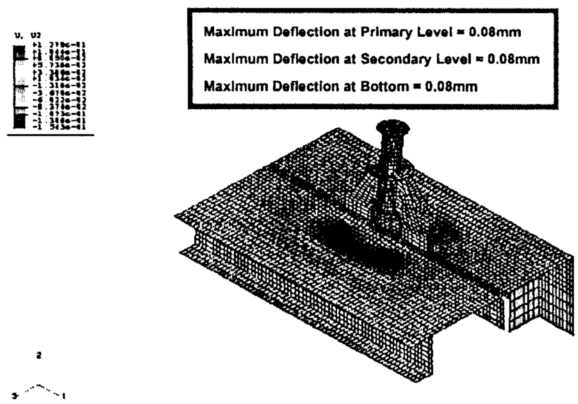


(b) partial fillet welding

Fig. 2 Deformed shape due to fillet welding of additional stiffener



(a) continuous fillet welding



(b) partial fillet welding

Fig. 3 Deformation contour due to fillet welding of additional stiffener