Control of Buckling Distortion in Stiffened Panels

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Introduction

Thin section panels have been increasingly used in ship construction. These panels consist of AH-36 or DH-36 steel plates that are less than 3/8-in. (9.53-mm) thick with T-section stiffeners welded to them. The stiffeners are welded continuously on both sides with flux cored arc welding (FCAW). This has resulted in more distortion leading to additional costs for fitting and flame straightening. Previous work identified buckling as the dominant mode of distortion, followed by angular distortion.

Steady-state thermal tensioning the weld zone by heating strips on both sides of the weld while cooling directly underneath the weld is effective in eliminating buckling distortion on small-scale mockups. The use of steady-state heating and cooling is impractical in a manufacturing environment because of the time required to reach steady-state conditions.

Dynamic or transient thermal tensioning has been investigated using oxy-fuel gas burners placed to the side of each welding torch. The heating assembly traveled with the torches. Water-cooling was not used. Since the heating is applied only during welding, this method requires minimal disruption to the welding practices currently used in shipyards. This method proved to be effective for minimizing buckling distortion when welding small-scale mockups with one or more stiffeners.

Experimental Procedure

Experiments were done on larger mockups multiple stiffeners in the laboratory. Mockups were fabricated in the lab using 8-ft. x 20-ft. x 3/16-in. (2438- x 6096- x 4.76-mm) thick plate. Three 4- x 4-in. (102-mm) longitudinal stiffeners were welded to each plate 24-in. apart using 3/16in. (4.76-mm) fillet welds on both sides of each stiffener.

The mockups were measured to determine out-of-plane distortion. Finite element modeling of the fabrication process of this panel was done using decoupled buckling and stress calculations. Buckling analysis results were compared to empirical out-of-plane measurements to validate the model. The model was then used to predict the thermal tensioning parameters that would result in minimal out-of-plane distortion. Mockups were fabricated using these parameters. Experiments were then done in a shipyard using 8-ft. x 20-ft. x 7/32-in. (2438- x 6096- x 5.5-mm) panels with three stiffeners and 10-ft. x 40-ft. x 7/32-in. (3048- x 12192- x 5.5-mm) panels with four stiffeners to determine the effectiveness of this technique in a production environment.

Results and Discussion

Good correlation was found between the predicted results of the finite element model and the experimental results of the welded mockups. Optimal auxiliary heating conditions resulted in minimization of buckling distortion on larger panels with multiple stiffeners. In the best case in the lab, out-of-plane distortion was reduced from 1.2 in. to 0.4 in. over the 240-in. length of the panel. The shipyard trials confirmed that transient thermal tensioning was effective on both 20-ft. and 40-ft. long panels in a production environment.

Conclusions

A predictive tool for buckling distortion in stiffened panels, requiring small run times, has been developed and demonstrated. Transient thermal tensioning can be used to minimize buckling distortion in larger panels with multiple stiffeners in a production environment.