

Study on the relationship between shell stress and solid stress in the vicinities of ship's welded joints

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ABSTRACT

The surface stresses in the vicinity of the weld of a hopper corner joint model and a perpendicular joint model calculated by $t \times t$ shell models are compared with those calculated by fine solid models. Based on the results, selection method of a point to represent the weld toe in HSS evaluation is discussed. As results, the followings are found:

(1) Under conditions chosen, solid stress of the solid model with weld beads at a distance of D from the weld toe agrees with shell stress at a distance of D from the plate surface intersection of the solid model without beads apart from the shell element nearest to the structural intersection.

(2) Under conditions chosen, shell stress of the element nearest to the structural intersection underestimates solid stress substantially when shell and solid stresses are compared by the procedure of the preceding paragraph.

(3) It is recommended to select the point directory below the intersection of the plate surfaces as the point to represent the weld toe in shell analysis. In this case, the stress of the nearest element to the intersection should not be used in stress extrapolation.

KEY WORDS: Fatigue, Hot spot stress, Finite element analysis, Coupling analysis

INTRODUCTION

The approaches to the fatigue strength assessment have been further developed during recent years (e.g. Fricke, 2003). In addition to the conventional nominal stress approach, local approaches such as the (structural) hot-spot stress (HSS) approach have reached the stage of practical application.

Regarding HSS approach, experimental and analytical procedures have been derived for its determination by extrapolating the structural stress outside the localized notch-affected zone to the weld toe (e.g. Niemi, 1995). In most classification society rules, HSS is evaluated by shell FE models in which the weld geometry is neglected. In these cases, special care is needed to select an appropriate point to represent the weld toe for stress extrapolation. Frequently, the structural intersection is chosen as this point because the stress at the weld toe position might be non-conservative.

The Common Structural Rules, CSR, went into effect in 2006. In CSR, the fatigue design load has been raised drastically in comparison with the conventional rules. Over-conservative HSS evaluation could impair the economy of the ship design inadmissibly. It is necessary to establish a

HSS determination technique based on shell FE analysis with reasonable safety margin.

When a solid FE model is employed, modeling of welds is easily possible and the stress field in the vicinity of the weld can be investigated with a high degree of precision. The safety margin of shell-based HSS determination techniques can be examined by comparing shell stress and solid stress. HSS derived from shell and solid analyses are compared in some studies (e.g. Fricke, 2002). In these studies, only one layer of solid elements is arranged over the thickness and relatively coarse meshing is used in order to exclude the notch effect from the calculated solid stress. Such solid stress does not always correspond to the true stress and it depends on FE mesh. This ambiguity can be eliminated by comparing shell stress with solid stress calculated by fine mesh which can reproduce the notch effect. The reference HSS can be determined by letting this solid stress be the measured stress. So far as the authors know, such comparative study on ship structure has not been reported.

In this report, the relation of the stresses in the vicinity of the weld of stool-like and hopper corner-like joint models calculated by $t \times t$ shell models to those calculated by fine solid models is studied. Based on the results, selection method of a point to represent the weld toe in HSS evaluation is discussed.

METHODOLOGIES

Shell-solid coupling and shell FE analyses

Because ships are large plate structures, global shell FE models are usually employed for simplicity and low cost. Local solid FE models are employed for the investigation of the local stress field in the vicinity of the weld. It is needed to transfer the angular rotations or the moments of the global shell elements to the translational displacements or forces of the local solid elements. The rotation / moment can be converted easily by using shell-solid coupling FE models in the local analysis.

The shell-solid coupling can be achieved by a fictitious shell plane perpendicular to the original shell plane as shown in Fig. 1. Hereafter, this technique is called 'perpendicular shell coupling method (PSCM)'. The problem in PSCM is how to decide the stiffness of the fictitious shell. In this study, it is assumed that the elastic properties of the fictitious shell are equal to those of the original shell plate. Hereafter, let t_s denote the thickness of the fictitious shell, and t the plate thickness. The stiffness of the fictitious shell can be controlled by changing t_s . The value of t_s which gives reasonable results depends on the model and the boundary conditions.

Osawa et al. (2006) optimized t_s by examining the local stresses of the