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Submodeling Analysis of Ship Structure with Superconvergent Patch Recovery Method

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ABSTRACT

A new submodeling technique is proposed and applied to ship structure analysis in which a Bulk Carrier is selected. Two types of boundary conditions, the displacement boundary condition and the stress boundary condition based on the superconvergent patch recovery (SPR) method, are applied in submodeling analysis, and their results are compared. Two computational domains of ship structure for submodeling analyses are considered, and the accuracy of the submodeling analysis is investigated. According to the numerical analysis, the SPR method improves the stresses along the submodeling boundary and the proposed submodeling technique gives accurate solutions.

INTRODUCTION

Submodeling is a technique that is most useful when it is necessary to obtain an accurate and detailed solution in a local region of a large model. In this method, a global analysis using a relatively coarse mesh, namely driving mesh, is first run; then the local region of interest is broken out as a submodel and analyzed separately with fine meshes, taking into account the effect of the rest of the structure. In order to consider the effect of the rest of the structure upon the sub-region, submodeling procedures can be classified into several categories. Among these, the specified boundary condition methods are most popular, in which state variables are transferred from a global solution to determine the boundary response of the submodel for representing the effect of the rest of the structure. Two methods can be classified into this category. Applying the stress boundary condition method involves applying traction forces derived from stresses obtained by global analysis to the submodel boundary. Alternatively, in applying the displacement boundary condition method, displacements are interpolated from the global solution at the boundary nodes of the submodel grid.

Applying the displacement boundary condition to submodeling analysis is often used in practice and is a key study in the literature (Srinivasan, 1996; Cormier, 1999) for the following reasons. First, it is easier to be implemented, and second, for a raw FEM solution, displacements are generally more accurate than stresses. Employing recovery procedures has been studied recently (Zienkiewicz, 1992; Kitamura, 2000; Gu, 2000), and a more accurate stress solution than the raw FEM solution can be obtained. In this paper, the recovery procedure (Gu, 2000) is used to specify traction force as stress boundary conditions for submodeling analysis. Two kinds of boundary conditions, the displacement boundary condition and the stresses boundary condition, are applied to the ship structure analysis of a Bulk Carrier.

STRESS RECOVERY PROCEDURE

This paper uses recovered stress rather than that of the raw FEM solution to determine the traction force on a submodel boundary because of its better accuracy and convenience in implementation. By stress recovery procedures (Zienkiewicz, 1992; Kitamura, 2000; Gu, 2000), a much better result of stress distribution can be achieved; sometimes it even has the same rate of convergence as displacements. After performing the stress recovery process, a continuous stress field represented by polynomials is constructed for each stress component. For a submodel boundary either along elements' edge or crossing elements, the traction force can be computed conveniently. The modified SPR method (Gu, 2000) is adopted in this paper and its outline presented.

After performing finite element analysis, the patch is defined for each vertex node by the union of elements containing that node (Fig. 1). The displacement-based finite element method gives discontinuous stress distribution along an element boundary (Fig. 1b). For each patch, a continuous stress field represented by polynomial expansion is assumed over the patch for each stress component and is determined by requiring a least squares fit of the expansion to the raw FEM solution at a set of sampling points (Fig. 1c). To solve the least squares problem shown by

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