ABSTRACT
The authors developed the iterative substructure method (ISM) for welding simulations in order to analyze large and complicated problems. To improve this method for computing larger problems, the hierarchical multi-grid (HMG) method was developed based on the variational theorem. In this method, the domain to be analyzed is subdivided into a multi-grid, which has a hierarchical structure, and the solution is obtained by solving equations successfully for nodes at each hierarchy level. In this research, the potential capabilities of the HMG method and ISM using the HMG method (called the ISMMG method) were examined through simple example problems.

KEYWORDS: Weld; Thermal elastic plastic analysis; Finite element analysis; Variational theorem; Computational time

INTRODUCTION
During ship construction, welding is extensively used to join stiffeners to plates, build subassemblies, assemblies and blocks, and then to join these blocks in order to assemble the ship’s hull. This welding causes deformation and residual stress. To prevent or minimize welding distortion and residual stress, quantitative prediction by CAE is necessary. However, current finite element analyses of welding cases require very long computational times for two reasons. First, the welding simulation must compute each step from welding to cooling. Usually this requires 1,000 to 10,000 steps. Second, nonlinearity becomes very prominent due to temperature-dependent material properties near the welding torch. Consequently, it becomes difficult to reach convergence.

To analyze large and complicated welded structures, the authors developed the iterative substructure method (ISM) for welding simulations (Murakawa, Oda, Ito, Serizawa, Shibahara, and Nishikawa, 2005). However, ISM is not applicable to welding problems with more than 500,000 degrees of freedom (DOF) in today’s computers, because the solver is the direct method and the computing time tends to be generally proportional to the square of the DOF. To solve this problem, in this study, the authors developed the hierarchical multi-grid (HMG) method based on the variational theorem (Itoh, Taguchi, Umemoto, Serizawa and Murakawa, 2008). In this method, the domain to be analyzed is subdivided into a multi-grid that has a hierarchical structure, and the solution is obtained by solving equations successively for nodes at each hierarchy level. In this study, the potential capabilities of the HMG method and ISM using the HMG method, called the ISMMG method, were examined through simple example problems.