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Three-dimensional thermo-elastoplastic analysis by triple-reciprocity boundary element method

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ABSTRACT

In general, internal cells are required to solve thermo-elastoplastic problems using a conventional boundary element method (BEM). However, in this case, the merit of the BEM, which is ease of data preparation, is lost. The triple-reciprocity BEM can be used to solve two-dimensional thermo-elastoplasticity problems with a small plastic deformation without using internal cells. In this study, it is shown that three-dimensional thermo-elastoplastic problems with heat generation can be solved by the triple-reciprocity BEM without using internal cells. Initial strain and stress formulations are adopted and the initial strain or stress distribution is interpolated using boundary integral equations. A new computer program is developed and applied to solve several problems.

1. Introduction

The finite element method (FEM) requires several repetitions of remeshing for large-plastic-deformation analysis. Elastoplastic problems can be solved by a conventional boundary element method (BEM) using internal cells for domain integrals [1,2]. In this case, however, the merit of the BEM, which is ease of data preparation, is lost. On the other hand, several countermeasures have been considered. For example, Nowak and Neves [3] have proposed the conventional multiple-reciprocity boundary element method (MRBEM). In the conventional MRBEM, the distribution of initial strain must be given analytically, and fundamental solutions of higher order are used to make solutions converge. Accordingly, this method is not suitable for thermo-elastoplastic analysis. Dual-reciprocity BEM has been proposed to reduce the dimensionality, which is the advantage of BEM [4]. It is difficult to apply the dual-reciprocity boundary element method to thermo-elastoplastic problems with arbitrary heat generation. The real-part boundary element method is suitable eigen-value analysis [5,6]. The relation between the conventional MRBEM and the complex-valued formulation can be examined by the real-part boundary element method. Sladek and Sladek [7] applied the local boundary element method to elastoplastic problems without internal cells. Ochiai and Kobayashi [8] proposed the triple-reciprocity BEM (improved multiple-reciprocity BEM) without using internal cells for elastoplastic problems. By this method, a highly accurate solution can be obtained using only fundamental solutions of low orders and by diminishing the need for data preparation. Ochiai and Kobayashi [9] applied the triple-reciprocity BEM without using internal cells to two-dimensional elastoplastic problems using initial strain formulations. Ochiai applied the triple-reciprocity BEM to two-dimensional thermo-elastoplastic problems with arbitrary heat generation [10] and three-dimensional elastoplastic problems using initial strain formulations [11]. Only the triple-reciprocity BEM and the local boundary element method have been applied to elastoplastic problems without internal cells.

In this study, the triple-reciprocity BEM is applied to three-dimensional thermo-elastoplastic problems with arbitrary heat generation. Initial strain and stress formulations are adopted and the theory is expressed using a few fundamental solutions. In this method, boundary elements and arbitrary internal points are used. The arbitrary distributions of the initial strain or stress for elastoplastic analysis are interpolated using boundary integral equations and internal points. This interpolation corresponds to a thin plate spline. In this method, strong singularities in the calculation of stresses at internal points become weak. A new computer program is developed and applied to several thermo-elastoplastic problems to clearly demonstrate the theory.

2. Theory

2.1. Heat conduction

Point and line heat sources can easily be treated by a conventional BEM. In this study, an arbitrarily distributed heat source $W^{[1]S}(q)$ is treated. In steady heat conduction problems, the temperature T under an arbitrarily distributed heat source

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