A parallel preconditioned Gauss-Seidel iterative method tailored for smoothed finite element method's solving

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Abstract

It is well known that solving the discretized algebraic system of equations is very time-consuming in smoothed finite element method (S-FEM), especially when the scale reaches as large as size of more than millions. We found that the system stiffness matrix of S-FEM is sparse symmetric positive definite; moreover, the distributions of nonzero elements are centered on the principal diagonal and form an inclined banded structure. Gauss-Seidel iterative method is in common use because of its simplicity and stability when solving the large scale system of linear equations. Hence, based on the feature of the similar structures and distributions of the ultimate system stiffness matrix, the paper presents a modified preconditioned Gauss-Seidel iterative method tailored for S-FEM and FEM, which could significantly improve the convergence rate of Gauss-Seidel iterative method. In addition, we design a highly efficient parallel computing algorithm based on the modified preconditioned Gauss-Seidel iterative method using MPI and OpenMP mode to optimize the performance of our model. The numerical experiments are conducted through six groups with different sizes to validate the wide usability and high efficiency of presented method. Particularly when solving the problem owning size of millions, the computing speed can be over one hundred times faster than that of original computing, that is, the original elapsed time occupying several hours has decreased to only a few seconds with a huge speedup.

Keywords: FEM, S-FEM, solving large scale system of linear equations, system stiffness matrix, modified preconditioned Gauss-Seidel iterative method, parallel computing.