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Parallelized multi-level reduction method for large-scale dynamic analysis and design optimization

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Optimization of large scale problem requires a great amount of computation time because the optimization procedure requires repeated computations for various design variables. Furthermore, the model size for CAE is getting larger and larger these days because CAD model for structures are in high resolution and include every details in the modelling. Therefore, high resolution FE model is also inevitable as long as we keep the original high resolution CAD model in the design procedure.

However, dynamic analysis for structural behaviour requires only lower or intermediate range of frequency analysis. Therefore, proper reduction techniques are required for routine computations and designs of one ~ several million degrees-of-freedom (DOF) problems.

For this purpose, a number of reduction methods have been developed. They are DOF-based condensation method, Modal reduction techniques, POD (Proper Orthogonal Decomposition) -based reduced order model. In the DOF-based or eigen mode-based reduction methods, stiffness and mass matrix are reduced and these reduced matrices are used for dynamic analysis.

Recently, while growth of CPU clock speed is marginal, the number of cores in CPU is sharply increased. Thus, parallel computing is widely used in various computational engineering and science fields. However, substructuring technique through parallel computations has not been popularly combined with reduction methods until recently. The previous reduction studies reported until now only solved small scale problems for the developed reduction methodologies which are not practical for the applications to large scale problems. Thus, the object of this study is to develop an appropriate reduction method combined with substructuring technique for parallel computing. The substructuring technique is an efficient method especially for design optimization when the reanalysis or changes of design variables are localized in some substructures. Many design problems are under these local conditions and thus reduction parallel algorithm combined with a substructuring technique is very effective for design optimization problems.

One of the key points of parallel computing technique is to minimize information exchange between workers (core or computer). To minimize the information exchange, the proposed method reduces stiffness and mass matrix in each sub-structure and only exchanges the information of reduced matrix as shown in Fig. 1.

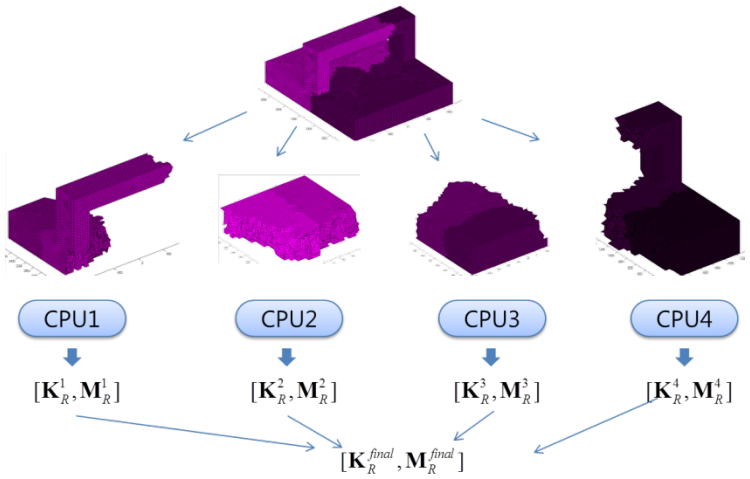

Fig .1 Reduction process using parallel computing

The proposed method reduces stiffness and mass matrix based on degree of freedom (DOF) [1, 2]. However, the sub-structuring based on DOF should include the interface nodes in each sub-structure. As the number of interface nodes increases, the size of reduced matrix increases. These increased interface nodes aggravate efficiency of the reduction method. To overcome the problem of a large number of interface nodes of reduced system, we device the hierarchical technique for reduction based on DOF. As shown in Fig. 2, previous interface nodes are eliminated in next level reduction process. Proposed method removes the extra transformation process to obtain displacements via the formulation of sub-structuring based on DOF and solve the interface problem existing in the DOF-based sub-structuring via the hierarchical sub-structuring technique. We expect that the proposed method is critical to the efficiency of the analysis and design optimization of large-scaled problems.

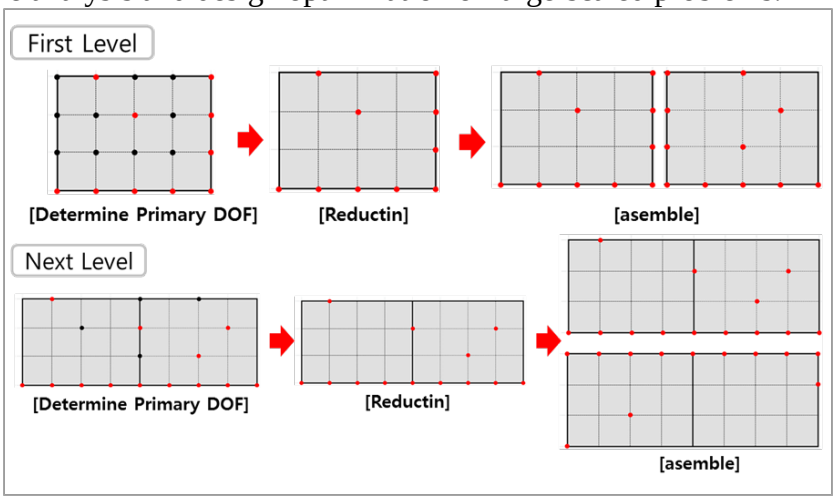

Fig. 2 Schematic figure of hierarchical reduction technique

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