11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

EFFICIENT STRUCTURAL OPTIMIZATION USING EQUIVALENT STATIC LOADS COMBINED WITH PARAMETERIZED FINITE ELEMENT APPROACH

Jaehun Lee[1], Euiyoung Kim[2] and Maenghyo Cho[3]

[1] Ph. D Candidate, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 151-742, Republic of Korea, spin9900@snu.ac.kr

[2] Ph. D Candidate, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 151-742, Republic of Korea, takeme04@snu.ac.kr

[3] Professor, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 151-742, Republic of Korea, mhcho@snu.ac.kr

Key Words: *Structural Optimization, Equivalent Static Loads, Proper Orthogonal Decomposition, Parameterized Finite Element Method.*

Introduction: Nowadays, due to the fast development of computational capabilities, it become possible to solve not only large scale structural static/dynamic problems which have millions of, even some cases, tens of millions of degrees of freedom, but also multi-physics problems which contains more than two physical fields, i.e., fluid-structure, acoustic-structure interactions and etc. However, a tremendous amount of computational time makes it almost impossible to deal with linear/non-linear dynamic transient analysis and structural optimization problem. To overcome the existing time-related computational limitations, especially in dynamic response optimization which requires a huge amount of time resources, equivalent static load (ESL) method was introduced [1]. ESL method considers the dynamic optimization problem as static optimization with multiple loads, resulting in a reduction of computational time and resources. Moreover, mathematical validation supports the accuracy and usefulness of the ESL method [2].

In the present study, a dynamic structural optimization based on the ESL method is performed combined with a parameterized finite element method [3]. The parametric finite element method constructs global system matrices in terms of parameter-dependent and parameter-independent parts using an affine decomposition. Due to the easiness of decomposing thickness parameters from the system matrix during the finite element formulation, parameterized finite element model is a powerful approach for the structural size optimization. Thus, we combine the ESL method with parameterized finite element model for the dynamic response optimization.

Methodology: For the structural size optimization problem, design variables (parameters) are explicitly decomposed during the system matrix (stiffness and mass) calculation and assembling process. The parameterized system matrix are used in the process of ESL calculation. Thus, one can maximize the computational efficiency since the system matrix which have to be reconstructed as the design variables change need not be regenerated, but the system matrix can be simply expressed as a linear combination of the design variables and parameter independent matrices. Moreover the system matrices can be reduced in the

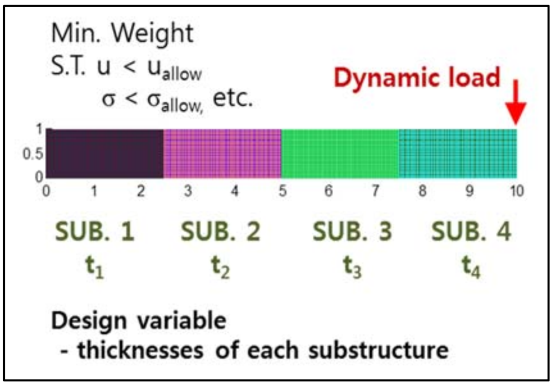

Fig. 1 Size optimization of clamped beam structure – 4-node bilinear plane stress element

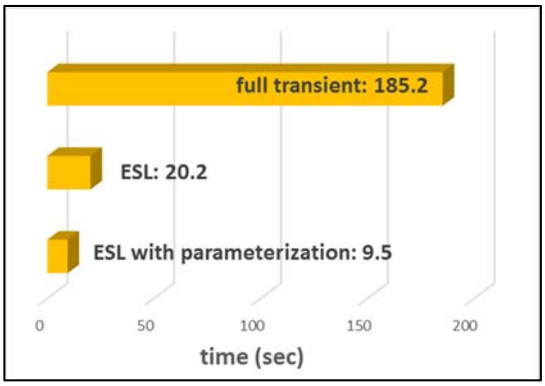

Fig. 2 Computational time – Full transient, ESL method and ESL with parameterized FE model

parametric space [4]. By changing the parameters in design domain, snapshot data are generated from the static and dynamic responses of the structure. Basis of the reduced system are obtained by applying proper orthogonal decomposition (POD) to the snapshots. Finally, Galerkin projection of the original full system to the POD-basis makes a reduced system which have much smaller degrees of freedom compared to the full system. Nevertheless, since the basis of reduced system include the change of parameters, size optimization of full system and the reduced system gives almost the same results. Fig. 1 shows simple example of dynamic size optimization. As shown in Fig. 2, ESL with parameterization is very efficient compared to the other methods.

Conclusion: In this study, we proposed an efficient structural optimization technique based on an equivalent static load method. The main idea of present study is combining the ESL method with a parameterized finite element model to reduce computational resources in dynamic response optimization. In addition, by applying reduced basis technique to the parameterized finite element model, one can obtain the reduced system matrices which extremely reduces the optimization time maintaining the accuracy of results. Since the proposed method can accurately and efficiently optimize the dynamic response of complex structures, large-scaled structural dynamic problems should be considered to validate the present optimization technique.

REFERENCES

[1] W. S. Choi and G. J. Park, Structural optimization using equivalent static loads at all time intervals. *Comput. Method Appl. M.*, Vol. **191**, pp. 2105–2122, 2002.

[2] G. J. Park and B. S. Kang, Validation of a structural optimization algorithm transforming dynamic loads into equivalent static loads. *J. Optimiz. Theory App.*, Vol. **118**, pp. 191–200, 2003.

[3] E. Balmes, Parametric families of reduced finite element models. Theory and applications, *Mech. Syst. Signal Proc.*, Vol. **10**, pp. 381–394, 1996.

[4] A. K. Noor and J. M. Peters, Reduced-basis technique for nonlinear analysis of structures. *AIAA J.*, Vol. **18**, pp. 455–462, 1980.