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

HIGH PERFORMANCE ALGORITHMS FOR THE MODAL LINEAR DYNAMIC ANALYSIS IN THE FREQUENCY DOMAIN

Mikhail Belyi[1]

[1] Dassault Systemés SIMULIA Corp., 166 Valley Street, Providence , RI 02909-2499, USA, Mikhail.Belyi@3ds.com

Key Words: *Linear Dynamics, Modal Analysis, Frequency Response, Performance.*

This paper will discuss high performance parallel algorithms used in Abaqus for solving large scale linear dynamic problems.

Abaqus has historically provided leading technology in nonlinear finite element analysis. In the last decade, SIMULIA has invested significant resources to deliver efficient linear dynamics functionality that meets our customers' current and future needs in terms of model sizes (total number of degrees of freedom), modal content, response domain (number of points in the frequency or time domain), and performance. Scalable linear dynamics solvers implemented in Abaqus enable effective large-scale linear dynamic simulations for example, automotive Noise and Vibration analysis in the so-called, “mid-frequency” range using traditional finite element approach.

In this paper we will discuss high performance parallel algorithms used in Abaqus for solving large scale linear dynamic problems in the frequency domain. We consider scalable shared memory parallel algorithms for modal frequency response analysis. Also, we discuss high performance modal dynamic computations on graphic processors (GPGPU).

Frequency response analysis is used to calculate response to steady-state time-harmonic excitation of engineering systems. The frequency response of the finite element model is obtained by solving the systems of complex linear algebraic equations at many excitation frequencies. In many engineering applications these systems may have millions of equations and can be solved at thousands of frequencies. Direct or iterative solution of the system of equations at each frequency is not usually feasible because of the computational cost. The modal approximation is a well-established method which is commonly used to reduce the cost of solving linear dynamic problems. The modal frequency response is obtained by solving the system of equations that is much smaller than the original one. However, in practical engineering simulations it can have thousands or tens of thousands of complex linear equations. Thus, solving for many excitation frequencies still can be costly. Performance of the modal frequency response calculation can be improved by taking into account various special cases of the matrix structure [1]. In some automotive dynamic simulations the global damping matrices may be of relatively low rank. For such cases the transformation of the modal frequency response problem to an equation with a “diagonal plus low rank” matrix can be used to significantly reduce the computational cost of the solution [2].

We will discuss an advanced high performance method for solving the modal frequency response problem based on the following idea [3]. The set of excitation frequencies is partitioned into smaller portions. Speedup of the frequency response calculation is achieved by processing equations at all frequencies within a portion together. The method allows calculating solutions at all frequencies within the portion using a single matrix factorization and a limited number of other lower order matrix operations. Effective implementation of this method requires some preparatory calculations to be performed and some data to be stored prior to computing the frequency response for groups of frequencies.

Performance and scalability of the new method will be illustrated with examples of the large scale linear dynamic analyses.

REFERENCES

[1] M.Belyi, V.Belsky, A.Bajer, M.Kim, C.Ianculescu, Advanced linear dynamics and substructuring capabilities in Abaqus with applications in noise and vibration analysis. Proceedings of ISMA2012, Leuven, Belgium, 2012.

[2] J.K.Bennighof, Damped Frequency Response Apparatus, Systems, and Methods, US Patent No.: US 7,188,039, March 6, 2007.

[3] M.Belyi, Accelerated Modal Frequency Response Calculation, U.S. Patent Application No. 13/730,403 filed on December 28, 2012