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# USING HIGH-PERFORMANCE COMPUTING FOR ACCELERATING LINEAR DYNAMIC AND NONLINEAR IMPLICIT COMMERCIAL FEA SOFTWARE

**Vladimir Belsky[1]**

[1] Dassault Systèmes Simulia Corp., Rising Sun Mills, 166 Valley Street, Providence, RI 02909, vladimir.belsky@3ds.com

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In the last decade, significant R&D resources have been invested to deliver commercially available technologies that meet current and future mechanical engineering industry requirements, both in terms of advanced mechanics and performance. While significant focus has been given to developing robust nonlinear finite element analysis technology, there has also been continued investment in developing advancements for efficient large scale linear dynamic analyses. The research and development efforts have focused on combining advanced linear and nonlinear technology to provide accurate, yet fast modelling of noise and vibration engineering problems. This effort has enabled high-fidelity models to run in a reasonable time which is vital for virtual prototyping within shortened product design cycles.

While it is very true that model sizes (degrees of freedom) have grown significantly during this period, the complexity of the models has also increased, which has led to a larger number of total iterations within nonlinear implicit analyses, and to a large number of eigenmodes used within linear dynamic simulations. An innovative approach has been developed to leverage high-performance computing (HPC) resources to yield reasonable turn-around times for such analyses by taking advantage of massive parallelism without sacrificing any mechanical formulation quality.

The accessibility and affordability of HPC hardware in the past several years has significantly changed the landscape of commercial finite element analysis software usage and applications. This change has come in response to an expressed desire from engineers and designers to run their existing simulations faster, or in many cases to run much more realistic jobs. Due to their computational cost and lack of high-performance commercial software, such "high-end" simulations were until recently thought to be only available to academic institutions or government research laboratories which typically developed their own HPC applications. Today, with the advent of affordable multi-core symmetric multiprocessing (SMP) workstations and compute clusters with highly efficient multi-core nodes and high-speed interconnects, equipped with general-purpose computing on graphics processing units (GPGPU) accelerators, HPC is sought after by many engineers for routine FEA. This presents a challenge for commercial FEA software vendors which have to adapt their decades old legacy code to take advantage of state-of-the-art HPC platforms.

Given this background, this paper focuses on how recent developments in HPC have affected the performance of advanced linear dynamic simulations, substructuring techniques (or Component Mode Synthesis), and implicit nonlinear analyses. Three main HPC developments are studied. First, we look into the performance and scalability of Abaqus AMS eigenvalue extraction solver, and its application for large AMS-based substructure generations running on multi-core SMP workstations. We will compare the efficiency of this technology with the conventional substructure generation procedures available in Abaqus for many years.

Next, we will discuss the progress made in relatively new, but very active area of high performance commercial FE software development, which is based on taking advantage of high performance GPGPU accelerators. Efficient adoption of GPGPU in such products is a very challenging task which requires significant re-architecture of the existent code. We describe the experience in integrating GPGPU acceleration into complex commercial engineering software. In particular we discuss the effect of GPGPU acceleration of the direct sparse solver factorization procedure.

Finally, we will compare applicability of the direct and iterative equation solver technology for large sparse systems of linear equation arising from FE discretization of structural mechanical problems using implicit time integration approach.