Introducing the Supernode Eigensolver

A new eigensolver in ANSYS 12.0 determines large numbers of natural frequency modes more quickly and efficiently than conventional methods.

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In a wide range of applications, parts are subject to cyclic mechanical loading, and engineers must use an eigensolver to determine the structure's natural frequencies — also known as eigen modes. With some modes, large vibration amplitudes can interfere with product performance and cause damage, such as fatigue cracking. In most cases, only the first few modes with the largest deformations are of particular interest, though determining even dozens of modes can be common.

In the CAE industry, the block Lanczos eigensolver is typically used more than any other for these types of calculations. This proven algorithm has been used in many finite element software packages, including ANSYS Mechanical technology. It brings together the efficiency and accuracy of the Lanczos algorithm and the robustness of a sparse direct equation solver. The software works in a sequential fashion by computing one mode (or a block of modes) at a time until all desired modes have been computed.

Although the method is considered efficient in solving for each of these eigen modes, the amount of time and computer resources (both memory and I/O) required adds up when many dozens of eigen modes must be found. Elapsed solution times of several hours — or days — are typical in applications that involve thousands of modes. Generally, determining large numbers of modes is required in capturing system response for studies such as transient or harmonic analyses using the mode superposition method.

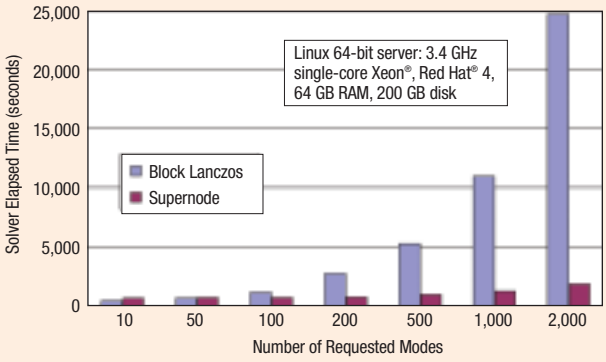
The ANSYS supernode eigensolver is well suited for applications such as seismic analysis of power plant cooling towers, skyscrapers and other structures in which hundreds of modes must be extracted to determine the response of the structures to multiple short-duration transient shock/impact loadings.

For such cases, the ANSYS release 12.0 includes a new supernode eigensolver. Instead of computing each mode individually and working with mode shapes in the global model space, the supernode algorithm uses a mathematical approach based on substructuring to simultaneously determine all modes within a given frequency range and to manage data in a reduced model space.

By utilizing fewer resources than block Lanczos, this supernode eigensolver becomes an ideal choice when solving on a desktop computer, which can have limited memory and relatively slow I/O performance. When combined with current eigensolver technology already available in mechanical software from ANSYS, virtually all modal analyses can be efficiently solved.

Comparing Eigensolvers

A sample comparison shows that the supernode eigensolver offers no significant performance advantage over block Lanczos for a low number of modes. In fact, supernode is slower when 50 or fewer modes are requested. However, when more than 200 modes are requested, the supernode eigensolver is significantly faster than block Lanczos — with efficiency increasing considerably as the number rises.



Performance of block Lanczos and supernode eigensolvers at 1 million DOF

Using Supernode Eigensolver

The supernode eigensolver can be selected in the ANSYS Mechanical traditional interface using the SNODE label with the MODOPT command or via the Analysis Options dialog box. ANSYS Workbench users can choose this eigensolver by adding a command snippet that includes the MODOPT,SNODE command.

The MODOPT command allows users to specify the number of natural frequencies and what range those frequencies lie within. With other eigensolvers, the number of requested modes primarily affects solver performance, while the frequency range is, essentially, optional. Asking for more modes increases solution time, while the frequency range generally decides which computed modes are computed.

The supernode eigensolver behaves completely opposite: It computes all modes within the specified frequency range regardless of how many modes are requested. Therefore, for maximum efficiency, users should input a range that covers only the spectrum of frequencies between the first and last mode of interest. The number of modes requested on the MODOPT command then decides how many of the computed frequencies are provided by the software.

Today, with the prevalence of multi-core processors, the first release of this new eigensolver will support shared-memory parallelism. For users who want full control of the solver, a new SNOPTION command allows control over several important parameters that affect accuracy and efficiency.

Controlling Parameters

The supernode eigensolver does not compute exact eigenvalues. Typically, this is not an issue, since the lowest modes in the system (often used to compute the dominant resonant frequencies) are computed very accurately — generally within less than 1 percent compared to using block Lanczos. Accuracy drifts somewhat with higher modes, however, in which computed values may be off by as much as a few percent compared with Lanczos. In these cases, the accuracy of the solver may be tightened using the range factor (RangeFact) field on the SNOPTION command. Higher values of RangeFact lead to more accurate solutions at the cost of extra computations that somewhat slow down eigensolver performance.

When computing the final mode shapes, the supernode eigensolver often does the bulk of I/O transfer to and from disk, and the amount of I/O transfer is often significantly less than a similar run using block Lanczos. To maximize supernode solver efficiency, I/O can be further minimized using the block size (BlockSize) field on the SNOPTION command. Larger values of block size will reduce the amount of I/O transfer by holding more data in memory during the eigenvalue/eigenvector output phase, which generally speeds up the overall solution time. However, this is recommended only if there is enough physical memory to do so.

Application Guidelines

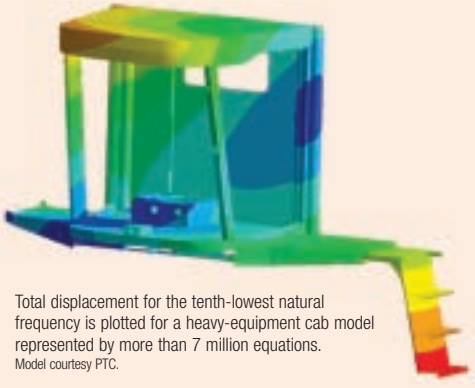
The following general guidelines can be used in determining when to use the supernode eigensolver, which is typically most efficient when the following three conditions are met:

- The model would be a good candidate for using the sparse solver in a similar static or full transient analysis (that is, dominated with beam/shell elements or having thin structure).
- The number of requested modes is greater than 200.
- The beginning frequency input on the MODOPT command is zero (or near zero).

For models that have dominantly solid elements or bulky geometry, the supernode eigensolver can be more efficient than other eigensolvers, but it may require higher numbers of modes to consider it the best choice. Also, other factors such as computing hardware can affect the decision. For example, on machines with slow I/O performance, the supernode eigensolver may be the better choice, even when solving for less than 200 modes. ■

Examining Real-World Performance

A heavy-equipment cab model with over 7 million equations was used to demonstrate the power of the supernode eigensolver. This model was solved using a single core on a machine with the Windows® 64-bit operating system with 32 gigabytes of RAM. Time spent computing 300 modes with block Lanczos was about 31.8 hours. The solution time dropped to 15.7 hours (a two-times speedup) using the supernode eigensolver. The model illustrates real-world performance for a bulkier model with only 300 modes requested. For modal analyses in which hundreds or thousands of modes are requested, users often see a speedup of 10 times or more with the supernode eigensolver compared with block Lanczos. In one recent project, a major industrial equipment manufacturer reduced analysis run time from 1.5 hours to just 10 minutes by switching from block Lanczos to supernode eigensolver.



Total displacement for the tenth-lowest natural frequency is plotted for a heavy-equipment cab model represented by more than 7 million equations.
Model courtesy PTC.