What’s **Shakin’?**

The combination of 3-D structural dynamics, ANSYS Workbench and classical rotordynamics modeling techniques helps solve rotating machinery vibration problems.

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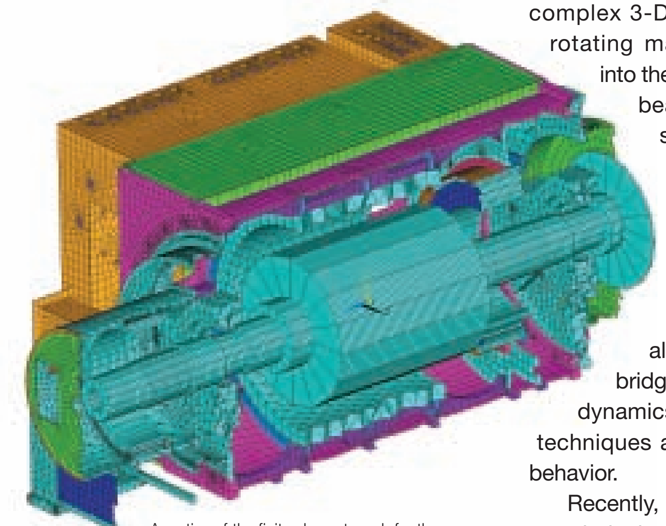


A portion of the finite element mesh for the shaft of a motor–generator

In the electric power generation industry, the ability to design and produce reliable and long-lasting rotating machines is, in part, dependent on the ability to control machinery vibration. Due to the dynamics of rotating machinery parts, mechanical vibration can’t be eliminated completely, but designing machines that meet industry standards for acceptable vibration levels is a crucial part of the product design process. Kato Engineering has been in the business of designing such machines since the 1920s.

Kato Engineering uses 3-D structural modeling tools from ANSYS to increase their ability to simulate and predict machine vibration. Classic rotordynamics modeling techniques involving spreadsheet-style programs with axisymmetric beam element solutions have been around for many years and are very useful tools. However, there are times when the complex 3-D structural details of a rotating machine cannot be cast into the form of an axisymmetric beam element model with sufficient accuracy. For critical applications and new designs in which vibration prediction is of the utmost importance, simulation using software from ANSYS allows Kato Engineering to bridge the gap between rotordynamics spreadsheet modeling techniques and real-world vibration behavior.

Recently, Kato engineers inherited a relatively large common shaft motor–generator design with unfavorable vibration performance. Their task was to modify the design, making it more reliable and easier to produce. This included improving the vibration characteristics of the machine.

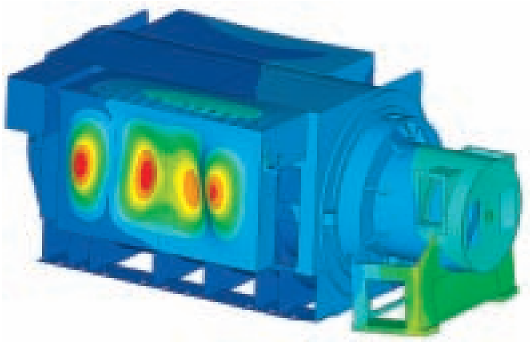
In order to tackle this type of problem using structural software tools from ANSYS, the engineers at Kato performed frequency sweep harmonic response analyses using a mixed-element modeling technique. This method combines the efficiency of beam element models — for the rotating portion of the machine — with more structurally complex 3-D shell and solid elements that represent the surrounding stationary structures. These surrounding structures include the machine frame, mounting structure, foundation and other components.

The simulation results provided structural vibration displacements and phase angles at each node of the model for all of the frequencies considered. Using the time–history post-processor, the team at Kato took data from nodes in the model where sensors would be installed during real-world vibration tests of the equipment and examined the predicted magnitude of the vibration response versus frequency. Later, the engineering team compared the simulation results with machine vibration Bode plots obtained during vibration testing of the production equipment.

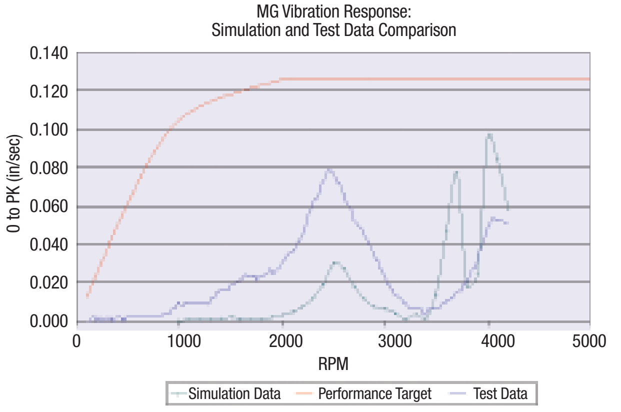
An important portion of the rotordynamic analyses focused on the bearing connections between rotating and stationary structures. Through the use of ANSYS Parametric Design Language (APDL) and MATRIX27 elements in software from ANSYS, the engineering team allowed for the inclusion of complex bearing stiffness and damping phenomena in the simulation model. They were able to include the bearing stiffness and damping characteristics, as a function of rotational speed as well as all of the cross-coupled stiffness and damping terms that are important in the simulation of the bearing behavior. While these types of bearing behaviors have long been a part of spreadsheet-style rotordynamics programs, the Kato team was now able to efficiently incorporate these behaviors into 3-D full-model vibration simulations using the flexible APDL structure and data input–output options. Speed-dependent bearing stiffness and damping coefficients — calculated using dedicated bearing performance software — were curve-fit and programmed into the structural model using an APDL routine.

The ANSYS Workbench framework has been a very powerful tool for Kato Engineering with regard to simulation model construction time. Using the ANSYS Workbench environment, the team was able to make the transition more quickly from CAD geometry to complex finite element meshes. Where 3-D structural model creation for a machine previously may have taken a week, it was now taking only a day or two with the enhanced geometry and meshing capabilities of ANSYS Workbench.

For this particular application, the Kato engineering team was able to predict the steady-state vibration response of the redesigned machine to a reasonable degree of accuracy using structural simulation tools. While the modeling technique relied on the placement of rotor imbalance forces, which were somewhat nebulous in reality, the team was able to get good correlation between simulation and test results using reasonable assumptions for expected magnitudes and locations of rotor imbalance. By iterating with the simulation model during the design phase, Kato engineers were able to determine that, if they control the imbalance of the rotor to a certain degree and at certain locations, they can expect to meet targets in terms of machine vibrations. The improved steady-state vibration performance of the redesigned machine provided a significant boost for customer confidence in Kato Engineering's capability to produce a reliable product. ■



Contour plot of vibration displacement for the whole assembly at a particular forcing frequency



Comparison of simulation and test data at one of the vibration sensor locations, indicating trends