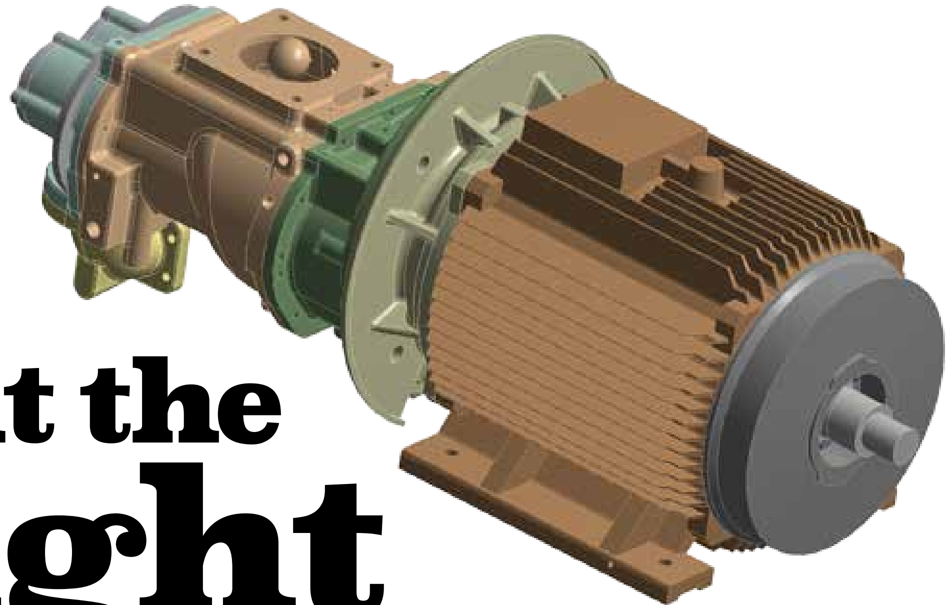


Put the Right Spin On It

Vibration can degrade the reliability of rotary air compressors. Ingersoll Rand engineers implemented rotordynamic simulation to predict vibration problems in the concept design phase so that they can be corrected before building prototypes. Ingersoll Rand has reduced prototyping costs and generated additional revenues by bringing products to market earlier.

By **Yi Liu**, Engineering Manager, Ingersoll Rand, Charlotte, USA

Control of potential vibration effects plays a critical role in the design of rotary air compressors. The traditional process of building and testing prototypes, and then performing redesign to reduce vibration, consumes manpower, budget and time. Every month of delay in getting a new product to market represents a significant revenue loss. With internal engineering resources stretched to the limit, Ingersoll Rand engaged ANSYS Customer Excellence (ACE) consultants to validate 3-D rotordynamic analysis of rotating and stationary components on a compressor design. This vibration problem had previously been solved only by painstaking trial and error. Without knowing details of the problems with the previous design, the consulting team used simulation to help predict the housing vibration caused by connection between the rotors and housing assembly. The team then trained Ingersoll Rand engineers, who simulated six additional design iterations and developed a solution to the problem in much less time than had been required to solve the problem previously. Ingersoll Rand has since saved hundreds of thousands of dollars in product development costs by using rotordynamic simulation upfront in the development process to identify and solve vibration problems on digital prototypes.

^ Ingersoll Rand rotary air compressor

Product Development Challenges

Ingersoll Rand rotary air compressors are used in mission-critical applications in many industries. To ensure product reliability, the company sets strict limits on vibration of rotating and stationary assemblies. The most common source of a vibration problem is a component that resonates at a potential operating frequency of the compressor. Because a typical rotary compressor has hundreds of components, even after a vibration problem has been identified with physical testing, it is often very difficult to determine which component is responsible for the issue. One approach is to hammer the component and measure its resonant frequencies. But connecting components often affects resonant frequencies. In addition, many components connect with others in ways that make it impossible to test them in an operational configuration. For example, components may connect deep inside a housing where they cannot be reached with a hammer-impact test, which is a physical test to determine the natural frequencies, modal damping or mode shapes of a structure. The rotational aspects often bring in other considerations, like speed-dependent dynamic bearing coefficients and gyroscopic effects of rotating masses.

Ingersoll Rand engineers tried using a one-dimensional rotordynamic model that relies on mass spring damper 1-D elements, but found that it could predict vibration of rotating but not stationary components. The engineers believed that 3-D simulation could solve the vibration issue, but to try to apply this new approach and gain the required insight would affect the design schedule. Ingersoll Rand engaged ACE consultants to validate the ability of 3-D rotordynamic analysis to locate the vibration problem and determine a solution. ANSYS rotordynamic software can account for all of the physics involved in rotating assemblies in a single analysis, so it can solve problems with a minimum of assumptions and provide answers that may not have been considered before. ANSYS software leverages robust 3-D analysis methods to couple the rotating elements to a full 3-D representation of the support structure, offering a more detailed result of the overall structural response.

ANSYS Team Applies Rotordynamic Analysis

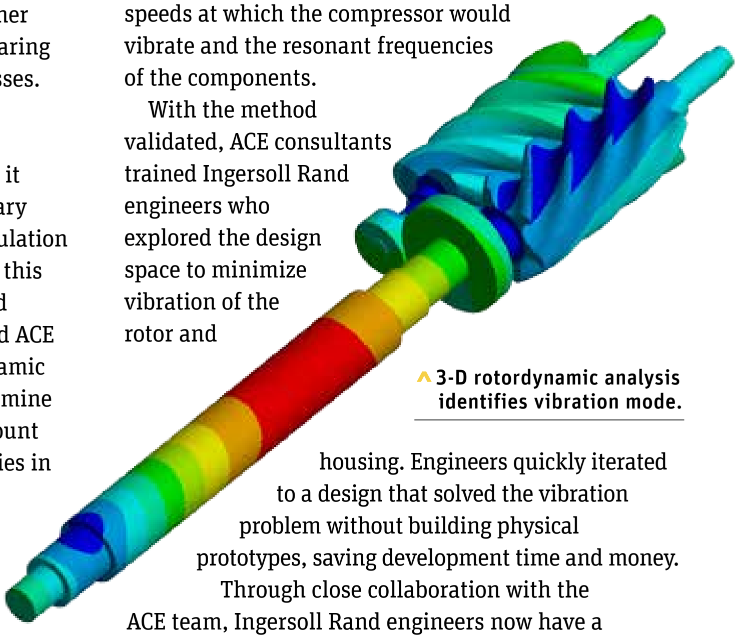
The ACE team integrated characteristic rotordynamic features such as gyroscopic effects and bearing support flexibility into an ANSYS Mechanical finite-element model of the rotating and stationary components of a design with a known vibration problem. The team modeled the rotating parts, stationary parts and bearings linking the rotating parts to the stationary parts. For the rotating parts, ANSYS staff selected elements that support gyroscopic effects while modeling the stationary parts with normal 3-D solid, shell and beam elements.

They defined material properties just as they would for any other analysis and designated the rotational velocity. Engineers accounted for the gyroscopic effect in rotating parts and the rotating damping effects. The consultants performed modal analysis to review the stability of the design and obtained critical speeds from Campbell diagrams. ACE team engineers leveraged harmonic analysis to calculate the response of the compressor to synchronous or asynchronous excitations and proposed using transient analysis to determine what happened when the compressor started and stopped.

Transferring Simulation Knowledge to Ingersoll Rand

The results predicted that the design would have a vibration problem that closely matched the magnitude and frequency of the vibration that had earlier been detected during physical testing. The rotordynamic simulation provided much more information than physical testing, including identifying the critical speeds at which the compressor would vibrate and the resonant frequencies of the components.

With the method validated, ACE consultants trained Ingersoll Rand engineers who explored the design space to minimize vibration of the rotor and housing. Engineers quickly iterated to a design that solved the vibration problem without building physical prototypes, saving development time and money.



^ 3-D rotordynamic analysis identifies vibration mode.

Through close collaboration with the ACE team, Ingersoll Rand engineers now have a streamlined process to expertly and independently leverage simulation to design six additional variants of the compressor. Ingersoll Rand engineers now use rotordynamic simulation to develop new compressor designs on a regular basis with a 50 percent to 70 percent reduction in the need to build physical prototypes for testing. The use of ANSYS simulation-based design has greatly reduced scheduling delays in delivering new products, resulting in a substantial increase in revenues. ∧

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