NASA Studies Improved Engine Performance with New Rotor Dynamics Code

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Customer:
NASA Glenn Research Center
www.grc.nasa.gov

Software:
MSC.Nastran™,
MSC.Nastran Rotor Dynamics

Summary:
NASA Glenn Research Center is using the new Rotor Dynamics capability in MSC.Nastran 2004 for engine performance analysis. MSC.Nastran Rotor Dynamics provides a standard rotor dynamics code, enabling much faster transfer of data and models, and a more streamlined capability for rotor dynamic analysis. With MSC. Nastran Rotor Dynamics, NASA Glenn engineers can calculate maneuver loads for microgravity experiments and perform blade-out analysis, ensuring that the physical test is passed the first time, saving millions of dollars.

Testing rotor dynamics is a critical function for ensuring safety, as well as cost and time-to-market reductions for builders of aerospace engines and turbines, air frame manufacturers and NASA, which collaborates with them. Until recently, software codes for simulating rotor dynamics - a necessity because of the tremendously high cost of physical tests - have been largely home-grown. This has created an environment that slows the transfer of simulation data and models between customers and vendors. However, the new Rotor Dynamics capability in MSC.Nastran 2004 enables analysis of engine performance and transient blade-off events, allows much faster transfer of data and models, and creates a more streamlined capability for rotor dynamic analysis.

"Because a comprehensive rotor dynamics code with the ability to analyze large models doesn't exist, a lot of time has been spent developing patches for MSC.Nastran and home-grown code," says Dr. Charles Lawrence, structural engineer, Structures and Acoustics Division, Glenn Research Center at Lewis Field, NASA. "With every new release of MSC.Nastran, each company has to update its patches. Because each company's data is in a different format, it has to be manipulated, causing delays in getting the component information and models to airframe manufacturers waiting to integrate them into an airframe model. With MSC.Nastran providing a common rotor dynamics code, everybody can use the same models so sharing data will be much faster and easier. The new code should help to take some of the pressure off of the people responsible for performing the analysis and exchanging models."

MSC.Nastran Rotor Dynamics supports modal analysis of critical speeds, whirl, forced response (unbalance and cabin noise), damping and static analysis (external loads and maneuver loads), transient analysis of blade-off events, and structural response due to windmilling. Dr. Lawrence explains, "We've done extensive textbook-type test cases with the Rotor Dynamics code to verify the theory. Here at Glenn Research Center, we have a large program for microgravity experiments. One of the places we're going to find this new code very useful is simulating the structural response of these experiments when they are flying either on the Shuttle or flying in the KC135 going through microgravity maneuvers. We can calculate the maneuver loads using MSC.Nastran to make sure the experiment is going to be structurally safe."

MSC Software

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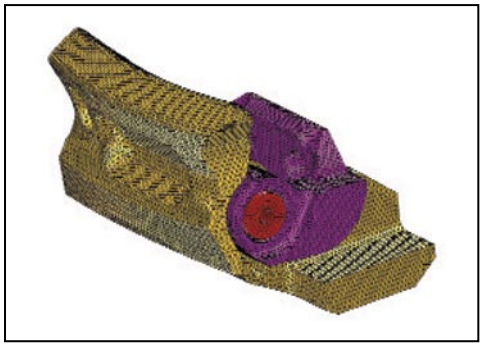

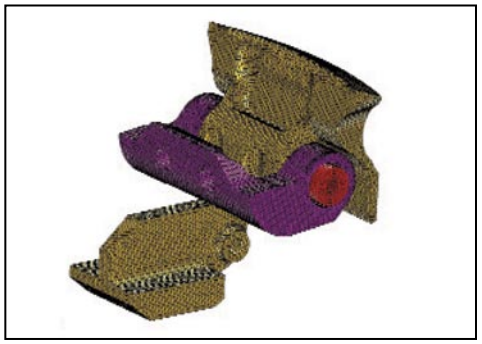

Many of NASA's microgravity experiments involve the study of some kind of fluid physics. One of these experiments, "Coalescence Inhibition of Bubbly Suspensions," involved determining the structural loads on the experiment support rack. The purpose of the experiment was to study how bubbles disperse in a fluid under different flow conditions. The fluid had to be spun in a rotating chamber to generate shear forces in the fluid, while the experiment flew on the KC-135 aircraft. Dr. Lawrence says, "I had to do hand calculations to determine the loads resulting from the experiment undergoing maneuver loads from the aircraft as it traveled through its parabolic trajectories while the experiment itself was rotating. The new version of MSC.Nastran with Rotor Dynamics could have easily calculated these loads and will be used in the future for these kinds of applications."

Another area in which NASA collaborates with engine companies is developing improved simulation tools for engine containment and blade-out simulations (a blade-out test is required for FAA certification). One aspect of the analysis is to make sure parts of the fan blade don't penetrate the engine case. Another is to ensure that the large unbalance forces resulting from the blade-out do not result in damaging forces transmitted through the engine and to the aircraft. This type of analysis requires very large and complicated models, and the only code that can accommodate them is MSC.Nastran. Because this is a pass/fail test, if the test is failed, the hardware has to be built again andthe test repeated - a very expensive and time-consuming process."A blade-out analysis determines what happens when a blade is released in the engine," explains Dr. Lawrence. "There aren't any codes out there that can do this type of complete engine-aircraft simulation with the fidelity required by the engineers. MSC.Nastran is now able to do that and do a very good job of it. The physical test normally costs 10 million dollars to run. You don't want to have to repeat the test. The new Rotor Dynamics code allows us to run the test in a virtual environment and ensure the physical test is passed the first time."

In a Virtual Product Development environment, a blade-out test can be run every 10-15 degrees around the circumference to make sure that no matter at what angle the blade is lost, the engine and airframe will remain safe and not overstress. Another issue is the complexity of a real blade-out event. Most codes allow a single unbalanced mass to simulate the effect of a lost blade. But in a real engine, it is more complicated. Initially only a piece of a blade may be released. After a short period of time, additional pieces are lost and then pieces start breaking off from adjacent blades. The pattern of blade loss is much more complicated than just a single unbalanced mass. While all this is happening, the rotor speed may also be changing since, the engine may be shutting down.

"MSC.Nastran has incorporated these modeling capabilities into the code, so you can actually simulate a complicated blade loss pattern and non-constant rotor speeds," notes Dr. Lawrence. "Anothe area we are working on is using magnetic bearings to replace conventional bearings in aircraft engines and turbo machinery to help attenuate the loads that occur during a blade-out event. We're building test rigs to validate these ideas: however, ultimately we'll want to test these ideas in an actual aircraft environment. We think MSC.Nastran will be useful in allowing us to perform these assessments."

Magnetic bearings are "active," allowing their stiffness and damping to be adjusted on the fly, which helps compensate for the loadings that result from blade-out events. Until now, engineers, for the most part, have worked with ground-based test rigs and relatively simple rotor-dynamic, magnetic-bearing models. Dr. Lawrence states, "With MSC. Nastran Rotor Dynamics capabilities, magnetic bearings can be ,incorporated into full-featured, complex engine-aircraft simulation models. Using these simulations, the performance of magnetic bearings can be assessed under realistic aircraft operating conditions." The benefits of MSC.Nastran Rotor Dynamics include improved product quality and weight reduction. Because the new code is faster, easier, and more reliable, it can help improve quality. It will allow engineers to run more design iterations, ensuring weight reduction. It will also allow reduced design cycle and testing time, or allow engineers to do more design iterations. In either case, costs will be reduced.

"When you look at the requirements, there are no other codes in the world that can do this combination of analysis," says Dr. Lawrence. "These models are incredibly large - millions of degrees of freedom. It was totally impractical and impossible to do these kinds of analysis on models this large. Some kind of model reduction method was needed. MSC.Nastran is the only code that can take these large models and reduce them to a smaller model and still produce accurate results. This code is what the companies are using and will use in the future to help design the engine aircraft systems. We think this code is going to be a way for them to do the designs faster and come up with better answers. This will lead to better and lighter structural designs for aircraft."

Corporate
MSC.Software Corporation
2 MacArthur Place
Santa Ana, California 92707
Telephone 714 540 8900

www.mscsoftware.com

Europe, Middle East, Africa
MSC.Software GmbH
Am Moosfeld 13
81829 Munich, Germany
Telephone 49 89 431 98 70

Asia-Pacific
MSC.Software Japan LTD.
Shinjuku First West 8F
23-7 Nishi Shinjuku
1-Chome, Shinjuku-Ku
Tokyo, Japan 160-0023
Telephone 81 3 6911 1200