Aerospace Systems

Engineering simulation is an integral part of the development process for critical components and major subsystems on today’s aircraft from nose to tail.

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Companies are under intense technical and business pressures in the aerospace industry, a giant market with annual worldwide revenues exceeding $250 billion. Manufacturers in commercial and military sectors are experiencing unprecedented global competition to shorten time-to-market and reduce costs while improving aircraft performance, increasing fuel efficiency, reducing noise and decreasing pollutant emissions.

F-16

Used in air defense around the world for decades, the versatile F-16 fighter aircraft continues to be updated with the help of engineering analysis.

In meeting technical and business requirements, aerospace engineers face some of the most demanding design challenges in engineering. Because of weight and space limitations, components often have highly complex shapes and are made of nontraditional materials. Parts must withstand extreme vibration, high acceleration loads and wide temperature fluctuations. Reliability standards and safety compliance regulations are some of the most stringent of any industry.

For decades, engineering simulation technology has been indispensable in addressing these complex issues in aircraft development. The aerospace industry was one of the first to implement computer-based approaches to design and analysis, and today simulation-based processes represent an integral part of the development cycle for critical components and major subsystems throughout the aircraft.

Simulation Tools for Complex Problems

Engineers use a wide range of simulation tools to refine concepts, pinpoint problems, evaluate alternatives and optimize designs long before the first hardware prototype is built and test pilots slide into the cockpit.

In the aerospace industry, engineers routinely use finite element analysis (FEA) to study stresses or fatigue in structural members. Explicit solvers analyze impacts and large deformations. Computational fluid dynamics (CFD) analyzes external aerodynamics, cabin HVAC and flow through engines. Advanced flow problems could include heat transfer, shockwaves, separation, combustion, chemical reaction or acoustics issues. Computational electromagnetics (CEM) predicts electromagnetic properties such as radar signature for military aircraft. Two-way fluid structure interaction (FSI) solves aerospace problems such as wing flutter.

A wide range of some of the most advanced solutions for analysis technologies such as FEA, CFD, EMAG and FSI is provided by ANSYS, Inc. — a leader in engineering simulation. Such single-vendor solutions avoid the problems of using different tools from multiple suppliers including lack of compatibility and difficulties exchanging files between systems. One unified simulation system facilitates the overall flow of design, cooperation between groups and interaction between separately analyzed physics and components. This enables companies to streamline their product development processes while reducing the number of vendors — two major goals for aerospace companies.

ANSYS has formed strong partnerships with aerospace R&D groups as well as with other software vendors. For instance, through cooperation with Dassault Systèmes, ANSYS ICEM CFD hexa meshing tools are now available within CATIA® V5. ANSYS Workbench software also has advanced geometry and meshing tools needed for complex real-world aerospace geometry. Design optimization and vertical applications specifically tailored to segments within each industry round out the tool kit.

Reducing the Need for Wind Tunnel Testing

When CFD is applied during the conceptual and preliminary design stages, it is possible to simulate complete design configurations in a short time so the analysis can have a significant impact on aircraft development, and then move forward with the best combination of design features to meet required flight characteristics.

Traditionally, CFD has been used extensively for predicting the aerodynamic behavior of aircraft. The technology is a valuable tool for engineers to gain insight into the way air flows over the complex contour of the plane.

F-35 Joint Strike Fighter

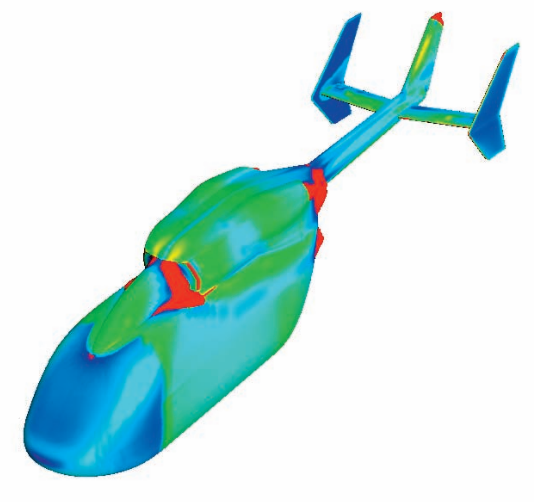
Simulation is being used extensively in development of the new F-35 Joint Strike Fighter. Versions of the supersonic plane are being developed for the U.S. Air Force, Navy and Marine Corps as well as many European countries.

Conventional CFD software is limited in predicting absolute values for drag, air pressure and other aerodynamic load parameters, and such restrictions have prevented CFD from more fully displacing wind tunnel testing. With improvements in solver technology, meshing technology and high-performance computing capabilities, this is quickly changing. These advances allow CFD to predict absolute characteristics more accurately and quickly so that aerospace companies can save significant time and expense by reducing their dependence on wind tunnel testing.

Advances in turbulence modeling are making significant strides in increasing the accuracy of predicting absolute aerodynamic characteristics, and ANSYS is at the forefront of this effort. The shear stress transport (SST) model, originally developed by Florian Menter, who now heads the turbulence modeling group at ANSYS, is now the day-to-day turbulence workhorse of CFX. Numerous test cases have been performed to verify its performance. In the NASA Tech Memorandum 110446, "Turbulence Modeling, Validation Testing and Development," the SST model was rated the most accurate model for aerodynamic applications. Developments continue with improvement to unsteady formulations such as detached eddy simulation (DES) and scale adaptive simulation (SAS), in which the larger scales of turbulence are calculated.

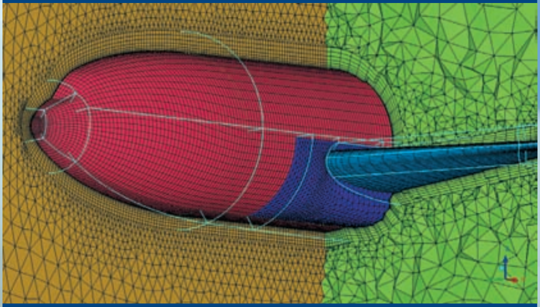
ANSYS CFX also offers the only commercially available predictive transition model, which allows the code to accurately predict the transition from laminar to turbulent flow. Accurately modeling this transitional region is critical for calculating absolute aerodynamic characteristics. ANSYS CFX performed very well at the 2003 AIAA drag prediction workshop, during which the software accurately predicted the drag increase due to engine installation for complete aircraft configurations over a wide range of angles of attack.

Aerodynamics



ANSYS CFX offers the only commercially available predictive transition model, which allows the code to accurately predict the transition from laminar to turbulent flow. Accurately modeling this transitional region is critical for calculating those absolute aerodynamic characteristics such as drag and skin friction, as shown on the geometry courtesy of Eurocopter. Blue areas indicate regions of laminar flow on the nose and tail sections, while skin friction due to turbulence is shown by the color-coded isosurfaces on the rest of the body.

Hybrid Meshing



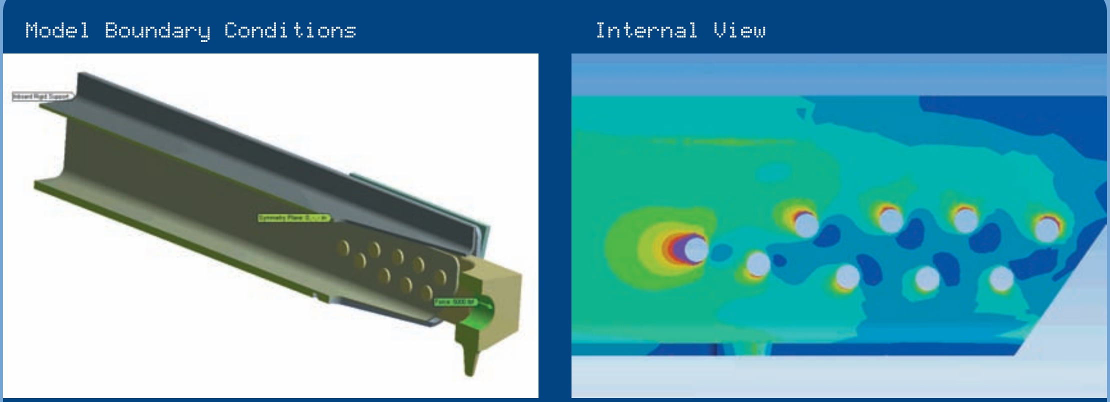
This hybrid mesh for a passenger aircraft study was created with multi-zone blocking. This semi-automatic approach is being developed by ANSYS and tested by military and commercial aircraft manufacturers. Zone edges are indicated by the light blue lines surrounding the plane.

Advanced Hybrid Meshing

For years, ANSYS ICEM CFD meshing technology has been widely used as a flexible and adaptable tool in the aerospace industry. More broadly, the software has the potential to change the future of meshing for the complex problems found in these types of applications.

In particular, ANSYS is working with military and commercial aircraft manufacturers to develop an advanced hybrid meshing approach. Rather than generating a tetra/prism mesh or manually blocking a structured hexa mesh, ANSYS is developing a rapid multi-zone blocking approach. The new process starts by auto-generating 2-D surface blocks. An automatic "2-D to 3-D fill" creates an unstructured volume block.

Some photos courtesy Lockheed Martin.



Model Boundary Conditions

Internal View

Engineering firm Raetech used ANSYS Workbench to analyze the riveted wing spar assembly of a T-34 aircraft under a range of loading conditions (left). The simulation determined stresses and fatigue life at the inner and outer panels (right), proving an adequate design when flown within the stated limits.

Then the automatic o-grid function is used to capture the boundary layer, and the aircraft block faces are extruded as swept or structured boundary layer blocks.

The end result is a quick and virtually automatic hybrid mesh consisting of high-quality hexa or hexa-dominant boundary layers surrounded by an unstructured hexa or tetra mesh. Hybrid mesh really means all the right mesh in the right place, with fewer nodes and better resolution.

Keeping Vintage Planes in the Air

Even aircraft that developed long before CAE software was available can benefit from today's advanced simulation technology. Case in point is the beloved World War II–era T-34 propeller-driven plane, still in use for pilot training and aerobatics.

In December 2004, the FAA grounded the entire fleet of about 500 aircraft due to a catastrophic failure stemming from metal fatigue in the lower spar carry-through structure. Detailed analysis of the complex riveted assembly was subsequently performed using ANSYS Workbench by engineering firm Raetech Corporation on behalf of General Aviation Modification Inc. and the T-34 owners' association.

The simulation determined stress fields with various rivet conditions and revealed a high stress concentration near the spar's innermost rivet hole at the exact point of failure. The supplied stress fields guided strain gage placement and crack-growth analysis. Based on the correlation between FEA and strain gage results, the FAA allowed the fleet back into the air with a revised maintenance schedule, including spar carry-through eddy current crack checks.

State-of-the-Art Structural Analysis

Aerospace engineers use a wide range of CAE tools in analyzing aircraft structural characteristics such as stiffness, stress, strength, fatigue and vibration. Advanced technologies from ANSYS include software for performing studies on design sensitivity to multiple complex variables, for optimizing designs and for developing robust designs that meet Design for Six Sigma standards.

The software has special modeling capabilities for representing composite materials so prevalent in airspace applications. Linear dynamics problems ranging from modal analysis and random vibration to specific applications like rotor dynamics all can be solved with ANSYS software tools. Large aircraft structures can take advantage of advanced capabilities such as component mode synthesis (CMS). Bird strikes, explosions, aircraft crashes and other high-impact events are simulated effectively with ANSYS tools. Current development plans include motion simulation and rebar modeling to more effectively model landing gear with tires and other similar challenging problems.

ANSYS excels in handling coupled physics applications that are common in the aerospace industry. Thermal stress analysis is now routinely done with ANSYS tools and is very important in developing gas turbine technology. ANSYS has partnered with companies such as LMS International in solving the coupled physics involved in aero-acoustics problems. For studying the effects of the airflow on the aircraft structure, engineers routinely map temperature or pressure results from CFD analysis as boundary conditions for FEA analysis.

Flutter and Fatigue

ANSYS software is well suited to studying phenomena such as aero-flutter that require including the effects of two-way fluid structure interactions. All aircraft vibrate and deform due to aerodynamic loads, but in some cases there are concerns that the deformation may increase the aerodynamic forces, which could then amplify vibration. This so-called flutter can lead to dangerously excessive stress and fatigue.

The two-way FSI approach requires solving structural motion equations simultaneously with equations of fluid flow. The solvers need to work together to exchange energy between the air and the vibrating structure. As the geometry flexes, the mesh will need morphing or remeshing between time steps.

For two-way FSI, ANSYS software offers the significant advantage of being a single-source provider so users need not string together CFD, FEA and meshing codes from different vendors (usually with the help of a fourth vendor to manage the communication among the other codes). This enables more implicit coupling between the codes that allows for faster, more robust simulations.

Aerospace FSI is still on the fringe, but academic research groups such as one at the University of Colorado are working with corporate and military research groups to apply FSI in a variety of aerospace applications.

High-Performance Propulsion Systems

ANSYS also has been closely involved with turbine and rocket engine design for many years. Engine design is more constrained than airframe design. Engineers look for small changes that improve power or efficiency. Since the topology is usually similar within a class, a large number of design iterations are achieved through a focus on automation.

The mesh quality has been shown to have significant effect on the analysis accuracy. Structured hexa mesh usually is preferred for bladed components, while combustors and other complicated shapes are more efficiently captured with a hybrid approach. Companies like GE Global Research and GE Aircraft Engines have found that the ANSYS ICEM CFD structured hexa mesher offers unique features with all the required capability and flexibility. The company has made it an integral part of their automated CAE process.

Through years of extensive work in this field, ANSYS has become a world leader in engine design optimization, particularly for rotating machinery. The design cycle can be greatly reduced with a combination of focused CAD and simulation technologies for advanced fluid dynamics, body dynamics, stress analysis and thermal simulation. Specialized tools such as ANSYS BladeModeler and ANSYS TurboGrid streamline the analysis process and aid the connection between CFD and FEA analyses. ANSYS Workbench optimization or FSI tools can help develop the best possible combinations of design elements.

Relying on an Industry Leader

ANSYS technology is widely used by aerospace OEMs and suppliers in the development of a broad range of critical components and complex systems for aircraft in the air today as well as those in the conceptual stages of design.

Engineers rely on analysis as an indispensable tool in their work. Aerospace companies continue to trust ANSYS, as they have for decades, in providing advanced simulation software for meeting the ever-increasing demands of developing aircraft and other aerospace products. These aerospace companies go with ANSYS as a technology leader and reliable partner because there is little room for error in this industry, either in design or business strategy. ■