SIEMENS

Ingenuity for life

Aerospace and defense

Solar Impulse

Flying around the world without a single drop of fuel

Product

Femap with NX Nastran

Business challenges

Optimize the design of the plane's metal components, composite and sandwich structures of the Kevlar paper honeycomb core to minimize weight

Keys to success

Integrated FEA solver, pre- and postprocessor that supports a wide range of analysis types

Ability to import CAD geometry

Custom functions created using the Femap API

Fast interpretation of results using data table; ability to combine output sets

Collaboration with Siemens partner AeroFEM

Results

Cockpit size increased by a factor of 3 with less than a 2X increase in weight

Ability to optimize carbon fiber ply thickness and number of plies helped hold down weight of wing structure

Femap with NX Nastran is being used to optimize and verify the structure of first plane to circumnavigate the earth using solar power alone

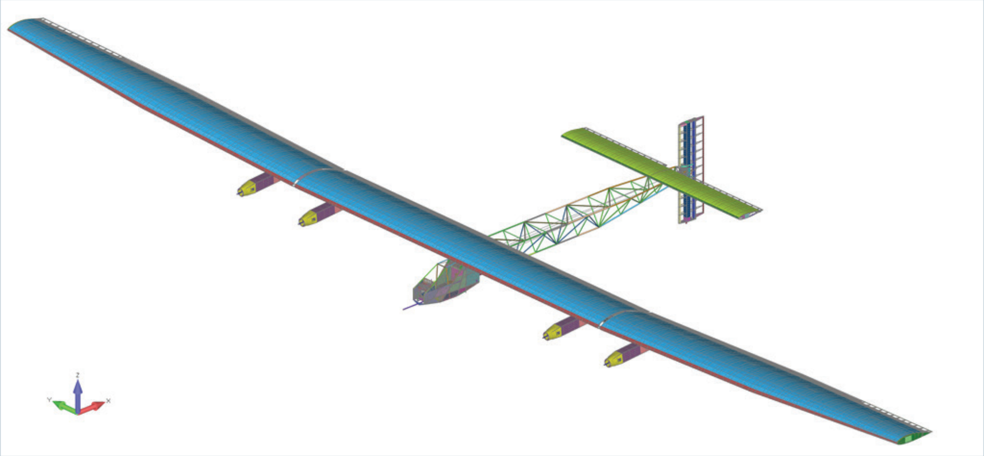
Around the world in a solar airplane

Solar Impulse is a solar-powered aircraft project led by Swiss psychiatrist and aeronaut Bertrand Piccard, who co-piloted the first balloon to circle the world non-stop, and Swiss engineer and entrepreneur André Borschberg. The project's goal is to circumnavigate the earth in a fixed-wing aircraft that uses only solar power. The circumnavigation, a journey of 35,000 km/21,000 miles and 500 flight hours, is scheduled to commence in March 2015.

The plane that will fly around the world is the company's second aircraft. It bears the Swiss aircraft registration HB-SIB, and is known as Solar Impulse 2. Its predecessor was the HB-SIA, which took its maiden flight in 2009 and flew an entire diurnal solar cycle, including nearly nine hours of night flying, in a 26-hour flight in July 2010.

Based on experiences with the HB-SIA, the Solar Impulse 2 was given a longer wingspan of 71.9 meters/236 feet; slightly less than that of the world's largest passenger airplane, the Airbus A380. It also has a cockpit that's three-times larger, to allow for multiday transcontinental and transoceanic flights.

One of the most remarkable aspects of the Solar Impulse 2 is the fact that, even with such a massive wingspan and all of the batteries required (633kg), it weighs just slightly more than an average automobile (2300kg). Obviously, minimizing weight was one of the most critical design challenges. "The plane needs a lot of batteries, and batteries are heavy," explains Geri Piller, head of structural analysis at Solar Impulse.



Results *(continued)*

Motor gondola supports heavier loads with minimal weight increase

Plane weighs lowest possible amount while still meeting rigors of around-the-world flight

"Ply definition is really easy. We were able to jump into that topic very quickly using Femap."

Geri Piller
Head of Structural Analysis
Solar Impulse

"Yet the plane gets only a small amount of energy from the solar cells, so it has to be really light."

One FEA solution for many types of analysis

Piller's structural analysis team, which consists of Piller and four other engineers, used Femap™ with NX™ Nastran® software, from product lifecycle management (PLM) specialist Siemens PLM Software, as the finite element analysis (FEA) solution for the design of both the HB-SIA and the HB-SIB. The company started using Femap with NX Nastran in 2007, and it is still using the software today as it fine-tunes the Solar Impulse 2 for its around-the-world journey.

Piller chose Femap with NX Nastran for the Solar Impulse project because it is the solution used by the Swiss engineering company and Siemens PLM Software partner AeroFEM, which was contracted by Solar Impulse to perform special analyses like aeroelasticity and rotor dynamics. Femap with NX Nastran supports all the different types of analysis (strength, buckling, large deformation, etc.) required for the Solar Impulse project, and choosing this solution would allow the two groups to collaborate seamlessly. "The engineers at AeroFEM are like part of my team," Piller says. "Our collaboration is really great."

Strong functionality for setting up analyses and for interpreting results

Femap accepts the Solar Impulse design team's geometry from the native CAD system, in STEP or IGES format. The geometry becomes the basis for finite element (FE) models. Femap also has its own modeling functionality, which Piller finds easy to use, especially for the composite materials that make up a large portion of the plane. "Ply definition is really easy," he says. "We were able to jump into that topic very quickly using Femap."

"Using Femap, it was really fast to see what we had to work on and where we could optimize."

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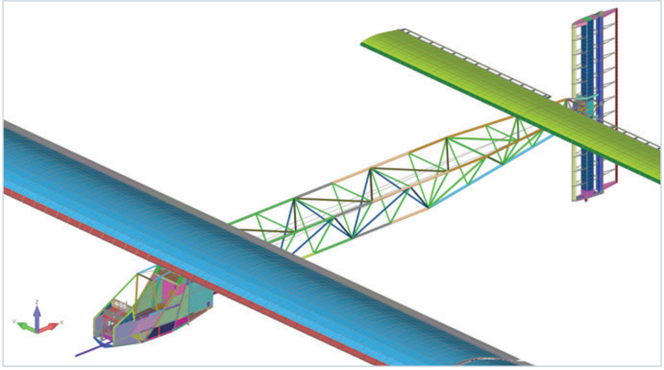

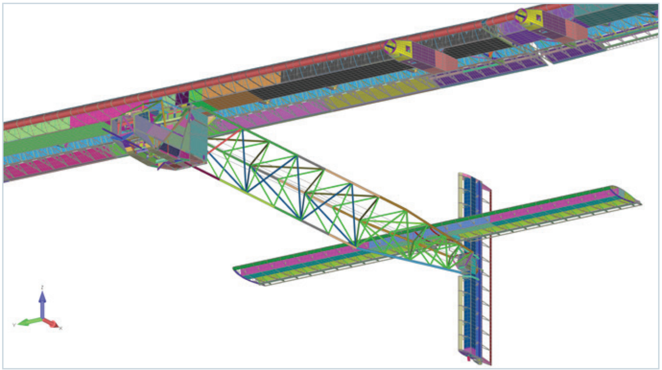

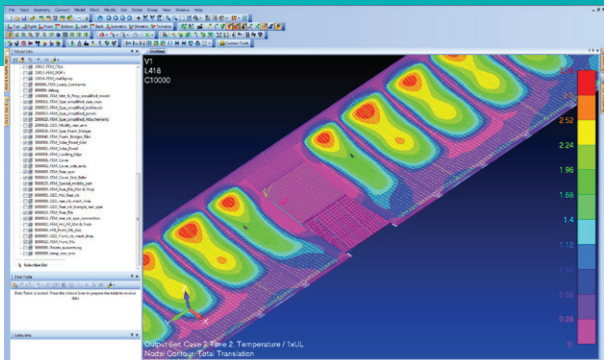

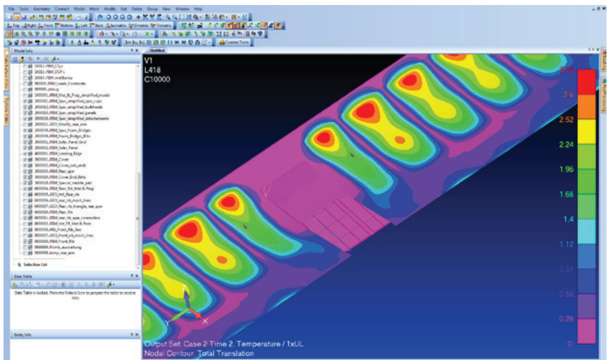

As an example of how the analysts use both imported geometry and the modeling tools within Femap, Piller describes some work done on the plane's wing structure. The analysts initially used the CAD geometry of the wing's outer surfaces to create a simple analysis model in order to look at load paths. Later, using Femap, they added 3D solid elements representing the Kevlar® aramid paper honeycomb core for more detailed analyses such as local and global buckling.

FE models for the plane's metal components range in size from 50,000 to 500,000 elements. The model of the main wing structure contains two million elements. Normally the analysts evaluate 10 to 20 load cases, but endurance analyses look at as many as 160.

Piller's team takes advantage of the Femap API (application programming interface) to write scripts that automate some of the analysis work. One very useful script applies the company's own programmed strength criteria for the composites, helping to automate laminate verification. Another runs after the analyses of composite parts, and automatically evaluates the results according to the ply with the highest stresses, quickly showing where the failures are in the laminate or sandwich structure. "Scripts such as these save time and, equally importantly, help ensure the accuracy of the analyses," says Piller.

The analysts use the Femap data table frequently as a way of quickly summarizing and interpreting analysis results. The data ranking function, for example, quickly shows minimum and maximum stress values. "We use this capability a lot; what makes it really useful is that it's possible to combine output sets," Piller says.

3X bigger cockpit without less than 2X increase in weight

A concrete example of the value of using Femap with NX Nastran on this project is the plane's cockpit, where the FEA solution played a role in minimizing weight. The single-seat cockpit of the plane that will fly around the world is tiny (3.8 cubic meters/134 cubic feet), but it's actually three times larger than the cockpit of the first Solar Impulse plane. (In fact, the new cockpit is so much roomier that the Solar Impulse web site jokingly claims that the company has "upgraded the pilot to business class.")

Although the new cockpit is three times larger, it weighs less than twice as much as the original (60 kg/132 pounds for the new cockpit versus 42 kg/93 pounds for the original).

The new plane's wing structure is another place where Femap contributed to a significant weight reduction. The wing consists of a Kevlar honeycomb core covered with an advanced carbon fiber material. Because the new plane flies faster than the first one, its wings had to withstand greater loads. Analysts used Femap to optimize the amount of the carbon fiber

By using Femap on this project, Piller and his colleagues were able to quickly determine how best to minimize the plane's weight while still meeting the rigors of an around-the-world adventure.

Solutions/Services

Femap
www.siemens.com/plm/femap

Customer's primary business

Solar Impulse SA is a solar-powered aircraft project led by Swiss psychiatrist and aeronaut Bertrand Piccard and Swiss engineer and entrepreneur Andre Borschberg.
www.solarimpulse.com

Customer location

Lausanne
Switzerland

Partner

AeroFEM GmbH
www.aerofem.com

Although the new cockpit is three times larger, it weighs less than twice as much as the original.

plies so that they could meet the needed loading conditions with the least amount of added weight. They were able to go from using a material weighing 100 grams per square meter to one weighing 25 grams per square meter, a significant weight reduction. Similarly, the motor gondola of the second plane has to carry a heavier load, but the weight increase was kept to a minimum, in part by changing from a framework structure with fairing to a sandwich structure and, in part, by using FEA to optimize components such as facings and spar caps.

By using Femap on this project, Piller and his colleagues were able to quickly determine how best to minimize the plane's weight while still meeting the rigors of an around-the-world adventure. "Using Femap, it was really fast to see what we had to work on and where we could optimize," Piller says.

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