Engineering the Fully Electric Airplane

By ANSYS Advantage Staff

Electric cars have gradually found their way from our imaginations to our roadways in recent years. Initially starting with limited range, electric cars now offer ranges comparable to internal combustion-powered cars. Now, all-electric aircraft are on the horizon. Engineers at magniX employ multiphysics simulation to develop powerful electric motors for propeller planes that could revolutionize the short-haul and middle-mile flight industry, making it more economical and convenient to take a 30-minute flight rather than a 2½-hour drive and a 1½-hour flight instead of an 8-hour drive.

While electrification is a powerful driving force in most industries, aircraft propulsion has not been one of them — until now. In order to carry hundreds of people thousands of miles, large jet-powered planes are the only solution. However, the aerospace industry has benefited from the electrification initiative. Some components of aircraft have been made more electric in recent years — power generation management, passenger comfort, air pressurization, air conditioning and flight control, for instance — but electric propulsion aircraft have not emerged because there has not been an electric propulsion system powerful enough and light enough to power an aircraft.

Now, an entrepreneurial propulsion company called magniX, with locations in Redmond, Washington, and Gold Coast, Australia, is revolutionizing the aviation industry. Its goal is to enhance global prosperity through connecting communities by providing clean, low-cost, electric-powered air transportation. magniX is designing electric motors to power propeller planes capable of carrying from 8 to 20 people on flights of 650 miles or less. These direct flights will avoid major airport and connect people and communities that are currently just a little too far away, with low-cost, efficient air connections.

With plans to begin test flights on a variety of aircraft later this year, magniX engineers are using ANSYS structural, electromagnetic and thermal simulation solutions to design and test the robust, reliable electric motors needed to ensure aircraft safety and reliability. Because many of the regulatory aviation commissions worldwide that certify aircraft for commercial use hold ANSYS simulation data in high regard, using ANSYS solutions could help speed magniX electric-powered airplanes to the marketplace.

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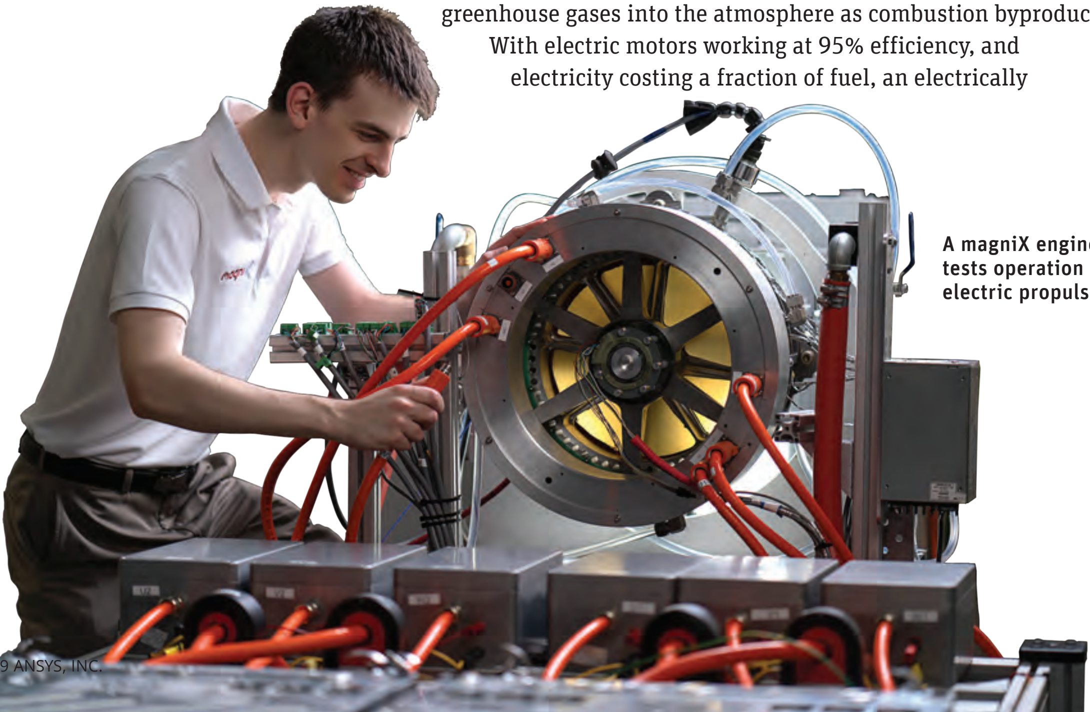
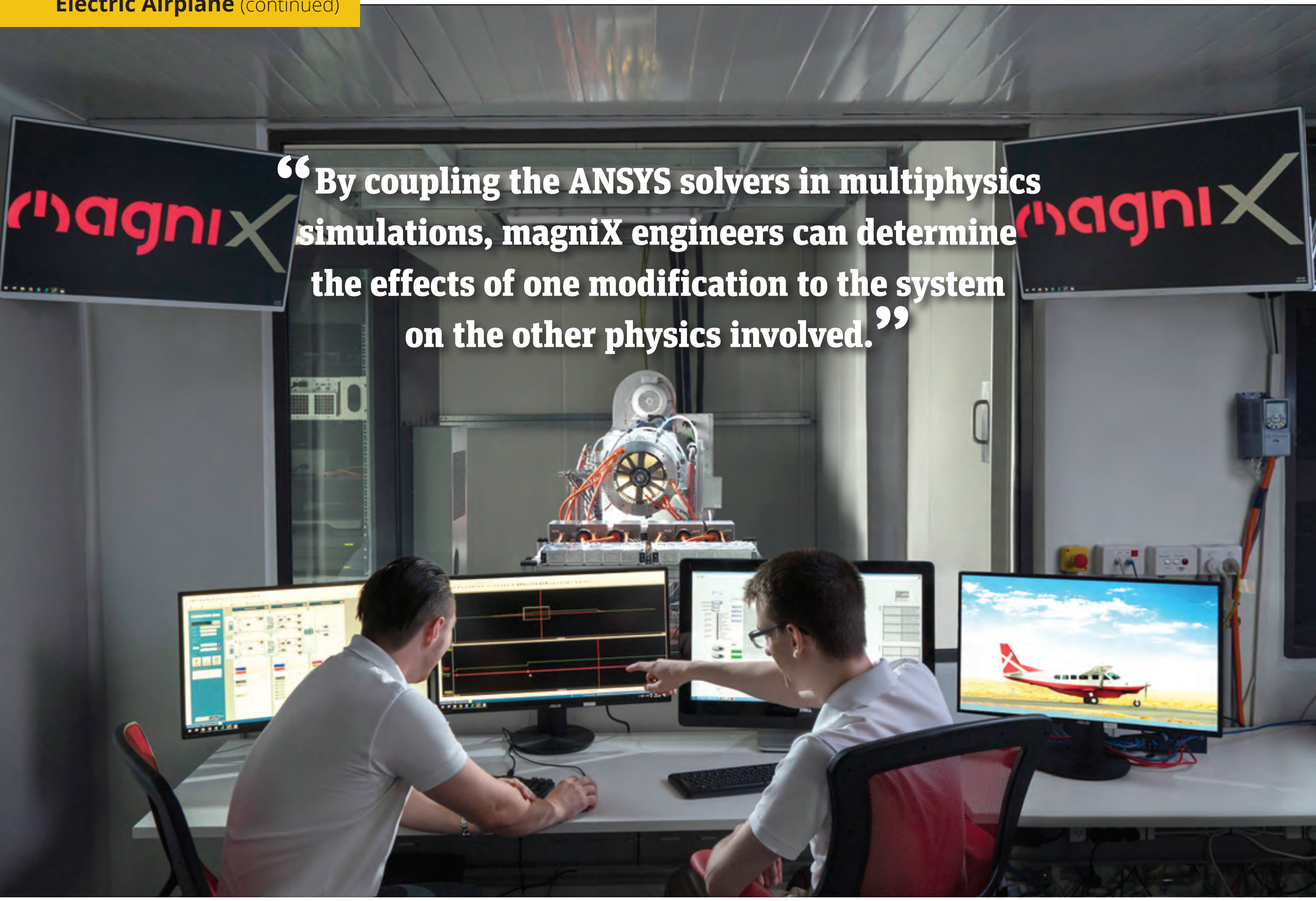
The Case for Short-Haul Electric Planes

According to the FAA’s National Plan of Integrated Airport Systems (2019–2023) report, the United States has over 19,000 airports. Major airlines fly to about 500 of them; if you include smaller airlines and chartered flights, this number increases to about 5,000. That leaves approximately 14,000 airports that could accommodate small, electric-powered planes conveniently and at low cost. The number of airports worldwide is greater than 40,000, so the opportunity is immense.

In 2018, approximately 5% of scheduled airline flights worldwide were 100 miles or less. Because turbine and piston engines are very inefficient, for this 100-mile flight a turbine or piston aircraft will consume about $400 in fuel and emit CO_2 and other greenhouse gases into the atmosphere as combustion byproducts. With electric motors working at 95% efficiency, and electricity costing a fraction of fuel, an electrically



A magniX engineer tests operation of electric propulsion



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magniX engineers reviewing results of electric propulsion testing

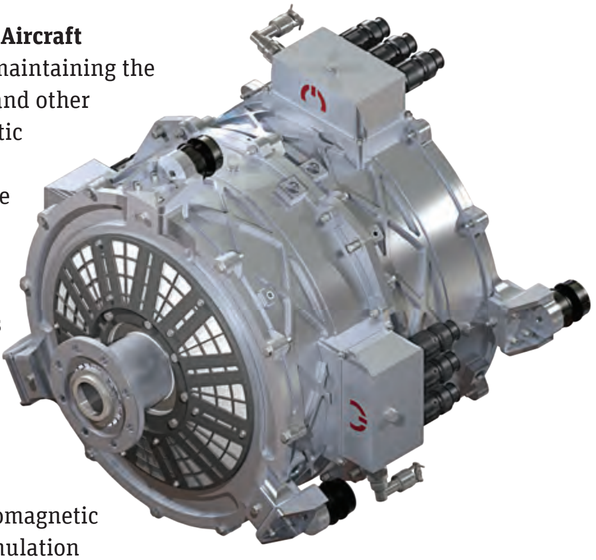
propelled plane could make that same trip using $12 worth of electricity while producing no tailpipe pollutants at all.

Finally, electric-powered planes will be quieter, eliminating some of the noise pollution we all experience.

Engineering Challenges of an Electrically Propelled Aircraft

Like anything in an aircraft, reducing weight while maintaining the mechanical strength and performance of the motor and other components is critical. Optimizing the electromagnetic properties of the motor to provide the most power possible in a small, lightweight package is of extreme importance too.

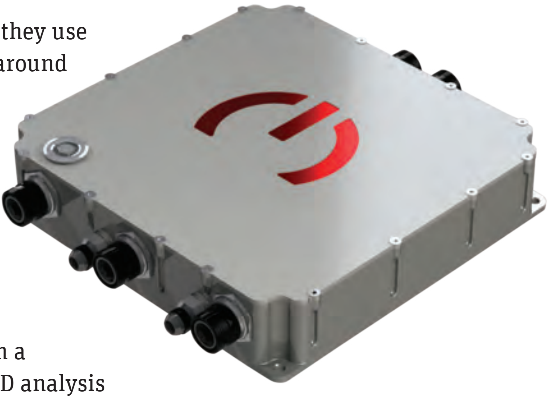
To meet these design challenges, magniX engineers use ANSYS Mechanical, ANSYS Fluent and ANSYS Maxwell to perform multiphysics simulations to optimize structural integrity, fluid flow and the electromagnetic properties of their innovative electric motors.



magni500 motor provides 560 kW of power output and 2,814 Nm torque at 1,900 rpm

Multiphysics Simulation of Electric Motors

magniX engineers use Maxwell to analyze the electromagnetic behavior of the motor and optimize it for weight. Simulation data from the electromagnetic analyses, such as losses and internal forces, are shared with Mechanical and Fluent to perform thermal and structural multiphysics simulations. Using Mechanical, they analyze the structural components of motors to ensure that they are robust and lightweight given all loading conditions. Finally, they use Fluent to study both air and coolant flow in and around the motor to understand how the motor will behave thermally in service.



By coupling the ANSYS solvers in multiphysics simulations, magniX engineers can determine the effects of one modification to the system — such as a change in the electromagnetic design — on the other physics involved, such as the mechanical and thermal properties. For instance, the resulting losses from a Maxwell simulation are exported to Fluent for CFD analysis to determine the thermal behavior of the motor under different operating conditions. The thermal loads from this analysis may then be exported to the Mechanical solver. Given the combined thermal and structural loads on the motor, engineers can determine maximum stresses and displacements, and then study the design to see what areas may need optimization. After deciding what area to focus on to improve the design, they modify the inputs to the relevant ANSYS solver and run another multiphysics iteration.

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Case Study: Eliminating the Gear Box

One advantage of the magniX electric motor is the ability to simplify the overall propulsion system by directly driving the propeller without the need for an intermediate gearbox between the motor shaft output and the propeller. Typically, for fuel-powered small airplanes, a motor turning at 10,000 to 20,000 rpm is connected to a propeller turning at only 1,900 rpm. A heavy mechanical gearbox is usually needed to step down the speed of the shaft to match the speed of the propeller, just as the transmission in an automobile adapts the output of the internal combustion engine to the speed of the wheels. This gear box adds weight, complexity and more maintenance to the overall system.

The magniX motor creates its power while turning at 1,900 rpm, thus matching the propeller and eliminating the need for a gearbox. To accomplish this, engineers had to ensure that the speed of the motor shaft is equal to the speed of the propellers. Therefore, the motor had to be designed to withstand not just the torque and thrust loading but structural and vibration loads coming from the propeller. magniX engineers used Mechanical extensively to design and optimize the mechanical structure of the motor for strength, stiffness and weight.

Choosing ANSYS Simulations

In searching for a simulation solution, magniX knew that ANSYS technology was already used by many aerospace companies. Starting with a proven tool to solve the challenges of a revolutionary technology — electrically propelled airplanes — eliminates some of the risk. The fact that ANSYS also has multiphysics simulation capabilities, so data from electromagnetic, fluid and structural solvers can be shared seamlessly in one simulation environment, also made ANSYS solutions a good choice.

The company applies simulation to shorten the development timeline by ruling out options. When faced with many possible designs, the ability to rule out those that will not work well can be done quickly using simulation. Engineers can then focus on a smaller group of options that have the best potential. Without simulation they would need to build every motor, every inverter and every component of that motor or inverter.

Electric Machine Design Methodology: A Revolutionary Approach
ansys.com/electric-machine-design