



ROBUST ELECTRIC MACHINE DESIGN THROUGH MULTIPHYSICS

Electromagnetic, mechanical and thermal simulation plus design optimization help to improve energy efficiency, noise and bearing life of robust electric motors.

Electric motors are the single biggest consumer of electricity, accounting for about two-thirds of industrial power consumption and about 45 percent of global power consumption, according to an analysis by the International Energy Agency. The World Energy Outlook 2012 states that the developed world is planning to increase its energy efficiency by 1.8 percent annually over the next 25 years. Much of this improvement must come from advancements in electric motor design. Companies that develop these devices must ensure that motors have low operating noise and long life. Engineers have worked to balance these demands to improve and optimize the design of electric motors for almost two centuries, and now new methods and tools are needed to generate further progress.

WEG is the largest industrial electric motor manufacturer in the Americas and one of the largest manufacturers of industrial electric motors in the world, producing more than 10 million units annually. WEG engineers used the ANSYS comprehensive design solution for electric motors to leverage electromagnetic, mechanical and thermal simulation. Design optimization helped the engineering team to deliver optimal energy efficiency, low operating noise and long bearing life on the new W50 electric line

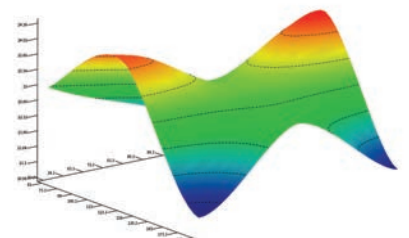


**ELECTRIC MACHINE DESIGN METHODOLOGY:
A REVOLUTIONARY APPROACH**
ansys.com/82robust

WEG's Robust Design of Electric Machines

APPLICATION	TECHNOLOGY	EXPECTED RESULTS OR TARGET
EVALUATE A WIDE RANGE OF COOLING AIR PASSAGE DESIGNS	COMPUTATIONAL FLUID DYNAMICS (CFD)-ELECTROMAGNETIC SIMULATION	REDUCE FAN LOSSES AND IMPROVE ENERGY EFFICIENCY
MINIMIZE TOTAL NOISE GENERATED BY MOTOR • PREDICT AERODYNAMIC NOISE • PREDICT ELECTROMAGNETIC NOISE	ELECTROMAGNETIC-STRUCTURAL-THERMAL ANALYSES	LOWER OPERATING NOISE
REDUCE OPERATING TEMPERATURE OF BEARING	CFD-THERMAL SIMULATIONS	INCREASE BEARING LIFE
AUTOMATE DESIGN EXPLORATION	ANSYS DESIGNXPLORER AND ANSYS WORKBENCH	OPTIMIZE MOTOR DESIGN WITHOUT HAVING TO MANUALLY EVALUATE EACH DESIGN ALTERNATIVE

WEG engineers used a wide range of ANSYS tools to deliver optimal energy efficiency, low operating noise and long bearing life on its new line of electric motors.



▲ Response surface map depicts fan airflow efficiency as a function of several design variables.

WEG increased the number of CFD simulations performed from four per month in 2005 to 800 per month currently.

of motors. The broad range of ANSYS capabilities was instrumental in designing and optimizing the electric motor without the need to individually evaluate each design alternative.

IMPROVING ENERGY EFFICIENCY

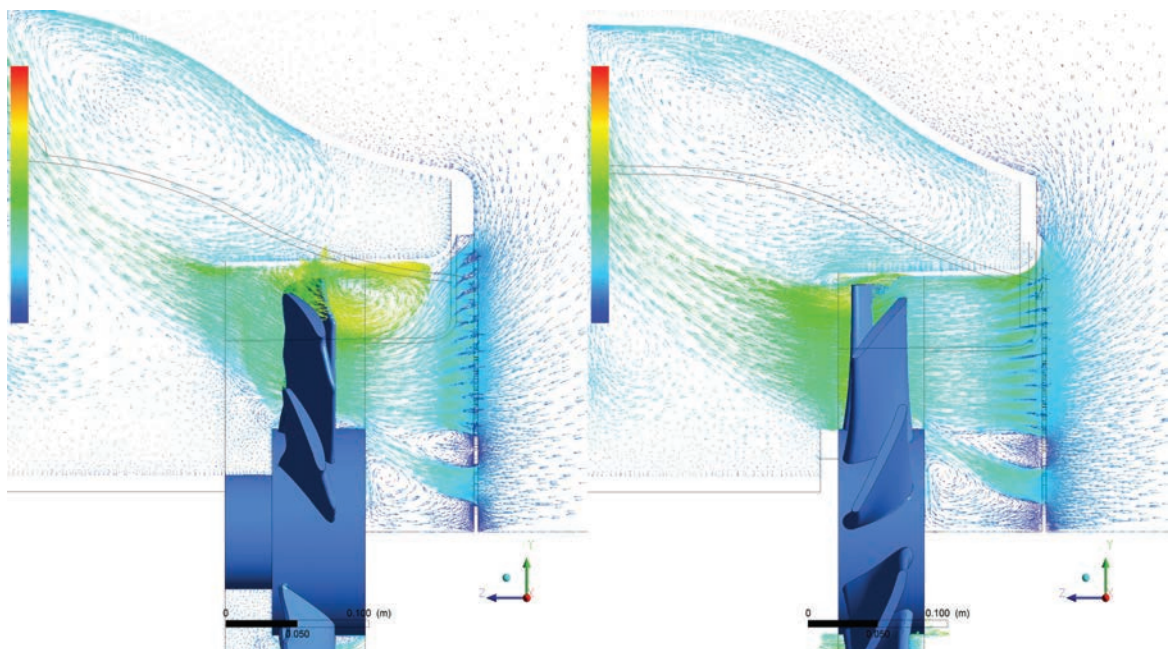
Large electric motors in the 125 horsepower to 1,750 horsepower range typically have two fans: one to cool the motor interior and the other to cool its exterior. These fans consume a considerable amount of power, and WEG engineers believed that a promising approach to improving energy efficiency was to improve fan efficiency. They focused on the internal fan, particularly on reducing losses as air flows through the motor. The airflow generated by the fan flows through openings in the frame. Losses could be reduced by increasing these openings — but this strategy would reduce the motor's electromagnetic performance.

WEG engineers used ANSYS CFD software to model the airflow through the interior of the motor. They defined key parameters, such as the openings where air passes through the frame, as parametric dimension variables. Since many of these design parameters impact the motor's electromagnetic performance, engineers produced an ANSYS Maxwell electromagnetic model of the motor with the same parametric variables as the CFD model. They generated a table of varying values for each of the parameters.

WEG employed ANSYS DesignXplorer to create a design of experiments (DOE) that subdivided the design space to efficiently explore it with a relatively small number of simulation experiments and to run multiphysics simulations without human intervention. Comprehensive simulation tools in the ANSYS Workbench environment and design optimization with ANSYS DesignXplorer enabled WEG

to increase the number of simulations performed from four per month in 2005 to 800 per month currently. High-performance computing (HPC) also helped enable this improvement. WEG uses HPC Packs for CFD, and Maxwell runs with 64 cores distributed across eight workstations.

Output results for each design point were stored in a table and visualized with a response surface map that completely maps out the design space. The response surface was used to graphically plot the effect of variables on fan losses. Simulations were not coupled in this case due to computing resource limitations; however, in the future, WEG will use coupled multiphysics simulations to even more accurately determine optimal values for parametric variables by considering all of the physics. WEG engineers manually compared response surface maps, plots and tables for the CFD and electromagnetic analysis to determine the



▲ Before-and-after comparison of ANSYS CFX simulations shows improved airflow that reduces fan losses in W50 motor compared to previous-generation design.

combinations of parametric variables that delivered the best mix of performance. Engineers then reran the electromagnetic and CFD simulation for the best combinations and selected the one that delivered the best performance: a substantial reduction in fan losses and a resulting improvement in energy efficiency without any sacrifice in electromagnetic performance.

REDUCING NOISE

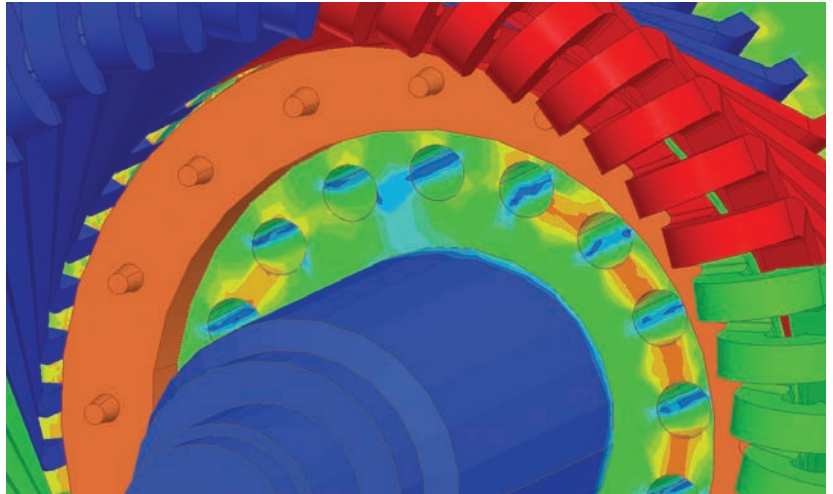
WEG engineers also wanted to reduce the noise generated by the new W50 motor design. An electric motor primarily generates noise through two independent sources: aerodynamic and electromagnetic. Aerodynamic noise is generated by the fan rotor and transmitted through the air; WEG engineers used ANSYS CFD to optimize the fan rotor geometry to minimize aerodynamic noise. Electromagnetic noise is created by the interaction of magnetic fields produced by stator and rotor. In extreme cases in which the resultant force frequency excites the natural frequencies of the mechanical structure, this noise will be dramatically amplified.

WEG engineers used ANSYS CFD to optimize the internal fan system. Engineers designed a new internal fan system to reduce the length of the motor, which improved the dynamic performance. However, the original design was not acceptable, so engineers used ANSYS DesignXplorer to optimize the internal fan geometry and develop a new solution that met the requirements. The new internal fan reduces vibration, improves power density of the motor, and increases the maximum rotating speed.

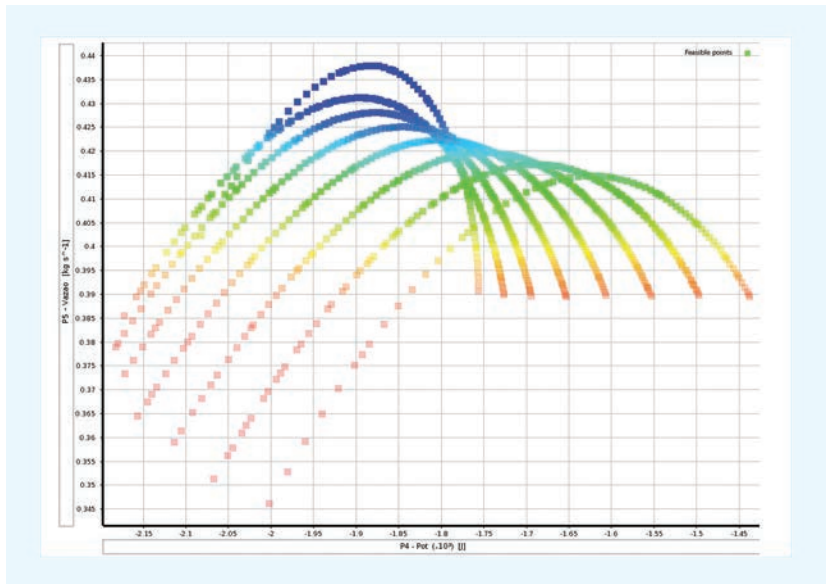
To predict and avoid electromagnetic noise of the motor prior to the prototyping stage, WEG engineers used electromagnetic simulation to calculate the electromagnetic force and losses. These quantities are used as inputs to the structural and thermal simulation to predict mechanical vibrations. WEG engineers used the ANSYS Application Customization Toolkit to implement the methodology of topological optimization to increase the natural frequency of the frame. They then set up parametric variables and used ANSYS DesignXplorer to run a table of design points and optimize the design to produce the lowest levels of noise.

IMPROVING BEARING LIFE

Bearings are usually the first component to fail during the lifetime of an electric

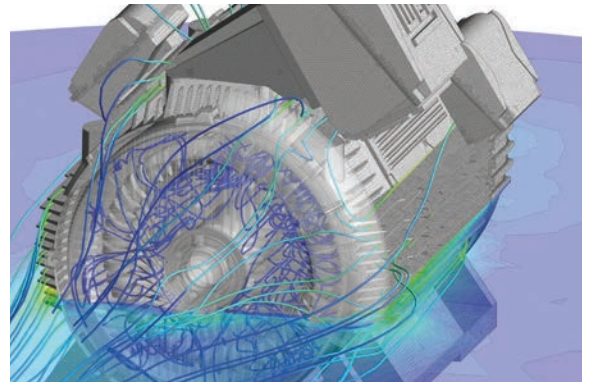
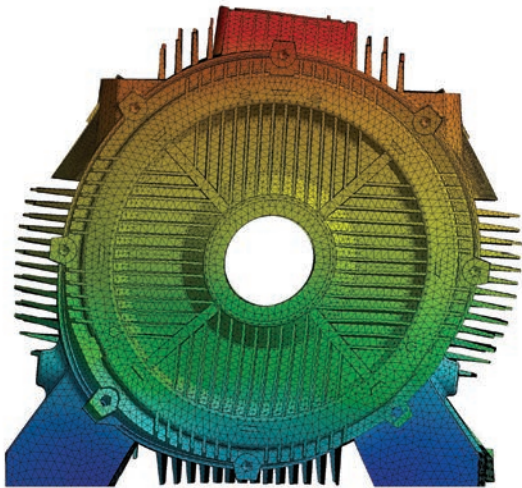


▲ ANSYS Maxwell simulation helps to optimize the trade-off between fan losses and electromagnetic performance.



▲ Fan efficiency plotted against two design variables (one on x axis and other in multiple plots)

ANSYS multiphysics tools help WEG deliver best-in-class performance for electric motors while substantially reducing the lead time and cost of the product development process.

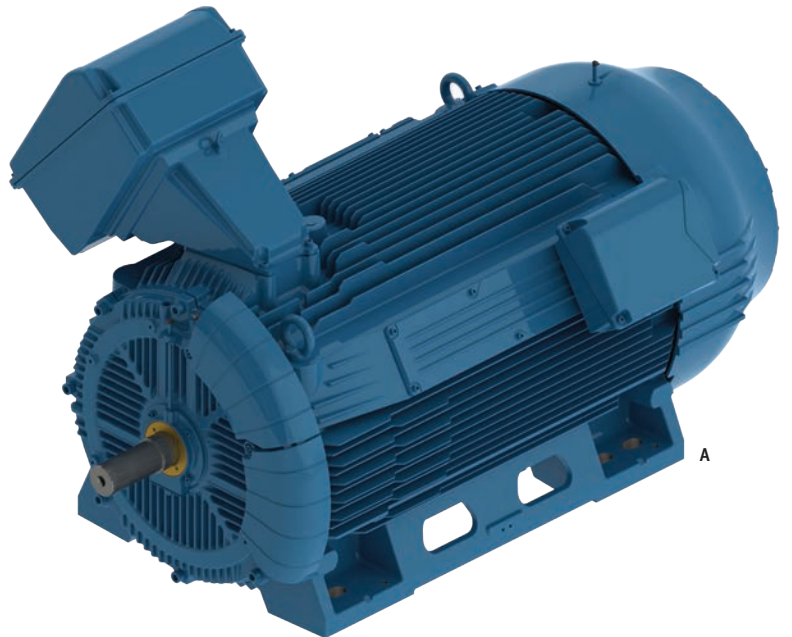


- ▲ CFD simulation of airflow around the bearing was used to reduce bearing operating temperature.
- ◀ ANSYS Mechanical simulation predicted vibration of the structure to reduce noise.

motor, and the life of bearings is strongly correlated with the operating temperature. The cooler the bearing runs, the longer is its life and the longer its lubrication intervals (how often grease is required), so the motor will require less maintenance. The team ran a CFD analysis of the airflow around the bearing and changed the shape and dimensions of some components in the region to ensure a constant airflow and reduce operating temperature.

Based on these and several other multiphysics simulations, WEG engineers developed the detailed design for the W50 motor. The company then built a prototype. Physical testing showed that the design worked exactly as predicted by simulation. As a result, only a few very minor changes were required during the prototype phase. Normally, a larger number of more substantial design changes are required. The ability to get the design right the first time provided a major cost saving.

The new W50 motors deliver significant improvements in performance over existing electric motors in their class. Energy efficiency varies depending on the application, but it is generally significantly better than today's best-in-class motors in the same applications. The new motors offer exceptionally low noise levels of 82 dB(A) at 3,600 rpm (60 Hz) and 78 dB(A) at 3,000 rpm (50 Hz). Bearing life has been improved to 100,000 hours of L10h life over the 40,000 hours previously offered. At least 90 percent of all motors produced will achieve the L10h



- ▲ The final virtual motor prototype required only minor changes, making it possible to get the product to market faster. Virtual prototype (A) with a low-voltage terminal box and final product (B) with high-voltage terminal box.

life. The use of ANSYS multiphysics tools helps WEG to deliver best-in-class performance for electric motors while substantially reducing the lead time and cost of the product development process. ▲

Technical support and sales for WEG is provided by ESSS, ANSYS channel partner for South America.

