# Software takes aim at energy efficiency

## CAD and simulation tools play bigger roles when efficiency is more than just a simple equation

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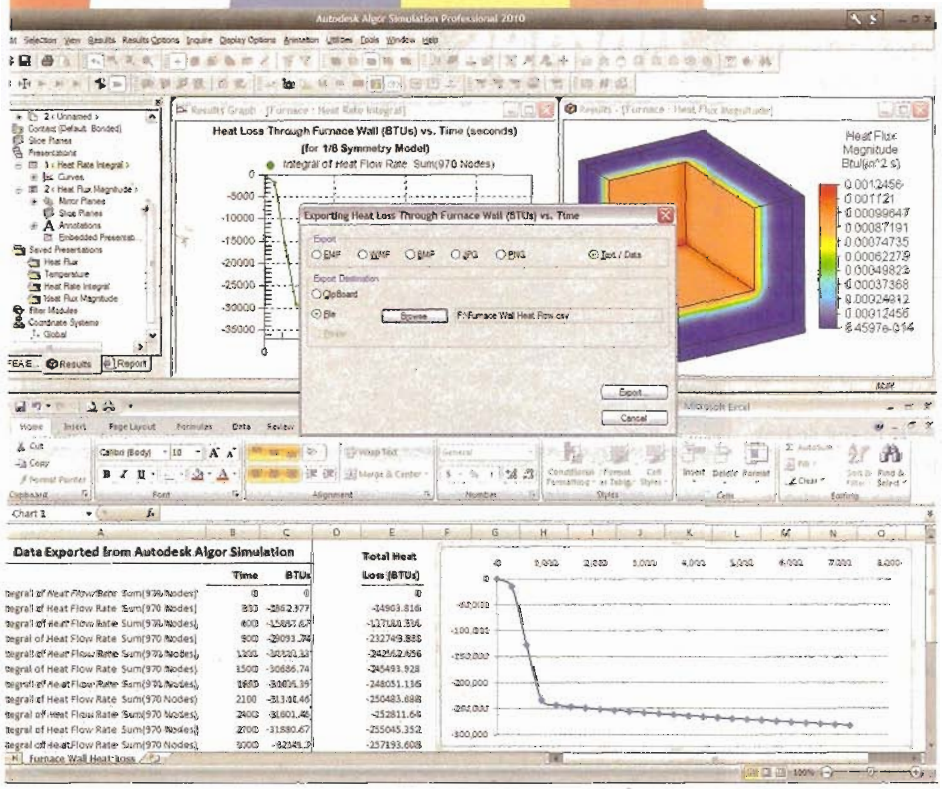
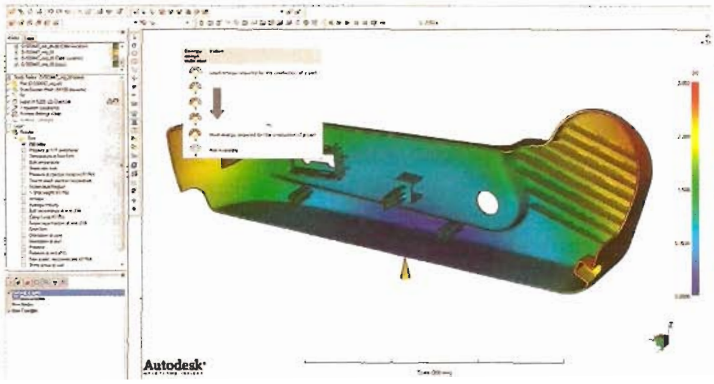



Autodesk Algor Simulation software can easily export contour and graph data to Microsoft Excel worksheets. Designers and engineers can use Excel to further evaluate results. In this example, the heat flux magnitudes for the interior walls of a furnace were summed, integrated, and plotted during a two-hour event. Then heat-loss results were multiplied to list and plot the total heat loss for the entire furnace.

Consider an electrical system — the design of just about every component must be based on the amount of current draw. Higher amps may mean more expensive, larger relays and larger-gage wires. In the case of powering a mechanism, cost comes from energy usage. Of course, the efficiency relationship for such systems is quite simple: *efficiency = output/input* (usually expressed as a percentage value). But the path to the point where you can use this equation can get quite complicated.



Autodesk Moldflow software includes an energy-usage indicator, so designers can reduce manufacturing energy requirements. With access to the world's largest plastic materials database, designers can easily evaluate different materials.

A large German printing-press manufacturer used MathWorks tools for model-based design to develop, test, and implement an efficient, production-ready control system for the cut registers of this state-of-the-art printing press. Engineers developed a Simulink model of the control system based on a proportional integral derivative (PID) controller. Open-loop testing of several strategies identified the one resulting in the most efficient device.

"When you are looking at a design from the high level of 'this input goes into this black box, and on the other side of the box is this output' — then what's needed is probably just a basic hand calculation," says Bob Williams, Product Marketing Manager for **Autodesk Algor Simulation**, Pittsburgh, PA, *www.algor.com*. "But say the design goal is to build a mechanism with a component that spins at 30 rpm. The question of interest: how fast does the motor need to turn to produce 30 rpm by the time energy among the gears, belts, and motor is lost? You know the input — the loads. Here, a general-purpose simulation tool is helpful in calculating output."

For example, says Williams, engineers design an efficient mechanism in Autodesk Algor Simulation software and Autodesk Inventor 3D CAD software by first building a digital prototype in Inventor. Its built-in motion-simulation tools help provide insight into how the design behaves when driven using different methods. Next, the mechanism is further studied using Autodesk Algor Simulation's Mechanical Event Simulation (MES) technology to simulate flexible-body motion and the corresponding stresses. Autodesk Algor Simulation includes the capability to add probes so users can easily measure velocity or load at specific locations in the model. Probe outputs supply data to plug into efficiency calculations.

In another example, consider the case of finding the thermal efficiency of a power source so it wastes less energy, says Williams. Energy goes into the unit in the

# EM pump efficiency

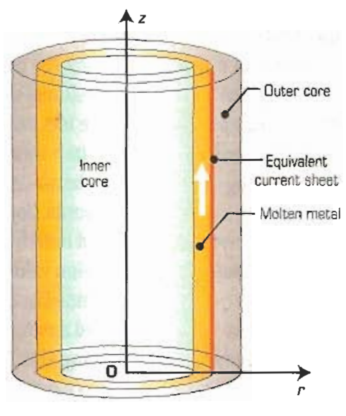
Electromagnetic induction pumps are attractive for moving molten metal because they have no moving parts to fail. However, experimental measurements on a molten lead-bismuth eutectic loop (called TC-1) at the Univ. of Las Vegas showed a surprisingly low efficiency — less than 1%.

When the pump operates, a 3-phase alternating current travels through the inductor coils. This current produces a magnetic field which, in turn, induces a current in the liquid metal in the pump annulus and inner core. Interaction between the magnetic field and induced current forces the liquid metal to flow down the length of the annulus, generating the pumping force. The magnitude of the pumping forces, and therefore the pump's operational efficiency, depends on factors such as slip and hydraulic loss, eddy current loss, hysteresis losses, and end effect (behavior of the liquid at the ends of the annulus or area the liquid travels).

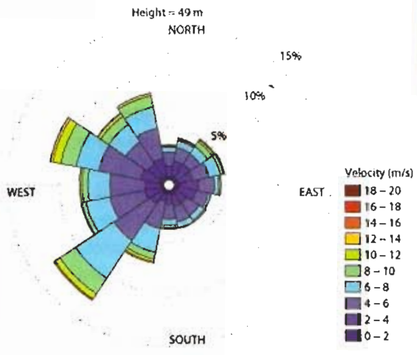
To figure out why efficiency was so low, engineers used both theoretical and numerical methods, with Comsol Multiphysics software from **Comsol Inc.**, Burlington, Mass., *www.comsol.com*, providing the numerical simulation. The engineers got the analytic model of EM behavior in a similar pump from published literature. The model used a combination of the separation method and Fourier transformations. Here, the engineers evaluated the resulting integrals to obtain values of the vector potential and magnetic flux density. From these values, engineers calculated the time-averaged body forces, power density, and pump efficiency.

In Comsol Multiphysics, the engineers simplified the modeling of the pump by replacing currents in the primary coils (embedded in the outer core) with an equivalent current located at the boundary between the liquid metal and the outer core – a so-called "current sheet." Next they used the azimuthal (an angle measured from any fixed reference plane) induction current and vector potential mode to perform a symmetrical 2D simulation based on the equivalent current sheet. With currents having only one nonzero component, the problem was formulated using the magnetic potential and solved for the same variables as above. Theoretical and numerical results closely agreed, and highlighted that the end effects have a significant negative effect on overall pump efficiency.

**AN ANALYTIC EM MODEL**




A schematic of an annular, linear induction pump shows its inner cylindrical core (fabricated from a ferromagnetic material), the annular channel through which the liquid metal flows, and the outer ferromagnetic core (in which a set of inductor coils is embedded).




A wind rose plot created in Matlab graphs wind speed and direction data collected from a meteorological tower.

form of known loads. Engineers analyze heat transfer for results such as the amount of heat flow and energy passing through the surfaces — output in terms of heat rate.

In each example, Autodesk Algor Simulation software has tools for performing mathematical calculations on input and output values, but users can also export simulation results as comma-delimited files to Microsoft Excel or a specialized mathematical tool such as Matlab to assist in calculating the design's efficiency. "Excel can sum values, such as a series of loads or results, and similar operations. Matlab, a program for technical computing, programming, and analysis, might be better suited for problems in which it is necessary to take a derivative, such as finding acceleration from a velocity value, or interpolating data," says Williams. "Should you find a design is not efficient enough, you could also change the loads and other parameters and let technical computing software such as Simulink help drive additional design iterations within the simulation software."

## Modeling controllers

In another area — that of modeling and dynamic simulation for control-system design — software such as Simulink from **The MathWorks**, Natick, Mass., *www.mathworks.com*, could be the ticket. "For instance, consider the design of a variable-frequency drive," says Tony Lennon, industry manager for Industrial Automation at The MathWorks. "The device regulates the frequency of power going to an ac motor to control its speed, and suits applications such as large industrial fans blowing cooling air throughout a facility. Modeling the motor and its drive lets developers design the control and signal processing algorithms using simulation. This approach lets you analyze overall system performance and quickly test and optimize various control strategies against multiple operating conditions of the drive."

Using modeling and simulation software also helps design power inverters, devices that convert dc to ac power from photovoltaic panels in a solar power system, says Lennon. Inverter developers use Simulink to create and simulate the control algorithms for converting dc to ac power and for maximum power point tracking to ensure that the inverter extracts the maximum power from panels under varying conditions of sunlight.

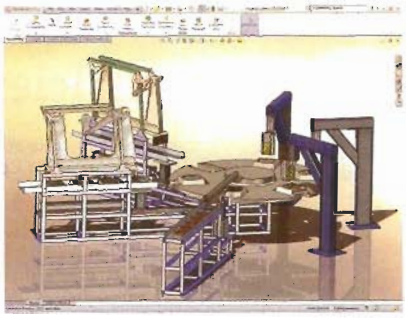
The software also handles code generation, handy because devices such as electric drives and inverters are controlled by embedded microprocessors, says Lennon. Efficient and compact ANSI / ISO C-compliant code can be generated from the control and signal-processing algorithms in the model. Developers can thus deploy and verify production quality software for a variety of microcontrollers used in these applications.

Such software finds application in the wind industry as well. Control systems in a wind turbine continuously adjust the blade angle to capture more or less wind and thereby control turbines speed to optimize energy capture. Here, the goal is to design a controller that keeps the turbine at a constant rotational speed while minimizing the motion of actuators on the blade. These kinds of problems are complex because they involve modeling and simulating mechanical, electrical, and control systems in one environment. "Using Simulink, engineers optimize the controller under a variety of mechanical and electrical operating conditions to ensure the turbine generates power at the proper voltage and frequency," says Lennon.

## Machines and motors

Simulation increasingly plays a role in efficiency calculations when determining how to best control motors, according to Kishore Boyalakuntia, Manager of Simulation Product Management, **Dassault Systemes SolidWorks Corp.**, Concord, Mass., *www.solidworks.com*. "For example, SolidWorks Simulation software lets users take a 3D model, put in a motor, and understand the machine's forces, velocities, and accelerations. Built-in analysis tools let users optimize the machine for weight. Additionally, SolidWorks Corp. partners with control-system companies so its programs link with control software. In this new integrated approach, users can match designs with controllers that make the systems most efficient." This allows upfront collaboration between machine designers and control engineers to fine-tune the mechanisms for efficiency.

For assembly components such as motors, two kinds of efficiencies are actually going on — electrical and mechanical. Designers gather all the mechanical and electrical data, and then calculate total efficiency.



Kinematic and dynamic analysis tools in SolidWorks 3D CAD let users perform efficiency-related design tasks such as size motors and actuators, determine power consumption, develop cams, understand gear drives, and determine how contacting parts behave.

Because friction loss is a big component in mechanical efficiency, the current version of the software lets users define their own friction between components. For standard materials, friction values are included in the motion simulation program. "Let's say you have designed a motor and you define the friction and friction loss and everything else," says Boyalakuntia. "All that's needed is to give the motor a certain rpm and the motion-simulation tool displays mechanical efficiency in the results."

On the electrical side, electromagnetic software helps users understand electrical and magnetic fields as well as magnetic and electrical fluxes in the design of a motor, Boyalakuntia says. "SolidWorks partners with other companies for electric and magnetic analysis. The way it works: users with both programs installed create a 3D model in SolidWorks and then run an electromagnetic analysis on it to optimize electrical efficiency." ■