# Multiphysics optimization

## A holistic approach to propulsion system design enables manufacturers to meet performance requirements while maximizing vehicle range

An e-motor cannot be developed just by looking at the motor as an isolated unit. The powertrain of electric vehicles must be developed to consider and fulfill an increasing number of internal, customer and legal requirements as well as increasingly ambitious target fulfillment goals for each component and for the complete powertrain.

Classical development strategies often take place among several parallel disciplines where negotiations and unfavorable compromises concerning attribute performance are common to reach a final design. How much stiffness and durability would need to be sacrificed in order to meet a motor's lightweighting target? Would changes made to improve thermal output affect the motor's efficiency? Is there a balance of attributes that would meet the program criteria better than an existing design option? All these questions are extremely difficult to answer without an integrated and holistic development strategy.

In order to better meet future requirements without significant sacrifices on target fulfillment, manufacturers are now turning to new optimization methodologies to support their integrated development strategies. This process, called multiphysics optimization, can account for requirements resulting from different physical phenomena simultaneously.

Manufacturers are responding to e-mobility challenges by implementing multiphysics simulation frameworks for designing high-performance electric powertrains. These methods enable designers to consider and optimize complex requirements to meet standards for performance, fuel efficiency, driving dynamics and everyday practicality. Altair has collaborated with leading auto makers to develop such a framework – an initiative called the Altair E-motor Director. This highly automated process is being developed to speed up e-motor development by facilitating multiphysics simulation, rapid design exploration and system-level optimization.

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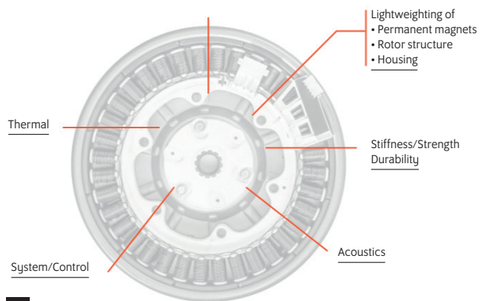
**1.** Altair E-motor Director will make multiphysics more accessible while streamlining optimized e-motor development

**2.** Parameters studied in a multiphysics design loop for an e-motor

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### DESIGN BALANCE

The challenge of improving the total design balance in e-motor development is confronted by taking a multiphysics approach. The classical motor efficiency and power design problem is coupled with other physics to account for thermal effects, structural boundary conditions and vibrations. Additional effects of the inverter on the motor performance can also be evaluated through integration of both controls and physical modeling. The objective of the design optimization and design exploration is to greatly improve the total design balance of considered attributes – including power, torque, vibration and efficiency – for the investigated driving conditions. At the same time, rotor stresses, motor vibrations and motor temperature must be kept within certain limits.

The design process accounts for both individual motor design points (such as maximum torque) and evaluation in standardized driving cycles using reduced order models based on data provided by full-order models in the Altair suite of physics simulation and optimization tools. Different physics simulation and optimization tools are combined and integrated to create a process for multiphysics e-motor optimization. The results of this effort are e-motor designs with improved design balance.





Altair is actively seeking OEM collaborators to guide the E-motor Director process and functionality development. This cooperation will involve leveraging the existing building blocks of the framework and incorporating customized modules to work in concert with manufacturers' established processes.

Integrating multiphysics into an existing powertrain design strategy can be a complex undertaking, but Altair's E-motor Director framework provides a pathway to implementation and the ability to automate key steps throughout the process for efficiency and repeatability. The workflow considers essential development requirements, including electromagnetics, thermal, NVH, stress and durability. It enables design of experiments, multi-objective optimization and design exploration methods to be used to explore and find feasible motor designs.

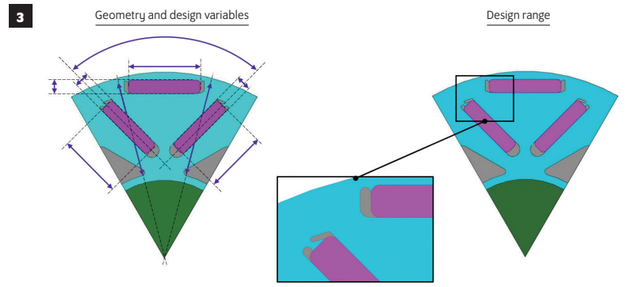
The process begins with domain experts from electromagnetics, durability, NVH and cooling providing their simulation models. The Altair E-motor Director platform then joins all attribute models together and identifies the best design considering the various attribute targets. The tool supports target negotiation, provides trade-off information and enables exploration of 'what if' scenarios. The optimized design decision information is then fed back to the design and attribute teams.

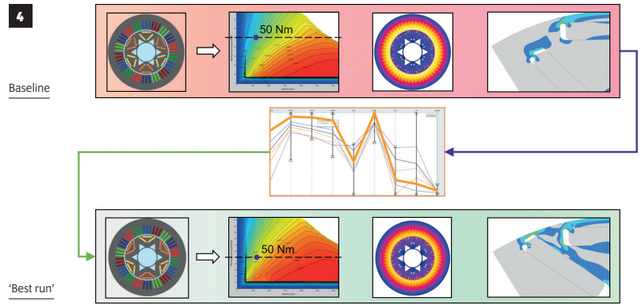
Multiphysics processes present many logistical challenges, particularly with setup time and repeatability. To create a more sustainable process, Altair focused its efforts on applying consistent treatment of design changes throughout different physics, installing high levels of automation and support to simplify the setup process, as well as ensuring efficient handling of data to and from the various design process tasks. The Altair E-motor Director strategy adds efficiency to the e-motor development process, which directly impacts the total cost of development.

This process ensures consistent geometry usage throughout all simulations, a high degree of process automation and a reliable data structure for storage and collaboration between attribute teams.

### MULTIPLE VARIABLES

Taking a true multiphysics approach enables e-motor developers to interrogate and optimize a design by balancing multiple variables. The first phase in this process concerns finding the right starting point for the multiphysics design process. Based on a classical rotor topology, different winding configurations can be investigated with respect to maximum torque and power for one working point close to the base point.

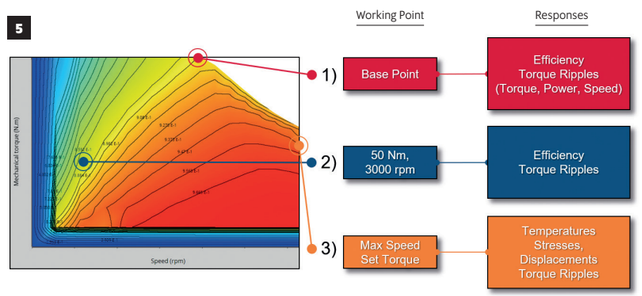



**3.** Simulation can be used to determine optimal location, orientation, and size of the rotor magnets

**4.** A comparison of electromagnetic, thermal, and structural performance – baseline vs optimal design

**5.** Working points and responses for a test scenario in the Altair E-motor Director




In Figure 1, Altair E-motor Director examines three working points along the mechanical torque and speed axis considering stresses, thermals and electromagnetic effects. After defining a design range, optimization helps to establish the best location, orientation and size of the magnets within the rotor. The simulation combines both global and local design variables to determine the optimal radii and view stresses at a detailed level.

Finally, a Design of Experiments study plots the responses of all geometry and design variants within a specified range. Macro-level domain constraints then narrow the number of viable designs, eliminating results that fall outside acceptable target values and enabling the designer to home in on a choice that best balances the desired performance and efficiency traits. All steps can be executed automatically using batch scripts, which not only saves time, but also ensures repeatability when making changes to geometry or examining design balance in future projects.

With Altair E-motor Director, users can set up and execute almost any multiphysics study, considering complex simulation chains, data dependency and multiple design requirements. Powertrain developers can define studies addressing the motor as an integration of systems models to understand and optimize the complete e-powertrain.

With the framework benchmarked and vetted by multiple customers, the Altair E-motor Director is now being developed as a customizable software package, planned for release in 2021.