Thermal Modeling of Electric Machines

Coupled electromagnetic-thermal modeling of permanent magnet motor

CHALLENGES: Thermal simulation tools to meet the challenges of electric and hybrid-electric

PRODUCTIVE SECTOR: Automotive industry

PROBLEM DESCRIPTION

The thermal behaviour of the electrical machine influences its lifetime, its efficiency, its performances and consequently the performances of the electric engine. So, the prediction of the temperature distribution inside an electric motor is required at the machine design stage in order to control the temperature rise and avoid overheating of the sensitive parts.

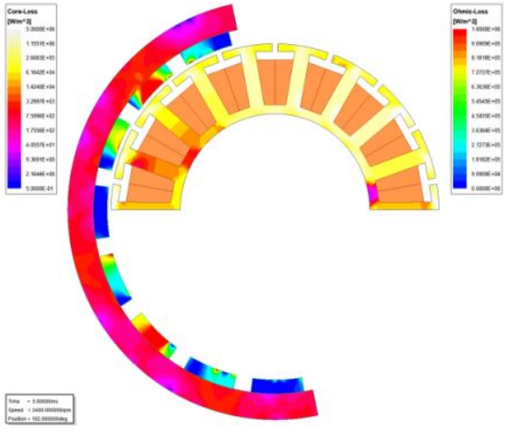
CHALLENGES AND GOALS

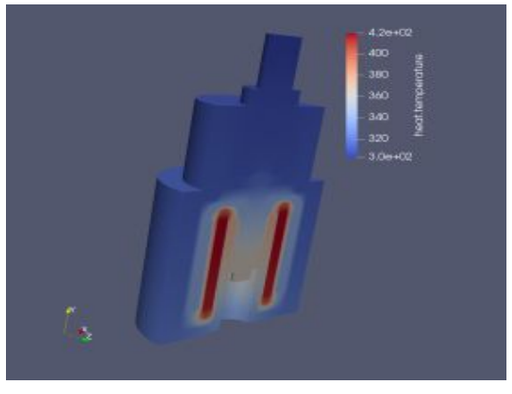
The main objective of our task is to develop a finite element model to analyse the thermal effects in electric machines during its various operating conditions.

MATHEMATICAL AND COMPUTATIONAL METHODS

The approach used in this work considers the entire system and takes into account the coupling among thermal and electromagnetic problems (EM).

The process of (EM)-thermal coupled analysis starts from the (EM) simulation that determines the losses for a given operating point. The losses are then fed into the thermal simulation to estimate temperature under such loss conditions. Since the material properties are temperature-dependent, they are updated according to the estimated temperature at the end of thermal simulation, and fed back to the (EM) simulation for another iteration. This iterative process stops when the temperatures converge.





The electromagnetic losses simulated in ANSYS Maxwell software used in the open source Feel++ software as the heat source to calculate the motor's temperature distribution.

Distributions of Ohmic loss and Contours of temperature

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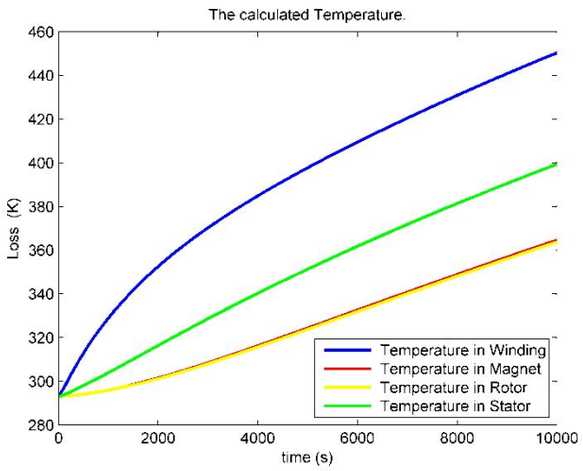
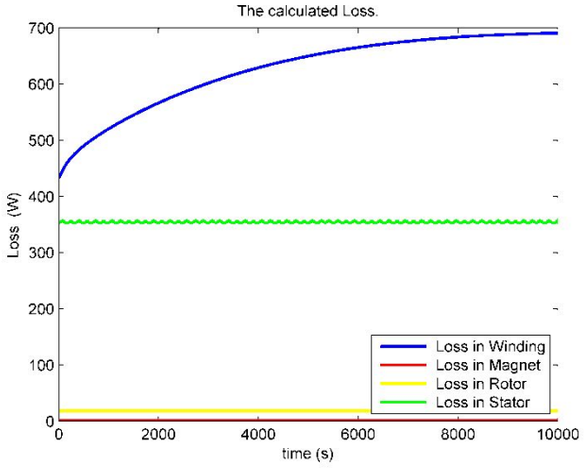
Results and Benefits

The suggested coupled thermo-magnetic model gives the possibility to evaluate the magnetic field distribution, the core losses in the ferromagnetic material and the temperature distribution of PM motor for different currents and for different geometrical parameters. The thermal model has been developed in multiprocessor environments and validated with experimental results.



Time evolution of the temperatures



Time evolution of the losses

The developed numerical techniques allows a better understanding the thermal behaviour of the electrical motors and can be used for designing these machines.

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