Thermal Modeling of Electric Machines

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CHALLENGES

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

The Industrial Problem

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.

This method can be used in automotive industry and in many other industrial applications, such as induction heating and melting.

Name of Research Group: Simulation and Optimization Mathematics Research Group

Research group

Numerical methods of differential equations: Finite Element Methods, Computational Fluid Dynamics and their utilization for industrial purposes.

Company

Company name

The Research Center of Vehicle Industry aims at providing appropriate research and development cooperation between automotive partners and higher education.

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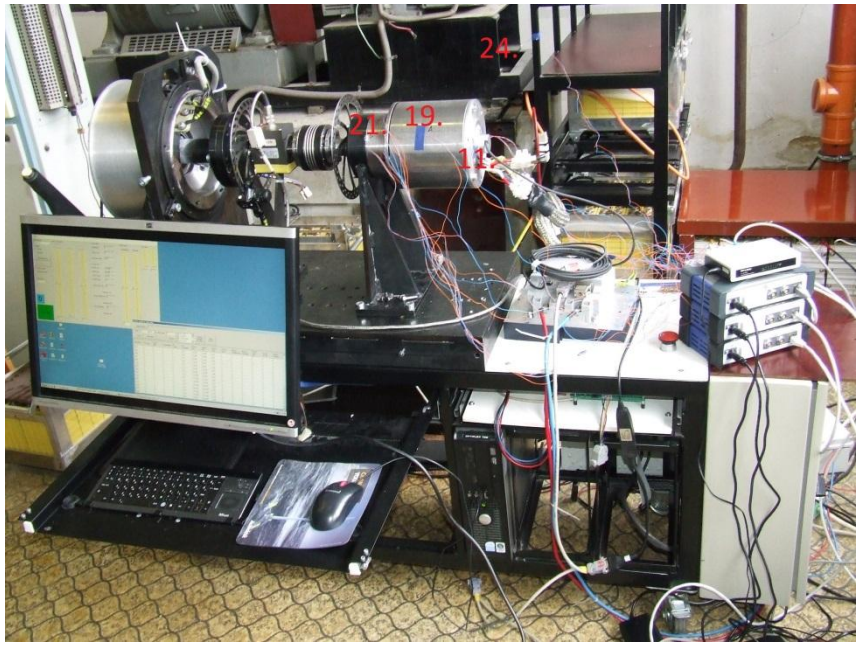
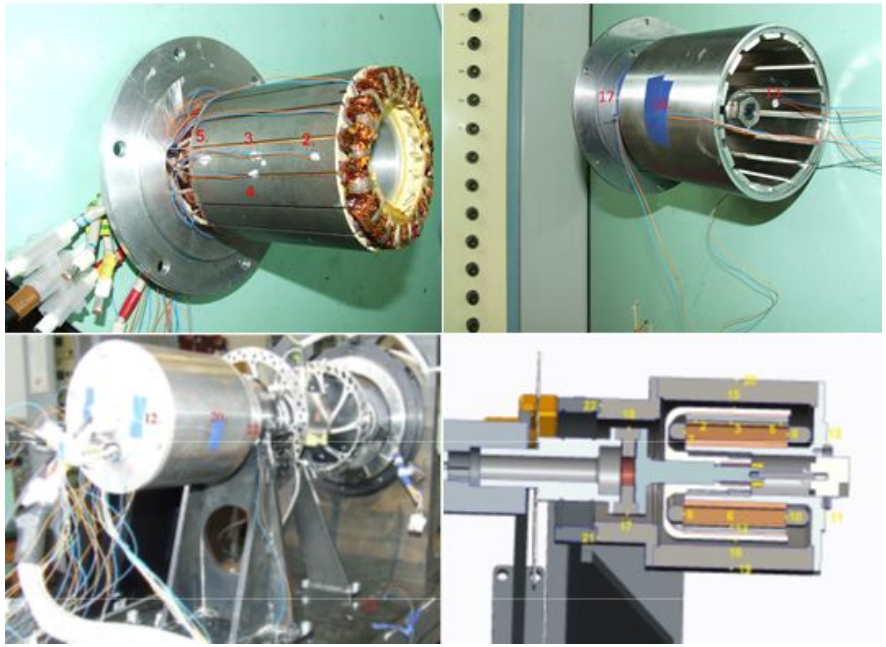
Challenges & Goals

- Development of numerical techniques and computer program for coupled magneto-thermal analysis .
- Implementation and validation of the developed algorithm in multiprocessor or multi-core environments.
- Sensitivity analysis to time increment and also to the mesh size in the numerical simulation.
- For validation purposes, the industrial partner provided us with the electric and thermal measurements data made on a 18-slots/16-poles outer-rotor permanent magnet synchronous machine (BMW C1 11 kW) .





Temperature test set up for the prototype machine and temperature sensors position

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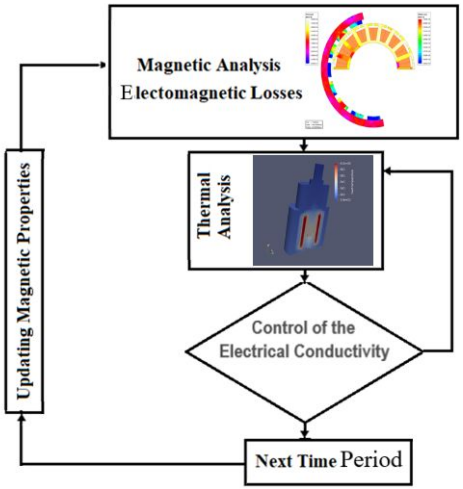
Mathematical and computational methods and techniques applied

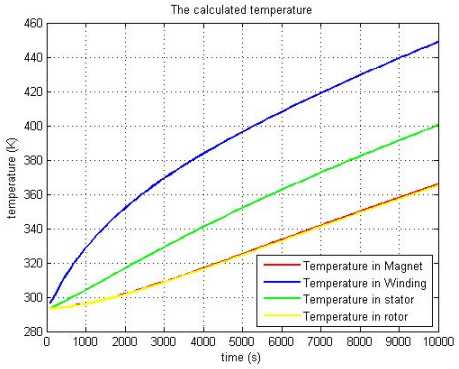
- The approach used in this work considers the entire system and takes into account the coupling among thermal and electromagnetic problems.

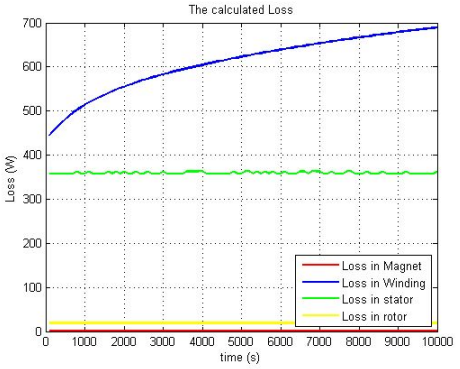
- Both thermal and electromagnetic processes are considered transient, solved by means of the FEM method on independent meshes and the time-discretization is realized using time operator splitting.

- To validate the effectiveness of the coupled thermo-magnetic model and code, two examples are presented. The first presents a numerical computation for the heat transfer in Toyota Prius 2004 electric motor. The second examines the transient thermal analysis of BMW C1 11 kW.



The Flow Chart of the Proposed Method





Time evolution of the simulated temperatures and losses in the (PM) motor.

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Results & Benefits to the company

- The simulation results show similar trends and the agreement is good for the critical parts of the electric machine such the winding, the rotor and the magnets.
- The thermal model has been developed and validated with experimental results.
- The developed method gives a fast and accurate way to evaluate magnetic field intensity, the core losses in the material and the temperature distribution of PM motor for different currents and geometrical parameters.

Simulated and measured temperature variation at different position of PM motor.

The studied examples have shown that the developed algorithm can be used to better understand the thermal behaviour of the electrical motors and would allow the development of new and more efficient motors.