PARTITIONED MULTIRATE SIMULATION OF ELECTROMAGNETIC-THERMAL PROBLEMS USING THE PRECICE LIBRARY

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Keywords: Electric Machines, Multiphysics Coupling, Multirate Simulation.

Abstract

This work explores the possibilities of using the library preCICE to couple different tools to solve electrothermal problems with multirate behavior. Exemplary results are shown for coupled simulation of a 2D transformer example.

1 Introduction

Computational efficiency is an important concern in the simulation of coupled multiphysical problems. When subproblems evolve on significantly different time scales, it may become inefficient to solve the problem as a single monolithically coupled system. This is, for example, the case for coupled electromagnetic-thermal problems, in which the temperature evolves much slower than the electromagnetic fields oscillate [1] but still requires time-domain solutions due to the nonlinearity of magnetic permeability and electric conductivity. Secondly, when using dedicated solvers for each phenomenon, possibly of black-box type, assembling and solving the equations of the coupled problem is hardly feasible. Therefore, in both cases, it is convenient to solve this coupled problem based on a partitioned approach and iterate between the subsystems.

Although there are various approaches, see e.g. [2], they all try to solve the different subproblems independently in time and exchange their mutual dependencies after time intervals at synchronization points. When waveforms are exchanged, in contrast to snapshots, this process can be iterated until convergence over the time interval, which is known as Waveform Relaxation [3] with windowing [4].

Open and closed source coupling libraries for multiphysics such as preCICE [5] and MpCCI [6] implement software interfaces, coupling algorithms and interpolation routines for time and space. While MpCCI has been used for a one-way electro-thermal-mechanical coupling in [7], we investigate here the simulation of fully coupled problems with preCICE. It has originally been developed for the cosimulation of partitioned systems with a focus on fluid-structure interaction [5] and has recently been extended to include waveform relaxation techniques [8].

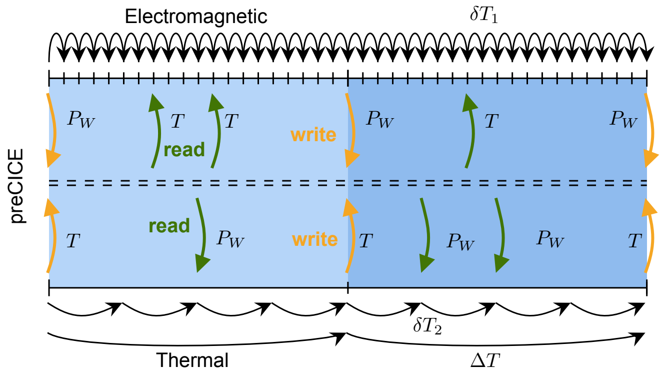

Figure 1: Schematic coupling an electromagnetic and thermal simulation with preCICE.

The aim of this work is to solve electromagnetic-thermally coupled problems with a focus on electric machines.

2 Multiphysical Coupling with preCICE

A schematic setup for the coupling of an electromagnetic and thermal simulation is illustrated in Fig. 1. The electromagnetic simulation is carried out with the time step size δT_1, the thermal one with δT_2, accounting for the individual physical time rates. When a time window of size ΔT is completed, the accumulated losses P_W and the temperature T are exchanged. Here, we choose to exchange values at the end of each time window without iterative solving for waveforms. The reading of losses and temperature is carried out adaptively. The tools necessary for time interpolation are provided by preCICE.

3 Results

The proposed method is applied to a benchmark example, seen in Fig. 2. The model consists of a 2D magnetoquasistatic simulation for a field-circuit coupled transformer. The circuit includes a source, load and resistors to model the coils. We investigate the heat generation, which is caused by eddy-currents in the core and ohmic losses in the coils. To this end, losses and temperatures are exchanged by providing the quadrature points of the Finite Element model to preCICE. Preliminary results can be seen in Fig. 3. On the left, one can observe the heat

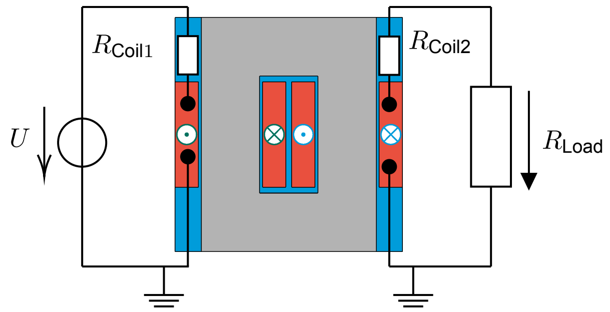

Figure 2: Simulation setup for testing the coupling with preCICE.

generation in the iron core due to eddy currents. On the right, the heat generation in the coils due to ohmic losses is visible.

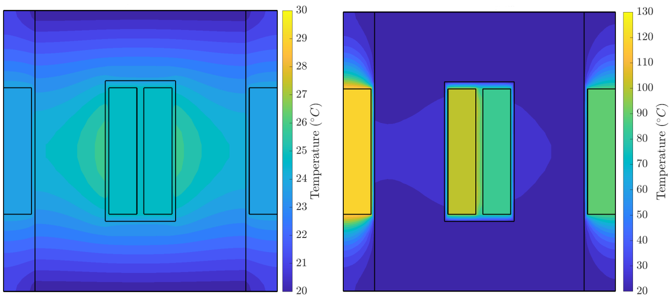

Figure 3: Simulation results for the benchmark problem. Left: Temperature distribution when only eddy-current losses considered. Right: Temperature distribution when only ohmic losses are considered.

Because the current in the coils is different, the temperature distribution of the left and right coils is not symmetric. The resulting temperature of the coils until steady state is given in Fig. 4.

4 Summary and Outlook

The coupling library preCICE is used to solve electromagnetic-thermally coupled problems in the context of electric machines with a partitioned approach. The presented results demonstrate the methodology applied to a field-circuit coupled transformer with temperature-dependent properties. The full paper will extend the investigations to coupled simulations of an induction machine. Also the coupling between open-source tools used in the community, such as GetDP [9] and openCFS [10], will be discussed.

Acknowledgments

This work is supported by the joint DFG/FWF Collaborative Research Centre CREATOR (CRC – TRR361/F90) at TU Darmstadt, TU Graz and JKU Linz as well as the Graduate School for Computational Engineering at TU Darmstadt.

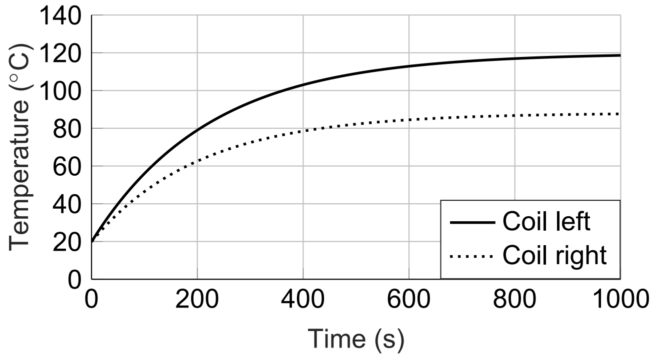

Figure 4: Temperature of left and right coils over time.

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