Modeling of a Magnetocaloric System for Electric Vehicles

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Introduction: Magnetocaloric heat pump system based on Magneto-Caloric Effect (MCE) is a promising alternative to vapor compression system.

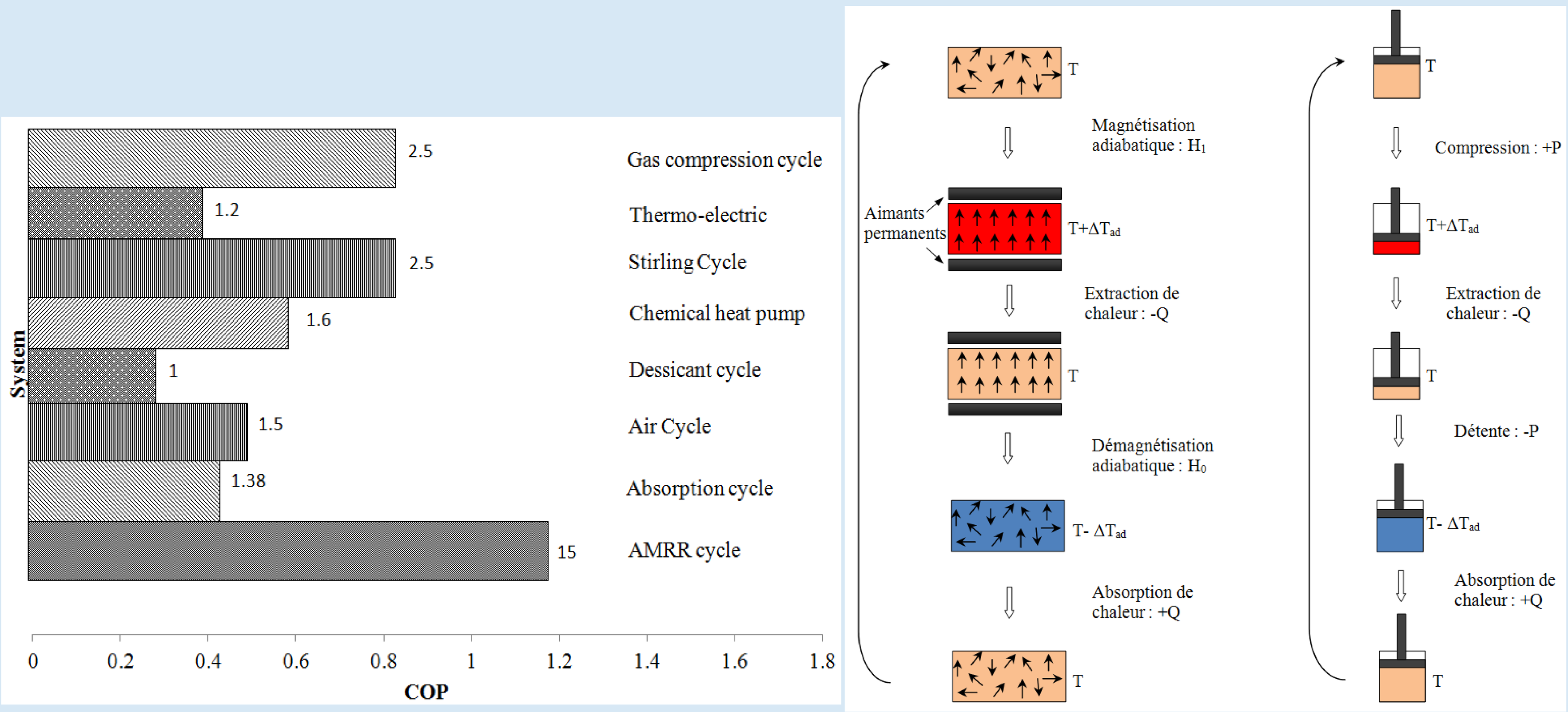

Figure 1. a) Comparison of principal refrigeration systems performance b) MCE and comparison with a vapor compression cycle

Magnetic refrigeration system combines the following advantages: efficiency, no use of polluting substances, low level of noise. It can be integrated in an electric vehicle to fulfill heating and cooling needs.

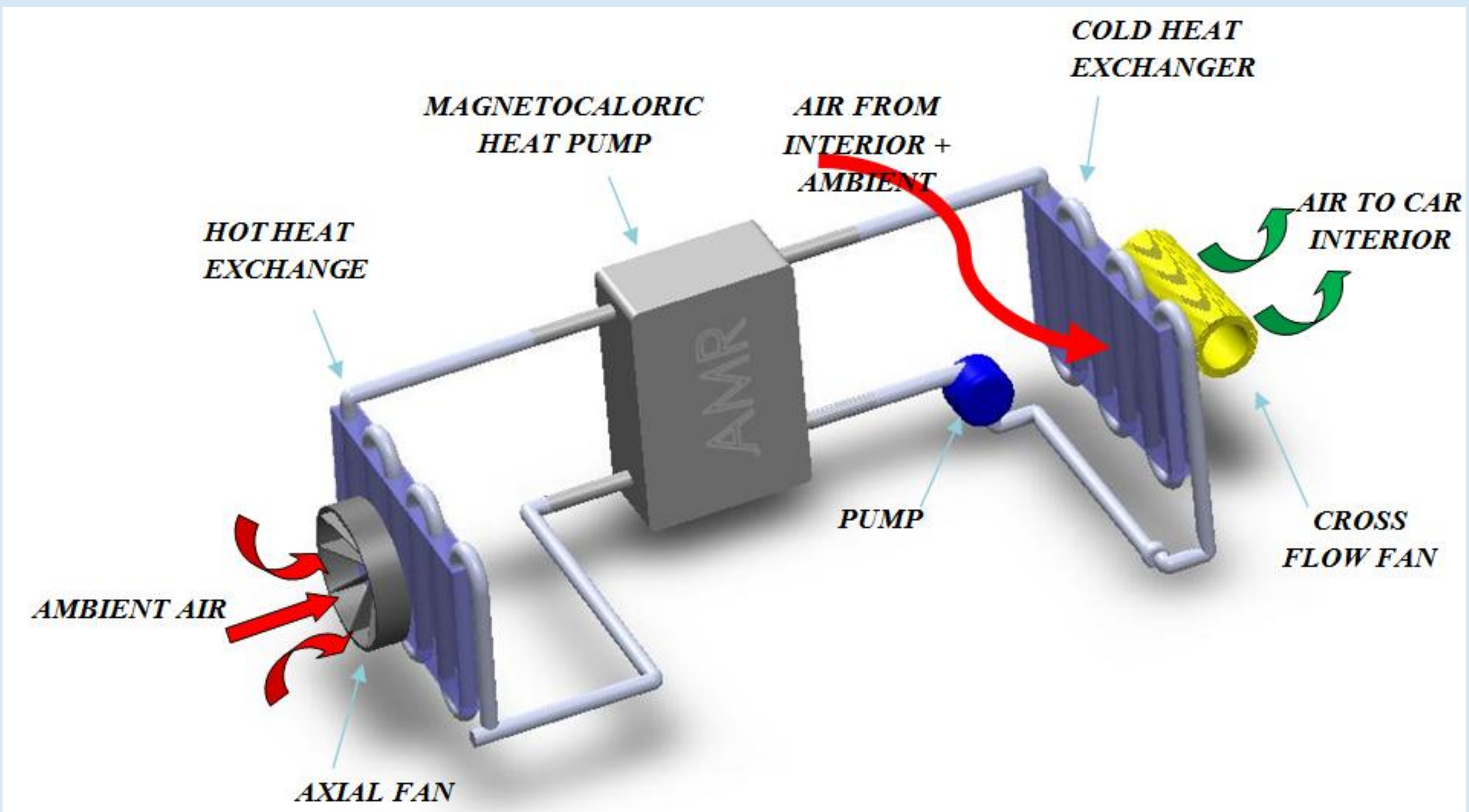

Figure 2. Scheme of Magnetocaloric heat pump integration in air conditioning circuit of electric vehicle

Computational Methods: A numerical study is needed and carried out in order to understand and optimize the behavior of that system. A 2D model is implemented using the following equations:

- Fluid domain

$$\rho_f C_{p,f}\left(\frac{\partial T_f}{\partial t}+(\vec{u}\cdot\nabla)T_f\right)=\nabla\cdot\left(k_f\nabla T_f\right)-\dot{Q}_{HT}$$

- Solid domain

$$\rho_s C_{p,s}\frac{\partial T_s}{\partial t}=\nabla\cdot\left(k_s\nabla T_s\right)+\dot{Q}_{HT}+\dot{Q}_{MAG}$$

The physical model is described in Figure 3. The solid regenerator is constituted of Gadolinium (Gd), the fluid is water.

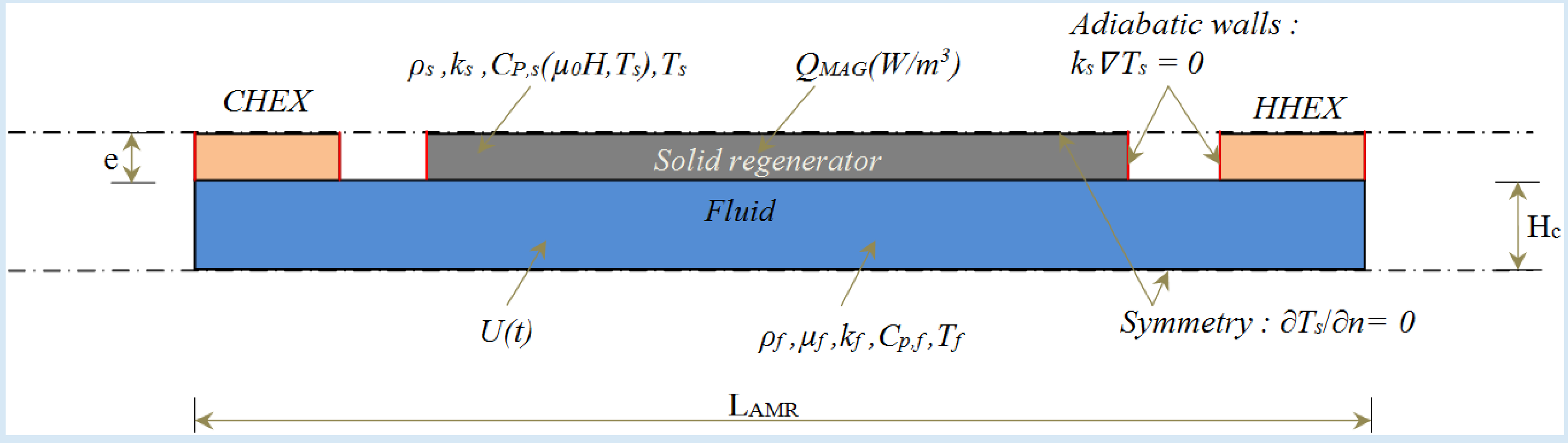

Figure 3. Physical model of an Active Magnetic refrigeration cycle

The "Conjugate Heat Transfer" module of COMSOL Multiphysics is used to model this physics. The "interpolation" function is used to interpolate the available data of Gd: $C_p(\mu_0 H,T)$, $\Delta T_{ad}(\mu_0 H,T)$, both depending of two variables, namely magnetic field and temperature.

Results: Following figures represent the obtained results

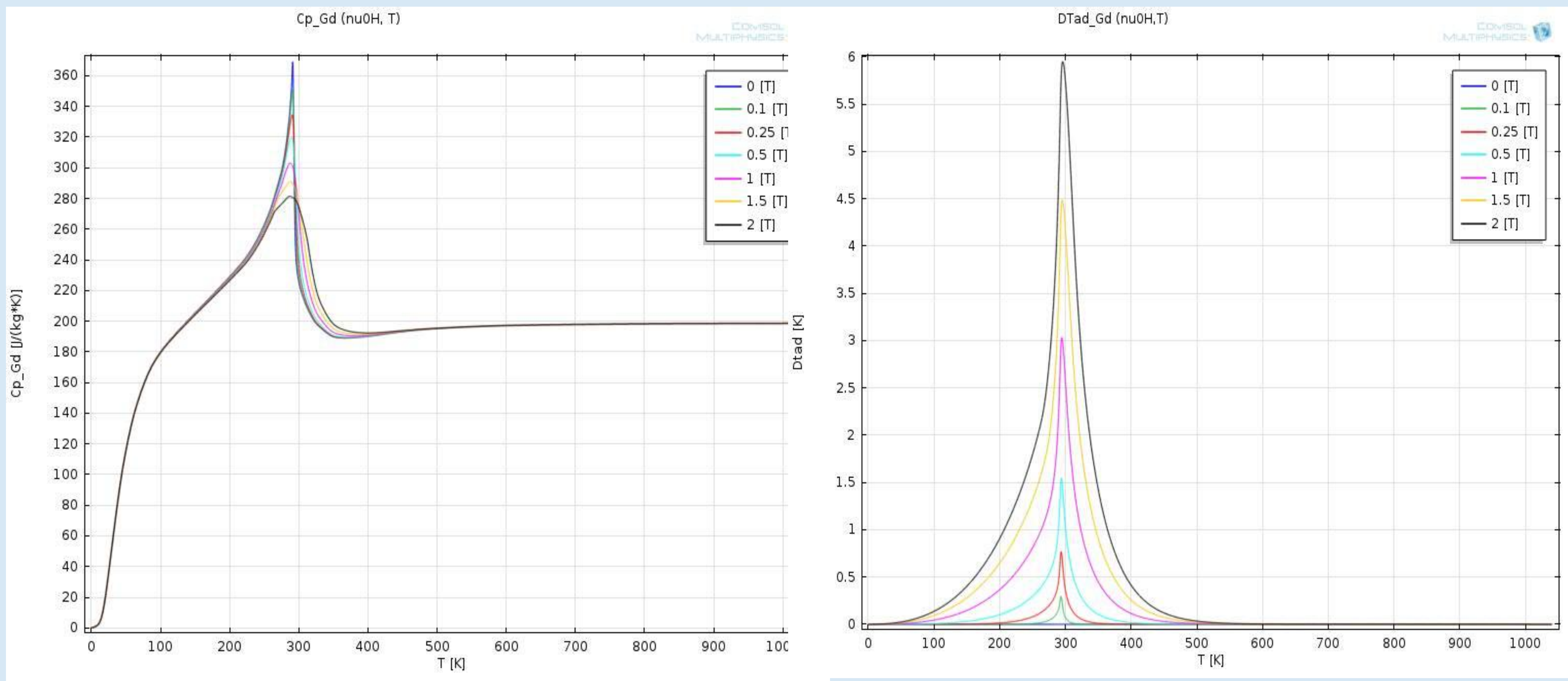

Figure 4. Interpolation of values of specific heat of Gd $C_p(T,\mu_0 H)$, and adiabatic temperature difference of Gd $\Delta T_{ad}(T,\mu_0 H)$, using COMSOL function "interpolation"

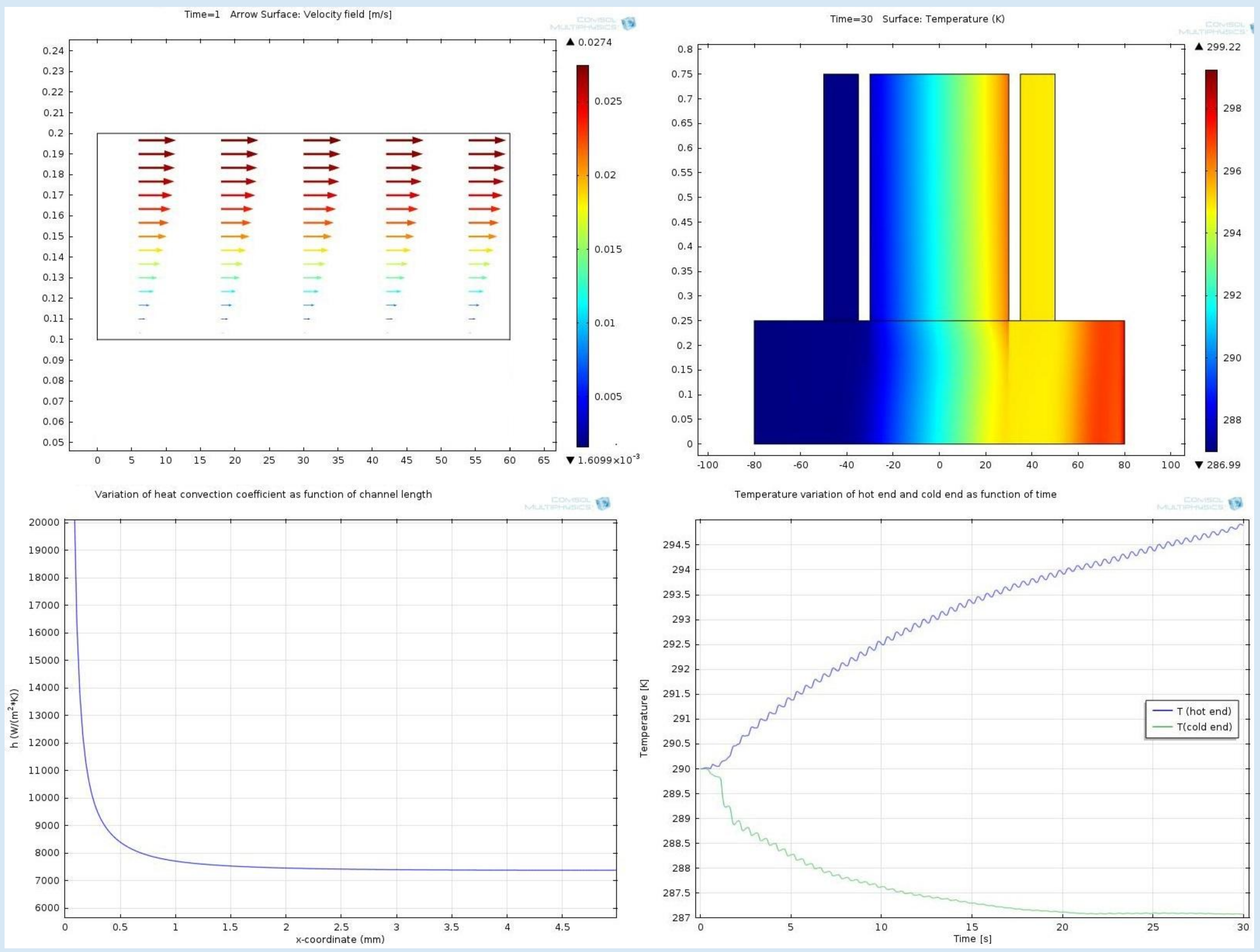

Figure 5. Representation of velocity field, temperature field, heat transfer coefficient variation, cold end and hot end temperatures variation

Conclusions: The model built in this study makes it possible to simulate a magnetic refrigeration cycle. The heat source (Q_{MAG}) which represents the MCE equation is modeled using available data from experimental measurements. The results obtained constitute a good base for a next optimization work.

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