FEMCE - A 3D simulation software for heterogeneous magnetocaloric studies, based on the finite element method.

Tutorial

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This document demonstrates the functionality of FEMCE by guiding the user step by step to simulate a conventional refrigerant in magnetic refrigeration systems. We are going to simulate the same Gd sheet present here https://doi.org/10.1063/1.3487943.

Step 1 - Model

The first step is to create a container. **Start by setting the "Cuboid dimensions - W D L" to 15, 7.5 and 3** (cm) (Figure 1) and then **press the "Add"** button.

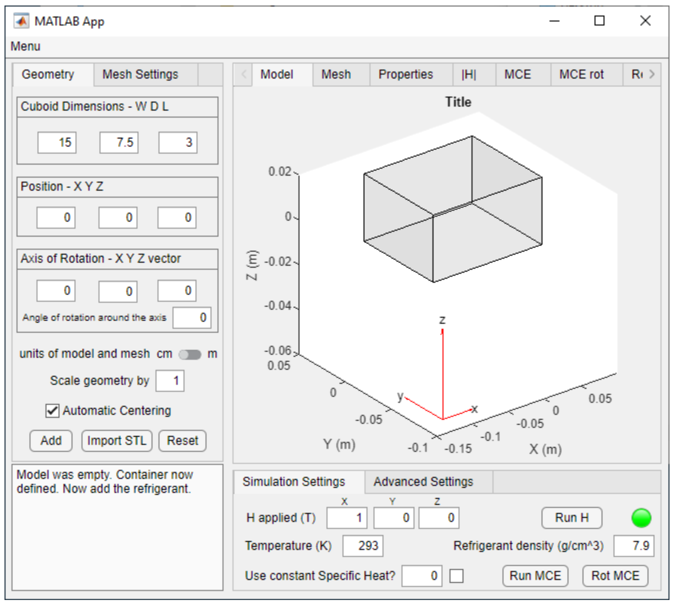

Figure 1: Adding a container.

Next, add the refrigerant dimensions on the **"Cuboid Dimensions - W D L": 4, 2.5, 0.09 (cm), and click "Add"**. You should now have a thin sheet inside the container (Figure 2).

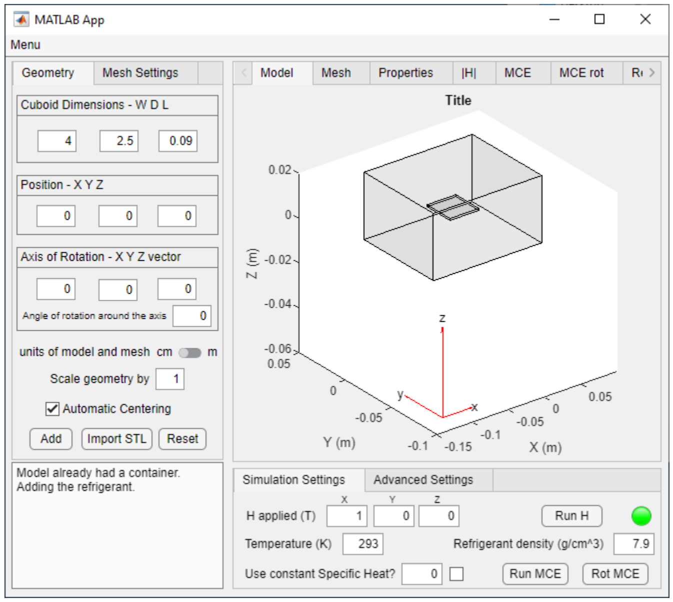

Figure 2: Adding the refrigerant.

Step 2 - Mesh and properties

Now, you must create a mesh for the model. **Press the "Mesh Settings" tab**, next to the "Geometry" tab. You can set a target size for the elements of the mesh, or leave it as 0 to let the app define the mesh for you. **Press the "Mesh" button**. Now, on the message terminal you should see that the mesh generation was a success. You can view the mesh by selecting the "Mesh" tab, next to the "Model" tab (Figure 3).

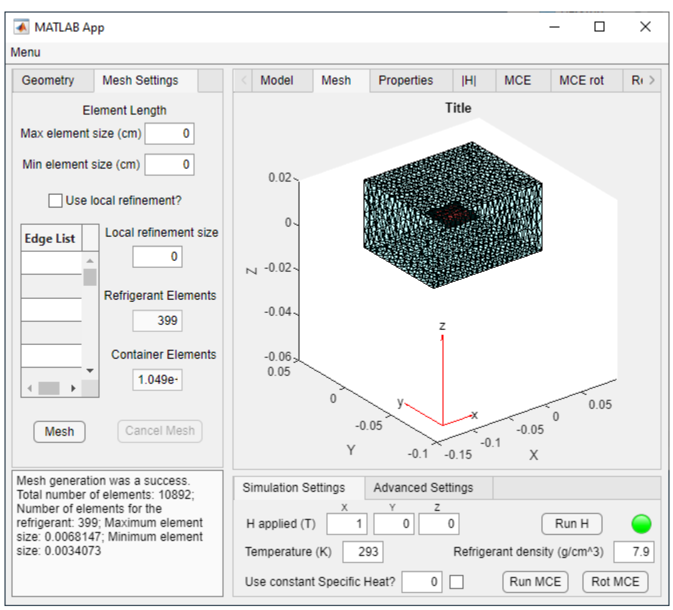

Figure 3: Generating the mesh.

Lastly, **load the magnetization and specific heat** data of the refrigerant by going to **Menu » Load Properties » Load All**, and selecting the folder that contains the data of the refrigerant (Figure 4). This data must be saved in a specific structure. For example, magnetization $M(H, T)$ must be a matrix where each row corresponds to M at a different magnetic field, and each column corresponds to M at a different temperature. You must also provide the H and T arrays of that data. You can load files individually, with any name desired, but for "Load All" the files must be named "Cp", "M", "TofCp", "TofM", "HofCp", "HofM" accordingly. You can also load the temperature change ($\Delta T(H,T)$) data just like you would the magnetization and specific heat, if you want the program to interpolate that information instead. C_p can be provided as solely temperature dependent, or you can select "Use constant Specific Heat?" and provide the value in J/g/K.

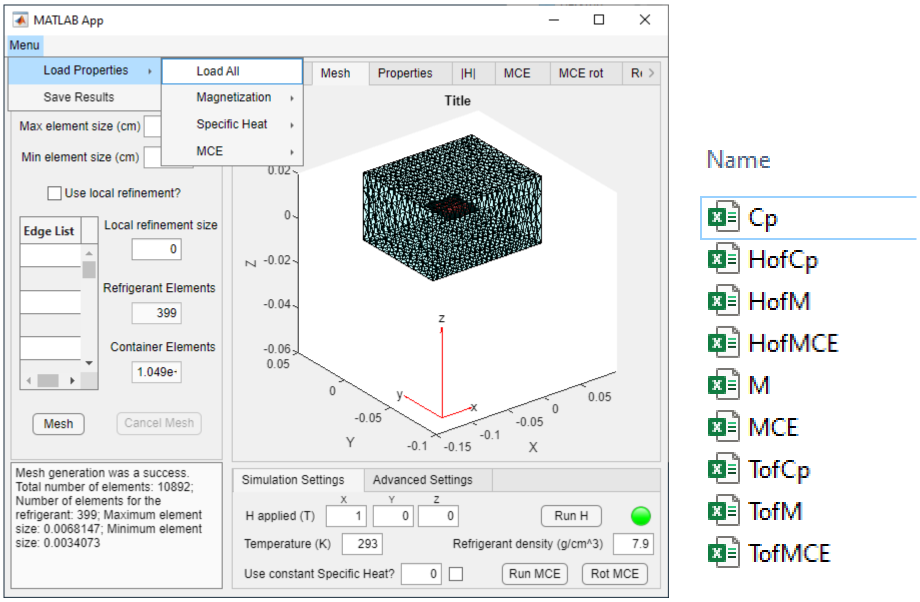

Figure 4: Loading material properties.

Step 3 - Run simulation

The next step is running the simulation. In this tutorial, the refrigerant is Gd so we keep the default refrigeration density of 7.9 g/cm^3 and we are going to keep the default field direction and refrigerant temperature. **Press "Run MCE"**. After the simulation is concluded, you can view the magnetic field of the sample and its temperature change. To view the magnetic field H press the "|H|" tab, next to the "Properties" tab. The heterogeneous magnetocaloric effect is on the next tab, "MCE" (Figure 5).

Looking at 5, the center of the sample exhibits the highest temperature change, and the extremities along the external field show the lowest temperature change. This is thanks to the demagnetizing field! The internal magnetic field is not uniform for non-ellipsoid geometries.

An alternative method of inducing the magnetocaloric effect was recently explored (https://doi.org/10.1088/2515-7655/ad1c61). It uses the demagnetizing field to generate the change in temperature, by rotating a sheet of Gd inside a uniform magnetic field. FEMCE can also calculate the ΔT of that procedure (Figure 6), showing a different temperature profile and of different overall intensity.

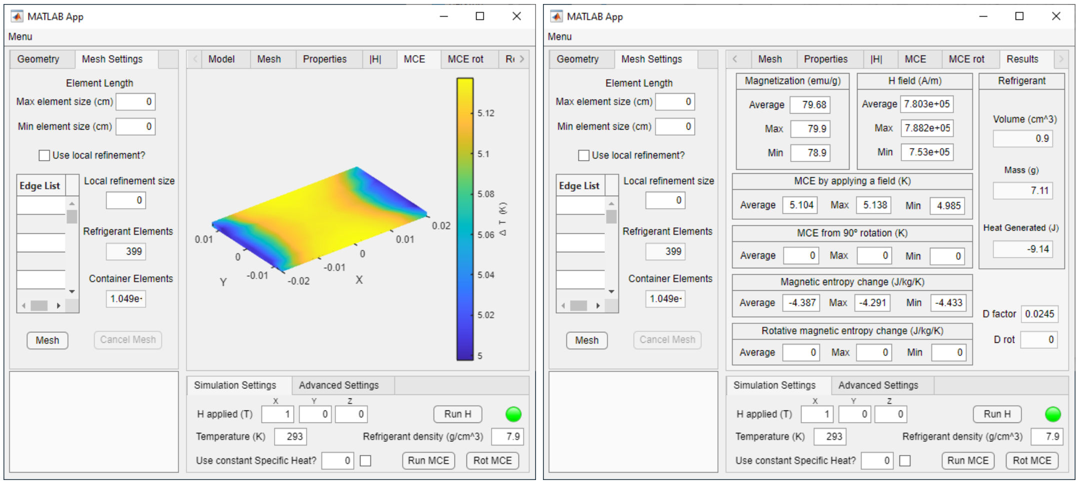

Figure 5: The heterogeneous ΔT (left) and the results table (right).

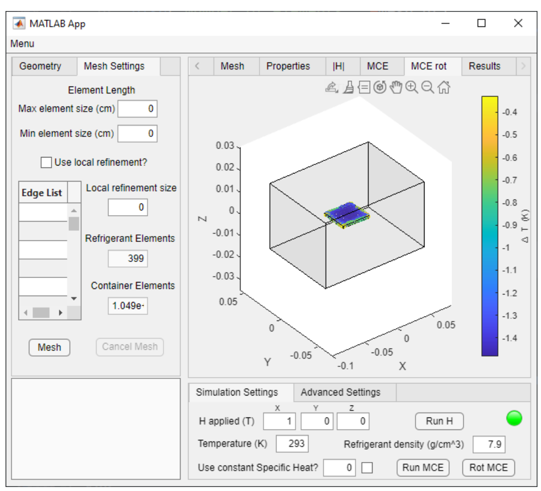

Figure 6: The heterogeneous demagnetizing field induced magnetocaloric effect. Effective $\Delta T = -1.28$ K for an external magnetic field of 1 T.