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Modeling a Thermoelectric Cooler in Thermal Desktop

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A thermoelectric cooler (TEC) is a solid state device based on the Peltier effect. The device is typically comprised of an array of P and N type couples sandwiched between two ceramic substrates. The couples are typically made of bismuth-telluride although other materials may be used. By applying a current across the device a temperature drop can be created, thus providing a cooling capability for sensitive electronics and other applications. By reversing the current the device can become a heater. Thermoelectric coolers are not very efficient and can draw large amounts of power.

Historically, modeling a TEC in a system level thermal analysis package was left up to the user. The sizing was done by hand using performance charts, etc. The user was required to create unique logic to simulate and control the device. SINDA/FLUINT now offers built-in TEC modeling methods. These techniques are also accessible from Thermal Desktop, SINDA/FLUINT's CAD-based GUI. With these new methods, the user can simulate a single stage, or a stack of multiple coolers. Options are available to obtain performance specs, model non-bismuth telluride devices, and perform parametric modeling and design optimization. Specific routines have been created to apply temperature control to the cooler using either thermostatic or proportional control methods.

Example Problem

The following sample model of a TEC has been created in Thermal Desktop to assist new users in setting up their own simulation. This example is based on a sample problem ublished by Melcor Corporation and Electronics Cooling[1].

A device, 1.56 x 1.56 inch, dissipating 22 watts of waste heat, needs to be cooled to 5C in an

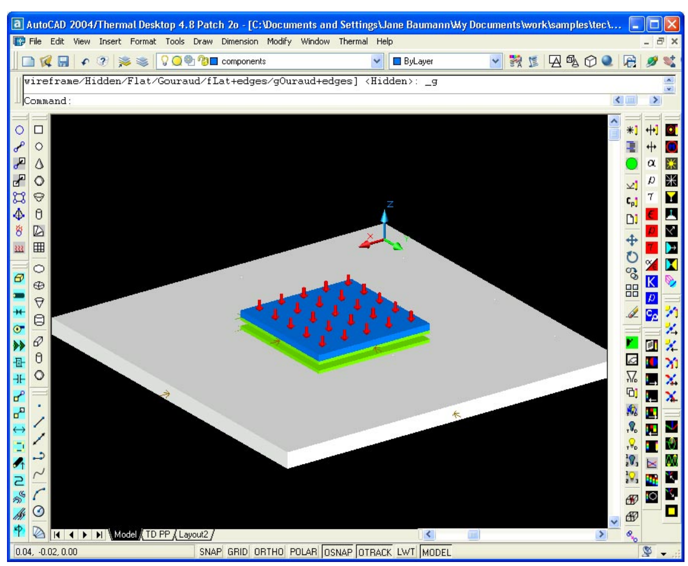

Figure 1: Thermal Desktop Sample Model

[1] An Introduction to Thermoelectric Coolers by Sara Godfrey, Melcor Corporation, http://www.cooling.com/Resources/EC_Articles/SEP96/sep

environment of 25C. The heat sink is placed in a convection environment with a resistance of 0.15 C/watts to the surrounding air.

In the Thermal Desktop model shown in Figure 1, the heat sink, shown in white, has been modeled using an FD brick with a conductor to the sink of 1/0.15 watt/C. This is a simple representation of the heat sink since the resistance provided is not a function of convection area. The device to be cooled (depicted blue) has also been modeled using an FD brick with an applied heat load of 22 watts. These surfaces could also have been modeled using Thermal Desktop rectangles but it was the analyst's goal to capture 3D gradients within the surfaces so FD bricks were used.

To model the TEC, the analyst has again used FD bricks to model the two ceramic substrates (the green surfaces in Figure 1). The substrate on the cold side is connected to the device to be cooled using a contactor. Likewise, the hot side substrate is connected to the heat sink using a contactor.

The array of couples between the two substrates is modeled using Thermal Desktop's TEC contact as shown in Figure 2 (menu: Thermal>FD/FEM Network>Thermoelectric Cooler). Upon creation the user specifies the hot and cold sides of the TEC along with the control parameters. Internally SINDA/FLUINT calculates the cooling capacity of the TEC, power required, and temperature gradients. The user has the option of creating conductors through the couples to capture the heat leak. It is recommended the user always model the heat leak through the device since it can be significant.

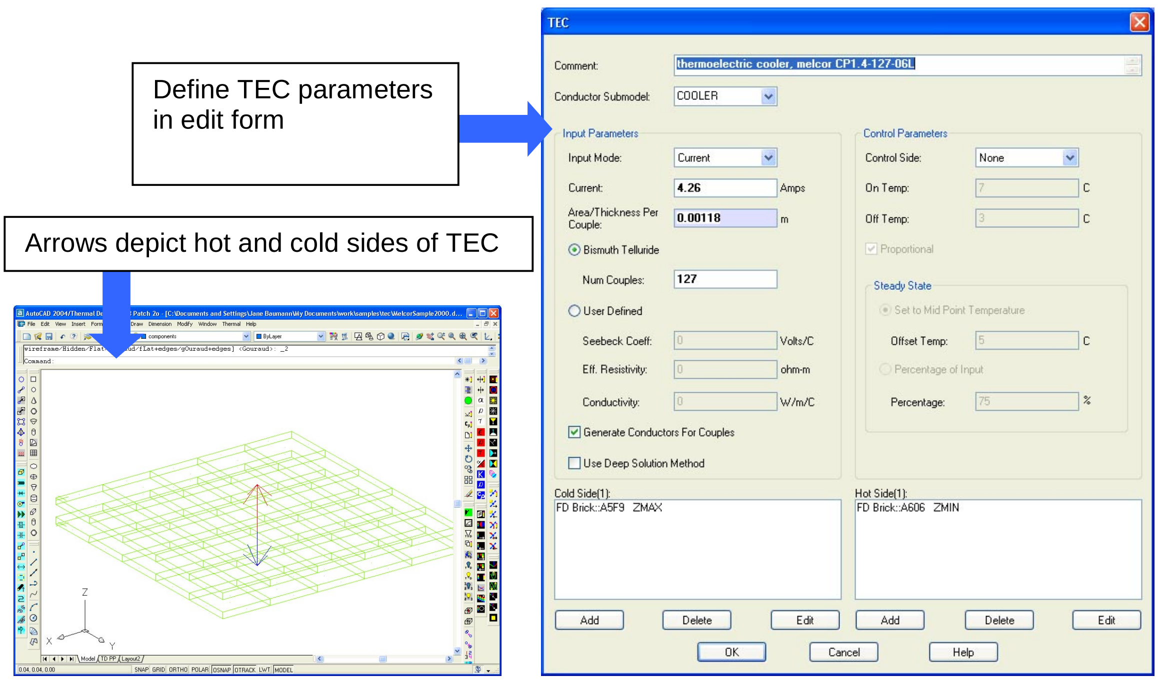

Figure 2: Defining a TEC in Thermal Desktop

Optionally, the user can model radiation across the interior of the TEC or conduction through an epoxy fill. These two paths are up to the user to define through additional user defined conductors or with contact. Please note that RadCAD is not appropriate for calculating the radiation across the TEC.

Temperature Control

You have two options for temperature control on a TEC device. You can use 1) the temperature control defined directly on the TEC input form or 2) create logic to access the SINDA/FLUINT cooler temperature control subroutines COOLCON and PCOOLCON. The first option (using the TEC form) allows you to define either thermostatic or proportional control. These options only apply to transient simulations. For steady state simulations you need to define the temperature set point of the device and an optional temperature offset.

If you are sensing from a remote location, you will need to use the second option, the routines COOLCON and PCOOLCON. These routines are useful when the TEC is being used for cooling a device. If the TEC is being used as a heater, use HEATER or PHEATER instead, and note that the output can be a current instead of a heat rate. Alternate logic (perhaps HTRNOD or BDYNOD) should be used for steady-states. All these SINDA based options need to be done in logic and will require editing the *.cc file outside Thermal Desktop.

Parametric Options

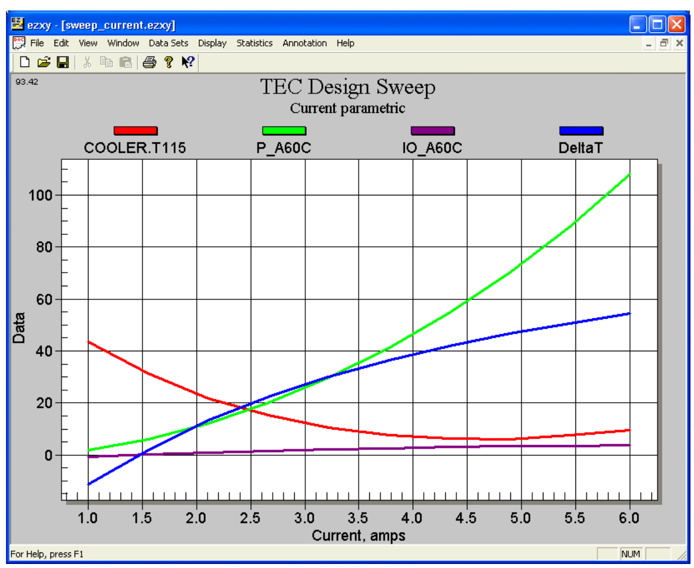

Figure 3: Parametric Sweep on Input Current

Thermal Desktop allows the user to define a parametric run on input current to see how the TEC will perform over the available current range. A similar parametric sweep can be performed if you have opted to use power or voltage control on the TEC. To setup the parametric run simply define the input parameter as a symbol in Thermal Desktop. Through the case set manager, on the S/F Calculations tab, edit the parametric parameters to select the appropriate symbol, its min/max values, and the number of steps to evaluate. Running a parametric from the Thermal Desktop Case Set Manager, invokes the dynamic SINDA mode. To make the parametric work, you must define the submodel in which the cooler resides to be static. This is done by going to the Dynamic tab of the case set manager and clicking on the Submodels button. Figure 3 shows the results of the current sweep for our example.

At this time, Thermal Desktop does not allow the number of couples and the aspect ratio to be output to SINDA as an expressions, thereby preventing the user from running parametric runs on these parameters through the case set manager. If you need to run these as parametrics, you can edit the underlying *.cc file to specify expressions for these variables in the call to the TEC2 subroutine. You can either setup the parametric by editing the parametric logic created by Thermal Desktop or you can create your own logic to run the SINDA/FLUINT subroutine PSWEEP.

For more information on modeling thermoelectric coolers or using Thermal Desktop, please contact C&R Technologies, Inc.

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