Simplifying the Model

Three global options for model simplification are provided.

Element Merging

Use *Element Merging* to merge the calculation points for selected elements, producing a smaller model to solve. This is equivalent to defining very large conductances between the selected elements, or forcing their temperatures to be identical. The temperatures of all elements are recovered after the solution.

You can use Element Merging to help "condition" a thermal model to reduce solution time by merging high conductance or low capacitance elements. You can also use it for symmetric models, parameter runs, or localized analysis.

If you wish to directly assign a label to the merged element, select *User Supplied* and enter its value. Otherwise, select *Automatic* and a label will be assigned to it at run time.

To perform element merging by proximity (i.e. to merge each primary element to the nearest secondary element), use the *Thermal Couplings Join* option.

Element Elimination

Use *Element Elimination* to reduce the size of the thermal model matrix by eliminating the calculation points of selected elements. This "substructuring" of the thermal model is carried out using the Star-Delta Transform technique for eliminating nodes from a network. Temperature results for all eliminated elements are recovered for post-processing. Element elimination can be used to effectively precondition a thermal model to reduce its solution time.

Elimination Criteria

You can select directly the elements whose calculation points are to be eliminated from the thermal model matrix, or specify a criteria by which TMG will select them.

With the *Time Constant* option, All elements whose thermal time constant is less than the time constant you specify will be eliminated from the model. An element's time constant is equal to its thermal capacitance divided by the sum of all conductances attached to it.

Alternatively, you can specify the elimination of all elements whose conductance is greater than a specified *Conductance Sum* or less than a specified *Capacitance Sum*.

Ineligible Elements

Certain elements are ineligible to be eliminated:

- elements that you have selected in an *Element Locking* set
- elements defined with a *Temperature Boundary Condition*
- elements with any other time varying boundary condition
- elements with temperature-dependent properties

- flow model elements
- convecting elements
- elements which can change phase

Element Elimination Concepts

Element calculation points are eliminated from the discritized thermal model matrix as follows:

1. Radiative conductances to the selected elements are linearized using

$$G = \sigma\varepsilon AVFG\left(4T_e^3\right)$$

where T_e is a global temperature estimate which you define with the TLIN parameter in *Advanced Solver Control*.

2. The conductance matrix is reduced using

$$G_{ij} = \frac{G_{ik} \times G_{jk}}{\sum_i G_{ik}}$$

where elements i and j are both coupled to element k which is eliminated. This process is equivalent to performing a row and column reduction on the matrix. Note that it can (and generally does) introduce conductance terms between elements that were not previously connected.

3. The heat load on the eliminated element k is redistributed using

$$\Delta Q_i(t) = \frac{Q_k(t) \times G_{ik}}{\sum_i G_{ik}}$$

4. The capacitance of eliminated element k is redistributed using

$$\Delta C_i(t) = \frac{C_k \times G_{ik}}{\sum_i G_{ik}}$$

In carrying out this process, TMG stores the element's conductances and heat load prior to eliminating it from the model. After the reduced model has been solved, this data is used to automatically recover the temperatures of the eliminated elements. For transient runs, this recovery process is only carried out at the Results Printout interval, and not at every time step.

This process of eliminating and recovering elements is in essence just a different method of solving the full model. For most models, the overall solution time will not be reduced by using this technique; in fact, solution time can often be substantially increased. Nevertheless, element elimination can prove beneficial in a number of particular situations:

- To eliminate elements which are strongly coupled to their neighbors. Large conductances (relative to some average value in the model) can cause the thermal model to be numerically ill-conditioned. Such models will converge very slowly for steady-state solution. Use the *Conductance Sum* option to automatically select such elements.

- To remove zero-capacitance elements from a transient analysis. These can slow down solution time since their temperatures are computed by iteration at each integration time step. Use the *Capacitance* option to automatically select such elements.

- To eliminate from a model the low-capacitance elements which govern the integration time step size for the Forward method. This will allow a larger time step to be used, reducing solution time. Use the *Time Constant* criterion to automatically select such elements.

- To produce a reduced but accurate thermal model for repeated parameters runs, localized analysis, or incorporation into a large system-level model.

- To compute a single equivalent conductance for a conductive heat path through a complex object or assembly.

Accuracy of the Elimination Process

For steady-state analysis, the element elimination process yields a mathematically exact reduction of the thermal model if the eliminated elements are fully linear (connected only by linear conductances) or fully radiative (connected only via radiative conductances). If the element is connected by both linear and radiative conductances, there will be an error introduced by the reduction process; this error will be small if any of the following are true:

- The eliminated elements are either conduction or radiation dominated

- A good temperature estimate is used for the radiation linearization

- The redistributed conductance or heat load is small

For transient models, the redistribution of the eliminated element's capacitance always introduces an error, which is equal to:

$$\frac{\left[\frac{dT}{dt}\right]_{max} \times C_k}{\sum_i G_{ik} \times DT_{max}}$$

This error is small if the element has little capacitance, strong coupling, or low temperature volatility.

Notes on Element Elimination

- Use *Advanced Solver Control* to specify the temperature estimate for linearization of the radiative conductances.

- You can prevent elimination of selected elements by including them in a *Locked Element* set.

Element Locking

Use *Element Locking* to prevent elimination of selected elements. The selection of elements for *Element Elimination* can be performed automatically by specifying global criteria such as element time constant value or conductance sum. If an element is selected in an *Element Locking* set, it is not eliminated from the model.

Element Deactivation

Use *Element Deactivation* to deactivate elements in the thermal model. The selected elements are simply ignored by TMG as it generates the finite difference model. You can use *Element Deactivation* to perform localized analysis, or to build up a system level thermal model by individually computing thermal model data for subassemblies (see *Setting Restart Comtrol* for information on reusing thermal model data).
