Contents   Find

Setting Steady State Analysis Parameters

For most models, you will not have to reset any steady state parameters: the default settings will give good results.

Iteration Control

The *Maximum Number of Iterations* you specify does not affect solution accuracy; it simply sets a "hard stop" for the iterative solver.

Most thermal models will converge in less than the default of 10000 iterations. If you find that convergence has not been achieved within the iteration limit, increase its value. You may also consider some of the *Solution Method Options* to accelerate convergence.

Use the *Relaxation Factor* to increase the stability of a steady state model solution. At every iteration, TMG calculates new temperatures based on the element heat imbalance. The new temperature T_{new} is calculated by

$$T_{new} = (1 - \delta) \times T_{old} \; \delta \times T_{eq}$$

where δ is the *Relaxation Factor* and T_{eq} is the element's equilibrium temperature, at which its heat flows are balanced. Values of less than 1 will "damp" the iterative solution process, increasing both stability and solution time.

For models that are highly non-linear (e.g. dominated by radiation or fluid effects), the iterative solution can oscillate or even diverge. Use smaller *Relaxation Factors* (to increase stabilizing effect) combined with a higher iteration limit to ensure convergence for such models. Values of 0.1 or less may be required.

For linear models (conduction dominated), set the *Relaxation Factor* to 1 (off) to minimize solve time.

Convergence Criteria

TMG uses an iterative technique to solve the thermal model. This requires *Convergence Criteria* to determine when the model solution is "good enough". Excessively loose convergence criteria can result in poor accuracy; very tight criteria can unnecessarily increase solution time.

The *Temperature Stability* criterion is the maximum temperature change of any element from the previous iteration. Enter the value for determining convergence; typically a value of 0.001° will give adequate results. Note however that temperature stability is not a "true" indication of model convergence: you should always check the overall heat balance.

Activate the *Heat Balance* option to establish an additional convergence criterion based on global heat balance.

Select *Residual Fraction* to apply a convergence criterion based on the model heat imbalance normalized by the heat flow into the "sinks" (fixed-temperature elements).

Generally a value of 0.005 gives good results.

Select *Absolute* to define the heat balance criterion based on the difference between the heat applied to the model and the heat flow into the sinks.

Transient Boundary Conditions

Specify the treatment of time-varying boundary conditions for the steady state analysis. Three options are provided:

- The *Time Average* option computes the time average of all element heat loads and use them as steady state boundary conditions. This is useful when the heat loads are periodic (e.g. orbital heating).

- The *Use loads at specified time* option allows you to specify the time value at which TMG will evaluate the transient boundary conditions and apply them as steady state. Enter the time case for the simulation. TMG will evaluate transient boundary conditions for that time, and apply them as steady state.

- The *Do not use transient loads* option tells TMG to ignore all time-varying boundary conditions.

Handling Thermostats in Steady State Solutions

If your model includes thermostats, you must also specify how the thermostat should be handled during a Steady State calculation. You can use the THERMOSTAT parameter for this.

The THERMOSTAT parameter must be specified as a Text Entity. To do so, create a new Card 9 text entity, and enter one (and only one) of the following three options:

```
PARAM THERMOSTAT AVGTEMP
PARAM THERMOSTAT PROPORTIONAL
PARAM THERMOSTAT Q_EQUIV [T2] [T3]
```

The three options

- *AVGTEMP* sets the heater elements at the average of the set point temperatures. The physical interpretation of this option is that the heaters are thermally close to the sensor, and will be near or between the set point temperatures. For this option, the heater elements are treated as temperature sinks; that is, heat can flow into or out of a sink.

  PROPORTIONAL creates a linear ramped heat load between the set point temperatures. At the top of the dead band, the heat load is the maximum heater output. At the bottom of the dead band, the heat load is zero. With this option, the solution algorithm will iterate to find the correct heat load and temperature combination to achieve the time averaged steady state solution. In a true transient simulation, heaters can cycle on and off: in this case, the result is a time averaged picture. Use a large damping factor when using this option.

- *PROPORTIONAL* creates a linear ramped heat load between the set point temperatures. At the top of the dead band, the heat load is the maximum heater output. At the bottom of the dead band, the heat load is zero. With this option, the solution algorithm will iterate to find the correct heat load and temperature

combination to achieve the time averaged steady state solution. In a true transient simulation, heaters can cycle on and off: in this case, the result is a time averaged picture. Use a large damping factor when using this option.

- *Q_EQUIV* instructs the solver to make multiple steady state iterations to determine the required heater power to keep the sensors at the average set point temperature. It then solves a linear system of equations which determines the heat load required at each heater in order for the sensor temperature to be at the mid point of each dead band. For nonlinear models, such as those with strong radiation or temperature dependent conductivities, multiple outer iterations are automatically performed to find the target temperatures. The heat loads required on each heater are reported at the end of the analysis. This option is useful for heater sizing studies. It is possible that this option can return negative heat loads on the heaters, which indicates that those heater locations must be cooled for all the sensors to be at their target temperatures in the steady state condition. [T2] is the temperature convergence criterion. By default [T2] is 0.1 degrees. [T3] is the maximum number of iterations performed. By default, T3 is 10 iterations. If the model is linear, set an iteration value of 2.

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See the article *Defining TMG Entities* for more information.

Additional Options and Flow Options

Use *Additional Options* to adjust the default convergence parameters, or to select an alternate conduction algorithm. An option to output detailed convergence data is also available. See *Additional Solver Options*.

Use Flow Options to set the duct flow solver controls. See *Setting Flow Options*.

Understanding the Steady State Solver

For a Finite Volume thermal model, the formulation for steady state conditions is based on element heat balance.

TMG's steady state solver uses an iterative process to solve these equations. The solver uses the Conjugate Gradient method to solve the linearized system of equations and a global Newton-Raphson method for the nonlinear system.

The solution formulation for Duct Flow models is similar to the temperature solution, where total pressure is analogous to temperature.

Convergence of a steady state simulation is determined by either maximum temperature change between iterations or energy balance criteria. For Duct Flow models, a total pressure convergence criterion can also be set.

Two alternative methods are available for handling radiative conductances. The default method is successive linearization, where the current temperatures are used to calculate the radiative conductance.