

# Using Thermal Couplings

Use *Thermal Couplings* to create area-proportional conductances between dissimilar element meshes. At run time, the conductances are established from each of the *Primary Elements* to the nearest of the *Secondary Elements*; the two element sets do not have to be aligned. A variety of different conductance types may be specified, many of them can be defined as varying with different model parameters determined during the solution.

[Locate the icon.](#)

## Element Types for Thermal Couplings

### Solid Elements

- may not be used for *Thermal Couplings*

### Shells

- may be used as either *Primary* or *Secondary Elements*
- surface area computed by TMG

### Beams

- may be used as either *Primary* or *Secondary Elements*
- surface area is obtained from Beam Cross Sectional Properties.
- beams with surface area = 0 are ignored, even as *Secondary Element*

### Lumped Mass

- may be used as either *Primary* or *Secondary Elements*
- surface area is that of a sphere of the diameter specified when defining the physical property of the Lumped Mass element

### Fluid Elements

- may be used only as *Secondary Elements*

### Non-Geometric Elements

- may be used only as *Secondary Elements*

## Thermal Coupling Types

### Absolute

Does not use surface area of primary element: creates conductances (per element) of magnitude  $h$  between each *Primary Element* and the nearest *Secondary Element*.

## Conductive

Creates conductances  $G = (h \times A) / L$  from the primary elements to the nearest secondary elements, where  $L$  is the distance to the secondary element along the primary element's surface normal. By specifying  $h$  as the thermal conductivity, this option can be used to model conduction through a variable thickness interstitial material or object.

## Constant Coefficient

Standard option: creates conductances  $G = h \times A$  from each *Primary Element* to the nearest *Secondary Elements*.

## Interface

There are two modeling scenarios for *Interface couplings*, which we can call "Conduction Interface" and "Free Face Interface" summarized here and described in detail below:

- *Conduction Interface*: the Interface Thermal Coupling adjusts conduction between two volumes that share nodes on a surface, or two surfaces that share nodes on an edge. Since the nodes are shared, conduction is already modeled. The Interface Thermal Coupling inserts additional conductances in series with existing conductances. The magnitude of each of these additional conductances is defined by the specified heat transfer coefficient  $h$  multiplied by the area of the associated primary element. For each primary element, a conductance  $G = 2 \times h \times A$  is created in series with the existing conductive conductances.
- *Free Face Interface*: the Interface Thermal Coupling inserts an additional conductances in series with an existing external conductance (such as radiation, convection or another Thermal Coupling) and the selected surface or edge. The magnitude of each of these additional conductances is defined by the specified heat transfer coefficient  $h$  multiplied by the area of the associated Primary element. For each primary element, a conductance  $G = h \times A$  is created in series with the existing conductances.

Apply an Interface thermal coupling to Free Faces of solid elements, or free edges of shell elements. An Interface Thermal Coupling has only Primary elements (no secondary elements).

## Conduction Interface

The problem is to model the thermal effect of a mechanical interface (bolted or bonded for example). Use the interface coupling type to insert additional conductances in series between two adjacent volumes or two adjacent surfaces. The volumes or surfaces must be meshed with the appropriate elements (3D solid elements or 2D shell elements, respectively) and the elements must share nodes at the interface. Note that because they share nodes, these elements would conduct heat even without the thermal coupling. A discussion of the methodology follows.

Start with two adjacent volumes that are meshed with 3D elements that share nodes. A typical way to do this is to partition one volume into two volumes at the interface and mesh the two volumes, using free or mapped meshing to ensure that the elements share nodes at the interface. Create a geometry group containing the shared partition surface and define it as an Interface thermal coupling. The conductances of the Interface thermal coupling will be added in series to the conductances of the 3D solid elements on either side of the shared surface.

A similar technique applies to two surfaces sharing an edge, which are both meshed with 2D shell elements that share nodes along an edge. Create a geometry group containing the shared edge and use it to define an Interface thermal coupling. The conductances of the Interface

thermal coupling will be added in series to the conductances of the 2-D shell elements on either side of the shared edge.

Note that the conductance of an interface coupling is rolled into the other terms and does not appear in the element heat balance output.

### Free Face Interface

Use this modeling technique when you have already defined radiation, convection or another thermal coupling on a surface of a volume, and wish to introduce an additional conductance between the volume and the surface. There is no need to mesh the surface.

Similarly, it may be used when you have defined a thermal coupling on an edge of a surface, and wish to introduce an additional conductance in series between the surface and the edge. There is no need to mesh the edge.

Create a geometry group that contains a *surface* of a volume meshed with 3-D solid elements, and use this group to define the Interface thermal coupling (you can alternatively select Free Faces of the solid elements for this purpose). In this case the interface conductance is placed in series with the conductance spanning the solid elements and the surface itself. For example, this technique is useful when you need to establish a boundary condition or model radiation on a surface that is coated with a different material than the underlying solid.

A similar technique applies to the *edge* of a surface meshed with solid elements. The interface conductance is placed in series with the conductance spanning the plate elements and the edge coated beam elements.

### Join

Performs element merging based on proximity: creates an "infinite" conductance between each of the primary elements and the nearest of the secondary elements. The *Join* option will always produce inaccuracies in the conductance matrix, and especially where the primary and secondary element meshes are very different. Use only where the meshes are nearly aligned, or where the in-plane temperature gradients are insignificant.

### Length Proportional

The *Primary Elements* must be beam elements. Creates conductances  $G = h \times L$  between each primary element and the nearest secondary element, where  $L$  is the beam's length.

### Radiation

Use the radiative coupling type to create heat paths or conductances between Primary elements and the Secondary elements. Define the magnitude of the conductance by specifying one of two values, *ScriptF* or *Gray Body View Factor*.

The ScriptF value is derived by multiplying the Gray Body View Factor *GBVF* by the emissivity of the surface. Thus the ScriptF value includes the emissivity of the surface. With this option, the coupling will ignore any emissivity defined as a material property.

The Gray Body View Factor value does not take the emissivity into account. Thus you must also define the primary elements using a material property table with a defined emissivity, which will be used to compute the conductance.

Regardless of whether emissivity is rolled into a ScriptF value, or defined as a material property when using the Gray Body View Factor option, the magnitude of the conductance between each Primary element and its Secondary element is equal to:

$$\sigma \times GBVF \times \epsilon_1 \times A_1 (T_1^2 + T_2^2)(T_1 + T_2)$$

where

$\sigma$  is the *Stefan-Boltzmann* constant,

*GBVF* is the specified gray body view factor,

$\epsilon_1$  is the *emissivity* of the *primary* elements,

$A_1$  is the *area* of the *primary* elements,

$T_1$  is the absolute temperature of the primary elements, and

$T_2$  is the absolute temperature of the secondary elements.

This coupling type is useful for modeling radiation between surfaces as well as radiation heat transfer to or from ambient surroundings. Values for radiative black body view factors can be obtained from engineering and heat transfer handbooks for common geometry.

Reverse side emissivity as a material property is not supported. If the surface has different emissivity on front and reverse sides, create a *Reverse Sides* entity and use the *Reverse* option on the Primary Elements selection panel to select the primary elements.

The gray body view factor is the net amount of radiation emitted by *i* and absorbed by *j* (emitted by the primary elements and absorbed by the secondary elements, in the case of radiative type Thermal Couplings), including all intermediate reflections. Gray body view factors are derived from geometry (black body view factors) and the emissivities of *all the surfaces in the enclosure*. This can be an extremely complex calculation, depending on geometry. However, for close parallel surfaces (black body view factor approaching unity):

$$GBVF = \frac{1}{1 + \frac{\epsilon_1}{\epsilon_2} - \epsilon_1}$$

Where  $\epsilon_1$  and  $\epsilon_2$  are the emissivity of the primary and secondary elements, respectively.

When you create a radiative thermal coupling, the orientation of the element is ignored, as are reverse side material properties. If you want to model radiation on the reverse side of a surface that has an emissivity different from the front, you must adjust the specified GBVF to account for the difference.

An alternate method to model an emissivity that differs from that defined as a material property is to create a *Reverse Sides* entity for the primary elements. Define the second emissivity on the *Reverse Side* entity. Then create the thermal coupling between the *Reverse Side* entity and the secondary elements.

### Series Area-Proportional

Creates a conductance  $G = h \times A$  in series with the existing conductances between the primary and secondary elements.

### Series Absolute

Creates a conductance  $h$  in series with the existing conductances between the *Primary* and *Secondary Elements*.

## User defined

The user defined correlation is provided through a USERF subroutine. Refer to the USERF subroutine description in *Solving the Model*.

## Resistance

Creates a resistance to conduction or  $1/\text{conductances}$  between the primary elements and the nearest secondary elements. The resistance value specified is proportionally divided among the primary elements based on their area. This total value is expressed as degrees per heat flow.

## 1-Way Coefficient

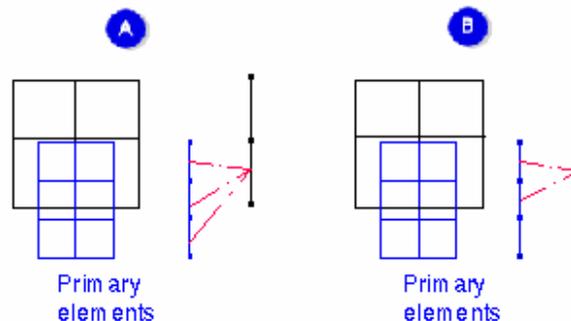
*1-Way Coefficient* creates a one-way conductance from the primary to the secondary elements, based on area.

## Understanding Thermal Couplings

To establish *Thermal Couplings*, TMG first subdivides each Primary Element into a number of sub-elements according to the selected thermal coupling resolution. For each of the primary sub-elements, a conductance  $G_i = h \times dA$  is created to the nearest of the secondary elements.

The nearest secondary element is determined by tracing a perpendicular ray originating at the primary sub-element's centroid; the first secondary element which the ray intersects is chosen. After couplings have been established for all sub-elements, TMG merges them again into a single element and combines all parallel conductances. The result is area-proportional thermal couplings which are distributed among the secondary elements according to the amount of overlap.

By default, a conductance is established from each primary sub-element to the nearest secondary element as shown in **A** below. Using the *Only connect overlapping elements* option specifies that couplings are only established along a path normal to each primary sub-element. No conductance is created for primary sub-elements that have no overlapping secondary element, as shown in **B** below.

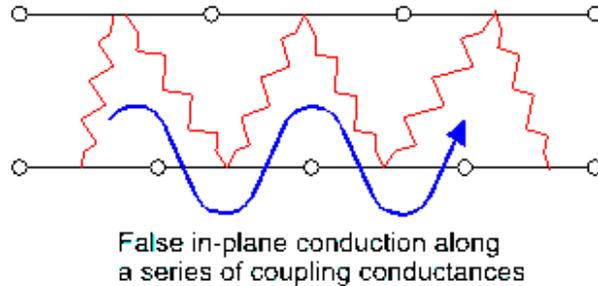


For a typical Thermal Coupling modeling conduction, *Only connect overlapping elements* (**B**) is more appropriate. For a Thermal Coupling modeling convection or radiation, you must use the option that reflects the physical phenomena.

## Notes On Using Thermal Couplings

Consider the following items when using *Thermal Couplings*.

- *Thermal Couplings* are most accurate and reliable where the resulting conductances are small relative to the in-plane conductive conductances of the elements.
- Thermal Couplings are most accurate when the conductances between primary and secondary elements are relatively low compared to the in-plane conductances. If the conductances modeled by the Thermal Coupling are relatively high, the Thermal Coupling can create false in-plane conductive paths via heat flows which cross and re-cross the gap bridged by the coupling.



This problem is avoided if the magnitude of the coupling conductances are small compared to the conductance of the primary and secondary elements. If the value of the coupling conductance is large compared to the in-plane conductances you should use *One to One* resolution setting. For greater accuracy, try to make mesh size and alignment between primary and secondary elements as close as possible.

- The *Join* option will always produce inaccuracies in the conductance matrix, and especially where the primary and secondary element meshes are very different. Use only where the meshes are nearly aligned, or where the in-plane temperature gradients are insignificant.

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