Radiative Coupling Calculation

TMG uses one of two algorithms to compute radiative conductances from black body view factors: Oppenheim's method or Gebhardt's method.

With Oppenheim's method, radiative conductances are iteratively solved with temperature. Since this approach has proven to be more efficient and also allows for temperature dependent surface properties, it is the recommended method and is the default.

Gebhardt's method calculates radiative conductances based on the gray-body view factors. Gebhardt's method requires the inversion of the black body view factor matrix to obtain the gray-body view factors and solve the model for radiation.

Oppenheim's Method

Radiative heat transfer can be modeled using Oppenheim's method, which uses a radiosity approach. With Oppenheim's method, TMG creates an additional non-geometric surface element for each radiating element in the enclosure, and couples it to its parent with a conductance equal to $\sigma A \varepsilon / (1 - \varepsilon)$. Then the black body view factor matrix is used to create couplings between the new surface elements equal to $\sigma A \, VF_{ij}$.

This approach allows efficient and accurate modeling of temperature dependent emissivity values, since it isolates the emissivity dependence. The radiation matrices also tend to be smaller than those obtained through matrix inversion with Gebhardt's method. For these reasons, Oppenheim's method is the default and recommended method.

For transient analysis, it is suggested that an implicit integration method should be employed. Solution times tend to be longer with explicit techniques because of the presence of many zero-capacitance Oppenheim elements in the mode.

Gebhardt's Method

Alternatively, Gebhardt's method involves computing gray body view factors for each radiating surface element. The definition of gray body view factor is identical to black body view factor except that it also accounts for intermediate reflections by other surfaces. The radiative heat transfer between two surfaces is described by the equation:

$$Q_{ij} = \sigma A \varepsilon \, VFG_{ij} \, (T_i^4 - T_j^4)$$

An important property of gray body view factors is reciprocity:

$$A_i \varepsilon_i VFG_{ij} = A_j \varepsilon_j VFG_j$$

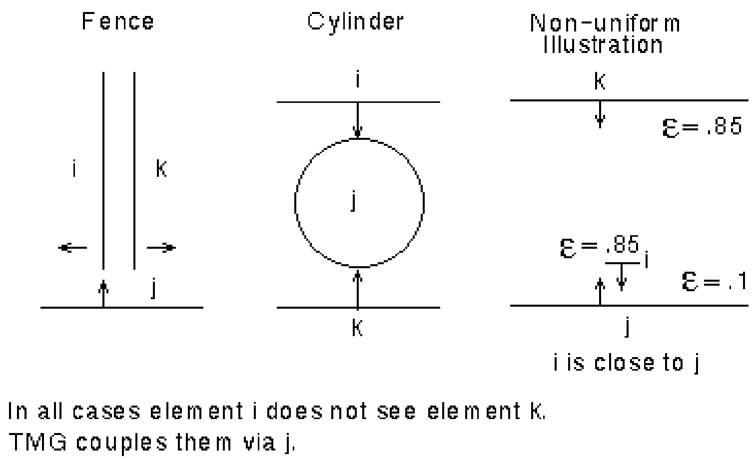
They are calculated by a matrix inversion process, using the black body view factors and the surface properties. TMG partitions the model into separate enclosures prior to carrying out this computation. An enclosure is defined as a group of surfaces which have view factors only to other surfaces within the group.

Limitations

Oppenheim's and Gebhardt's methods are based on a number of implicit assumptions:

- All surfaces reflect and emit radiation diffusely.
- The radiation incident on a surface is uniformly distributed.
- Surfaces reflect (scatter) radiation to other surfaces in proportion to their view factors to those surfaces.

Where the physical behavior differs from these assumptions, inaccurate radiative conductances will result. Where specular or transmissive processes are significant, *Ray-tracing* can be used to correct the radiative couplings. Problems associated with the other assumptions generally arise because of improper placement and meshing of surfaces. Some examples of this are shown below:



Note that generally, the gray body view factor of a surface to itself is not zero, since some portion of its emitted radiation is reflected back and re-absorbed.
