Modeling Radiation Effects in ANSYS 5.6

At ANSYS Release 5.6, the Radiosity solver was added as a new method for solving surface-to-surface radiation problems. In addition, the older methods of modeling radiation are still available. These include the AUX12 radiation matrix method, the radiation link element, and surface effect elements. With so many choices, it may not always be clear which method is most appropriate for your application.

Q: When should I use the new Radiosity solver for modeling surface-to-surface radiation?

A: The Radiosity solver, which works for generalized radiation problems involving two or more surfaces, is intended for very large 3D problems. It does not form a radiation matrix or use any elements to represent the radiation boundary condition. The solver utilizes a hemicube calculation for form factors, which is considered to be superior to the ray counting method used by AUX12 for problems that include hidden surfaces.

The Radiosity solver method computes a heat flux based on the current surface temperature, which is then applied as a surface load to the model. Iterations are performed until the surface temperature and radiation heat flux are consistent. One drawback of this method is that it can cause convergence difficulties when the surface temperature is sensitive to changes in radiation heat flux. Therefore, this method works well in a transient analysis where the enthalpy of the material stabilizes the surface temperature, and in a steady state analysis where temperature or convection boundary conditions exist to reduce the variability of the surface temperature as a function of radiation.

One of the main advantages of the Radiosity solver method is its ease of use. You simply flag each radiating surface using a surface load (**SF**) command (similar to applying a convection load). An example command format is **SF**,ALL,RDSF,*EMIS*,*ENCL* where ALL indicates that the load is applied to all selected nodes, RDSF indicates radiosity input, *EMIS* is the surface emissivity (you can also input a negative integer for *EMIS* to point to a temperature dependent emissivity table), and *ENCL* is an enclosure number which allows the input of multiple independent radiation domains.

Q: Given the capabilities of the new Radiosity method, is the older AUX12 method now obsolete?

A: No, AUX12 is still appropriate in some circumstances. For a radiation dominant problem between surfaces, the radiation superelement (MATRIX50) produced by AUX12 is still the most direct and accurate approach. The superelement represents the heat transfer between each element face and all the other element faces included in the radiation superelement. The orientation of the faces, their area, and their emissivity are all taken into account. This method can also account for whether surfaces are hidden from each other. Other features of the AUX12 method are an exact calculation of form factors for non-hidden applications and an axisymmetric option. The main drawback of the AUX12 method is that it is computationally intensive and may take several hours and a large amount of memory for large models. The cp-time and memory required when emissivity is less than one is especially large.

The table below shows benchmark results for a radiation analysis using the AUX12 method. The model used represented radiating surfaces in the interior of a cube. The results show the time and memory required to generate the radiation superelement on an SGI workstation. The number of element faces in the model was varied by changing the mesh divisions along each edge of the cube. The non-hidden option was used, along with an emissivity of 0.5. For larger numbers of faces, the data indicates that run times are proportional to the number of faces cubed, and the memory required is 24(number of faces)**2/(1024)**2 Mb. If a 2 Gb limit is placed on memory, the maximum calculated problem size is around 9500 elements. The run time for this size problem would be 65 cp-hours. If the problem can be split into two or more radiation superelements, the advantages are obvious.

Test Results on SGI Workstation (single processor)

Element Faces	Cp-secs	Max Memory (Mb)
600	33	8
864	115	17
1350	515	42
1944	1,773	87
2400	3,470	132
5400	43,000	668

Q: The Radiosity solver and AUX12 methods are obviously quite sophisticated. Is there a simpler method that can be used when radiation plays only a minor role in an analysis?

A: In thermal applications where conduction and convection are the dominant modes of heat transfer, there is a simple way to account for radiation without adding any additional elements or material properties to the model. If you know the approximate surface temperature, you can approximate radiation by following these steps:

- Compute the radiation heat flux based on the absolute values of the surface temperature (Tsurf) and the ambient temperature for convection (Tbulk) using an estimate of the form factor and the emissivity of the surface; divide this number by Tsurf-Tbulk.
- Add this quantity to your true convection coefficient, Hf.
- If you only know your surface temperature within a certain range, perform the above calculation for several temperatures in this range and specify a temperature dependent film coefficient. (This is essentially what the Radiosity solver does.)

This method can also be used on surfaces without convection if the surface temperature is stabilized by constrained temperatures or enthalpy. In this case, a film coefficient would be computed entirely based on the radiation flux, and Tbulk could be given any convenient value, such as absolute zero.

Q: Is there also a simple approach that can be used when radiation is more dominant? I have a small model in which I would like to model radiation from several nodes to a node of fixed temperature.

A: The radiation link element, LINK31, could be used in this case. This 2-node element is used between nodes and requires specification of the area, form factor, and emissivity as real constants. This may mean that each radiation link element has a unique set of real constants since the area and form factor associated with each node will typically vary. (You can get the area at a node by using the ARNODE "Get Function.") The LINK31 element can also accept a temperature dependent emissivity and an empirical radiation formula. Heat flow between the 2 nodes will be equal to sigma*epsilon*F*A*(Ti**4-Tj**4) where sigma is the Stefan-Boltzmann constant, epsilon is the emissivity, F is the form factor, A is the area and T is the temperature at the i and j nodes.

Q: Using the radiation link element could be cumbersome for large applications. Is there an easier method that does not require inputting the area and form factor?

A: Yes. You can use the SURF151 (2-D) and SURF152 (3-D) surface effect elements to model radiation between the surface of an element and a node. These elements offer a more automatic method than LINK31. You simply overlay the surface effect elements on a surface of selected nodes with the **ESURF** command. The surface area of each element is known and, therefore, does not have to be input. The form factor may either be input or automatically computed as the cosine of the angle between the element normal and a line through the element integration points and the extra node. Since there is only one form factor, only one direction of radiation is represented per element.

Q: Can I apply radiation on a model in which symmetry has been used?

A: The last three methods discussed would allow this, but the Radiosity and AUX12 methods require all the radiation surfaces to be modeled.

Q: Can you make any general recommendations for modeling radiation?

A: It is recommended that you assign initial model temperatures that are as close as possible to the anticipated final temperatures. In all of the radiation methods discussed here, convergence is improved if the initial surface temperature (applied with the **IC** or **BFUNIF** command) is in the ballpark of the expected temperature.

If your input is in centigrade or Fahrenheit, remember to specify the offset temperature (**TOFFST** command) since radiation must be based on the absolute temperature. If you forget to input **TOFFST**, the analysis will start at absolute zero. This typically results in a program abort with a message about a negative absolute temperature. The linearization of the T**4 stefan boltzman relationship cannot handle a negative temperature.

Q: Do all of the radiation methods apply to CFD applications?

A: No, only the Radiosity method. This method is ideal for CFD since convection dominates in fluid flow analysis.

Q: Could you briefly summarize the characteristics of each radiation method?

A: Radiosity solver – Only method available for very large systems, but radiation should not be dominant. Works well with convection/conduction/enthalpy dominated models.

AUX12 radiation superelement – Most accurate, but computationally intensive. Cannot model temperature dependent emissivity.

Approximated radiation (pseudo-convection) – Works well if radiation creates just an incremental change in the solution.

Radiation link element – Cumbersome because each link requires area and form factor input.

Surface effect elements - Convenient for parallel radiation, such as from the sun.