Modeling Diurnal Heating

Use *Diurnal Solar Heating* to calculate the solar heat loads on selected elements for a day, a part of a day or for a fixed sun position for a model situated on the Earth, Moon or any other planet of the solar system. In your analysis you can also include the effects of atmospheric attenuation, clearness, diffuse sky radiation and ground reflection.

The simulation of diurnal solar heating implies the calculation of direct and reflected solar spectrum radiation. Prior to the analysis, the material properties, element orientation, enclosures and other parameters must have been set properly.

Setting up a Diurnal Solar Heating Simulation

These steps guide you through the overall process of preparing your model for diurnal heating. (Details of how *Diurnal Solar Heating* works will be covered later.)

1. Build a complete enclosure model (see *Understanding Radiation Requests*).

   Use *Space Enclosure* on the *Radiation Control* form to create a non-geometric element modeling the ambient environment for radiation simulation.

Locate the icon.

   Be sure that there are no inactive element faces in the enclosure (see *Front and Reverse Element Sides*).

2. In the *Meshing* task define solar absorptivity for all illuminated elements, and emissivity for all elements in the enclosure (if you want to model diffuse radiation).

   Use the material type Fluid/Thermal, Thermal Solid.

3. Create *Radiation Requests* to compute a complete set of black body view factors for the enclosure. This step is necessary to model diffusely reflected solar radiation.

Locate the icon.

4. Create a *Diurnal Solar Heating* entity to specify the model orientation, sun position and other parameters.

   Select only elements that have a view to the sky or the planet surface. This is important because solar flux from *Atmospheric and Other Effects* will be applied to all selected elements based on orientation, not view factors.

Locate the icon.

5. For a transient analysis, enter the analysis *Start Time* and *End Time* on the *Solver Control* form.

Locate the icon.

6. On the *Solution Data* form, toggle on *View Factor Sums*, *Radiative Flux* and *Solar, Earth VF's.* This makes the results available for post processing.

Locate the icon.

7. You may specify an initial temperature for your model on the *Initial Conditions Control* form.

Locate the icon.

Selecting Illuminated Elements

Pick *Selected Elements* and identify the elements that will be exposed to the environment. You must identify which elements radiate from their front side and which radiate from their reverse side. To select the elements, you can either pick a geometry group, an element group or select the elements from the graphics screen.

Diffuse sky reflection and solar irradiation reflected from the ground are calculated for all illuminated elements. TMG does not check whether the view to the sky or the ground of some elements are shadowed by other elements.

Supported Elements Types

The following element types are supported as Illuminated Elements.

Front of:

- 2-D thin shell elements
- Beam elements with cross section defined
- Lumped mass elements
- Free faces of 3-D solid elements

Reverse of:

- 2-D thin shell elements

Solar Flux on the Model

To calculate solar heat loads on selected elements, TMG determines which elements have a complete or partial view to the sun. Some of the incident flux that falls on these elements is diffusely reflected to other elements in the model due to the material properties of the incident elements. To include this reflected flux in the element heat load calculation, you have to define a *Radiation Request* for your elements. (See *Solar Spectrum View Factor Calculation*).

The incident radiation on an element is the product of its view factor to the source times the flux from the source. In *Diurnal Solar Heating* you must specify how to determine the solar flux on the model.

Three options are provided for the calculation of the solar flux:

1. Use a constant value. You can use the day dependant default provided or enter your own value.

   The constant solar flux value on January first (without any atmospheric attenuation, diffuse sky radiation or ground effect) is the default.

2. Create a table of solar flux versus time. If the solar flux is defined via a table AND if a single solar position is defined, the absorbed flux on the elements will take into account the time varying solar intensity, even though the solar vector is not changing. If appropriate, this can be a simpler way to model diurnal heating.

3. Let TMG calculate the solar flux from the parameters provided in the *Use Atmospheric and Other Effects* section.

Atmospheric and Other Effects

With *Use Atmospheric and Other Effects*, the total solar irradiation on the planet is the sum of the direct solar irradiation, the diffuse solar irradiation from the sky and the reflected irradiation from the ground. Atmospheric effects are included in the direct solar irradiation calculation. You can disable any of these effects.

Atmospheric Attenuation

Atmospheric attenuation includes these three effects in the direct solar irradiation:

1. the variation in the Earth-Sun distance
2. the length the rays must traverse through the atmosphere
3. the air's vapor content in the atmosphere

To model these effects, three parameters must be defined: the *Apparent Solar Radiation*, the *Atmospheric Extinction Coefficient* and the *Clearness Factor*. The first two parameters are day dependant and are used together to calculate the attenuated direct irradiation. Their values have been selected to match measurements of the direct solar irradiation on a clear day at sea level. (ASHRAE. 1995. HVAC Applications. pp. 30.1-30.5)

The *Clearness Factor* is the ratio between the actual local clear day direct radiation intensity and the one calculated at sea level for the same location. The *Clearness Factor* adjusts the attenuated direct solar irradiation. A ratio greater than one reflects a high elevation (*compared to sea level)*, a ratio smaller than one reflects a cloudy sky. By default, this parameter is set to have no effect. (ASHRAE. 1995. HVAC Applications. pp. 30.1-30.5)

For other than Earth calculations these three coefficients are set to have no effect on the calculation but they can be changed by the user to model the effect of an atmosphere.

Diffuse Sky Radiation Factor

Diffuse Sky Radiation Factor allows to adjust for diffuse solar irradiation from the sky. It is computed for all illuminated elements with:

$$I_{dif} = I_{dn} \times C \times F_{ss}$$

Where:

I_{dif} = diffuse sky irradition

I_{dn} = direct irradiation of a horizontal surface

C = ratio of the diffuse irradiation to the direct normal irradiation of a horizontal surface.

$$F_{ss} = \frac{1 + \cos E}{2}$$

where E = angle between the surface and the ground.

You provide the C parameter. Data for this parameter are available from the form. These data are calculated from measurements made during clear days at sea level and vary throughout the year.

TMG calculates the direct irradation an horizontal element facing the sky receives for the given sun position and solar flux and uses it to calculate the diffuse sky irradiation of each element. An element pointing toward the ground does not receive any diffuse sky irradiation since its E angle equals 180°. (ASHRAE. 1995. HVAC Applications. pp. 30.1-30.5)

For other than Earth calculations, the *Diffuse Sky Radiation Factor* is set to zero but this can be changed by the user.

Ground Surface Reflectance

For ground reflection calculation, TMG does not model the ground. It applies the following equation to all selected illuminated elements without performing any shadowing:

$$I_r = I_{tH} \times P_g \times F_{sg}$$

Where

I_r = reflected radiation from the foreground

I_{tH} = total horizontal irradiation (includes both direct and diffuse irradiation

P_g = ground surface reflectance (Albedo)

$$F_{sg} = \frac{1 - \cos E}{2}$$

where E = angle between the surface and the ground.

You specify $P_{g,}$ the *Ground Surface Reflectance (Albedo)*. An average value for each planet is provided on the form for this property. Note that albedo can vary greatly depending on the material surrounding the model, although Earth has an averaged albedo of 0.3, fresh snow can have an albedo value as high as 0.87. (ASHRAE. 1995. HVAC Applications. pp. 30.1-30.5)

TMG considers your model as floating over the ground, even the bottom of you model receives ground reflection radiation.

Horizontal elements facing the sky do not receive any reflected radiation from the foreground. But if they are facing the ground, they receive the maximum amount of reflected radiation.

An alternative approach to calculate foreground reflection is to model the ground explicitely along with your geometry. This allows you to model the ground shape, its material properties and to include it in the shadowing process. You should define the emissivity and the absorptivity of the material you will use to mesh the ground. If you model the ground with your geometry, either toggle off *Use Atmospheric and Other Effects* or set the *Ground Surface Reflectance (Albedo)* to zero.

Model Orientation

The orientation of the model for the analysis is not a priori the orientation of the model within I-DEAS. You cannot change the orientation of your model in I-DEAS for the analysis since rotating or moving a part in I-DEAS changes its position relative to other parts.

Use *Model Orientation* to properly position your model in relation to the sun. With this option, you pick two edges from your model and assign each of them one of the seven directions available on the form. *Vector 1* will always aim at its specified direction. *Vector 2* will be aligned with its specified direction or as aligned as it can be in the event of two non-perpendicular vectors or two non-perpendicular directions.

Solar Vector(s)

To perform an analysis of a unique solar position, enter the local time on the *Diurnal Solar Heating* form. This information along with the *Solar Data* information and the latitude of the model uniquely define the sun's position. If a single solar position is defined AND if the solar flux is defined via a table, the absorbed flux on the elements will take into account the time varying solar intensity, even though the solar vector is not changing.

To perform a full day or a partial day transient analysis you must select the Time Varying option. Calculation points at which solar heat loads will be calculated are equally distributed on the sun's trajectory.

For partial day analysis, aside from delimiting which portion of the day you want to analyze, you must specify at which time (in seconds after the start of the analysis) the first solar heat load calculation should take place. This start time lets you model the effect of other transient boundary conditions that may occur before the model is illuminated and heated by the sun.

Shadowing Checks

Shadowing checks should always be performed for a *Diurnal Solar Heating* analysis. The only time you can safely disable this function is when you are sure that all your illuminated elements have an unobstructed view to the sun. (See *Shadowing Checks).*
