submission week **5**

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1 Write a summary of the topics about radiative heat transfer we went through including the definitions of emissivity, absorptivity, reflectivity and transmissivity, the view factor, the heat exchange betweeen two black surfaces, the heat exchange between the two gray surface and the definition of radiative resistances.

EMISSIVITY (ε)

- The emissivity of a surface is its ability in emitting energy as radiation.
- It's the ratio of the radiation from a surface to the radiation from an ideal black surface at the same temperature. The ratio varies from 0 to 1 (the emissivity of a black body surface is 1).
- Emissivity means how closely a surface approximates a blackbody.
- The emissivity of a real surface changes with the temperature of the surface (like the wavelength and the direction of the emitted radiation).

SPECTRAL EMISSIVITY (ε_λ) = emissivity of a surface at a specified wavelength

DIRECTIONAL EMISSIVITY (ε_θ)= emissivity of a surface at a specified direction
* θ angle between the direction of radiation and the normal of the surface

→ If ε_λ is constant the surface is said to be gray
→ If ε_θ is constant the surface is said to be diffuse

Absorptivity (α): the fraction of radiation absorbed by a surface $\alpha = \frac{G_{abs}}{G}$ $0 \leq \alpha \leq 1$

Reflectivity (ρ): the fraction of radiation reflected by a surface $\rho = \frac{G_{ref}}{G}$ $0 \leq \rho \leq 1$

Transmissivity (τ): the fraction of radiation transmitted by a surface $\tau = \frac{G_{tr}}{G}$ $0 \leq \tau \leq 1$

$$G = G_{abs} + G_{ref} + G_{tr}$$

$$\boldsymbol{\alpha + \rho + \tau = 1}$$

Kirchhoff's law tell us that the emissivity of a surface at temperature T is equal to its total absorptivity for radiation coming from a blackbody at the same temperature.

$$\varepsilon(\mathrm{T}) = \alpha(\mathrm{T})$$

Then the emissivity of a surface at a specified wavelength, direction, and temperature is always equal to its absorptivity at the same wavelength, direction, and temperature.

$$\varepsilon_{\lambda,\theta}(\mathrm{T}) = \alpha_{\lambda,\theta}(\mathrm{T})$$

EMISSIVITY

$$\mathbf{E = \varepsilon\, \sigma}\, \boldsymbol{T^4} \quad \rightarrow \quad \boldsymbol{\varepsilon = \frac{E}{\sigma T^4}}$$

VIEW FACTOR (F_{ij})

- The view factor is a geometrical quantity corresponding to the fraction of the radiation leaving surface i that strikes surface j.
- It doesn't depend on the surface properties.
- It is also known as shape factor, configuration factor, and angle factor.

$$F_{12} = F_{A_1 \to A_2} = \frac{\dot{q}_{A_1 \to A_2}}{\dot{q}_{A_1}} \qquad \dot{q}_{A_1 \to A_2} = F_{12} \times \dot{q}_{A_1}$$

$$F_{21} = F_{A_2 \to A_1} = \frac{\dot{q}_{A_2 \to A_1}}{\dot{q}_{A_2}} \qquad \dot{q}_{A_2 \to A_1} = F_{21} \times \dot{q}_{A_2}$$

Reciprocity Law: $A_1 F_{12} = A_2 F_{21}$

F_{12} and F_{21} are not the same: the difference depends on the surface area.

$\mathrm{F}_{ij} = 0$ if the surface is plane

$\mathrm{F}_{ij} = 0$ if the surface is convex

$\mathrm{F}_{ij} \neq 0$ if the surface is concave

$\sum \mathrm{F}_{i \to j} = 1$ for an enclosure surface

Radiation Heat Transfer between Black Surfaces

If the surface 1 is a black surface at temperature T_1:

$$\dot{Q}_{A_1 \to A_2} = A_1 \times E_{b_1} \times F_{1 \to 2} = A_1 \times \sigma T_1^4 \times F_{1 \to 2} \qquad (W)$$

In the other direction (surface 2 is a black surface at temperature T_2):

$$\dot{Q}_{A_2 \to A_1} = A_2 \times E_{b_2} \times F_{2 \to 1} = A_2 \times \sigma T_2^4 \times F_{2 \to 1} \qquad (W)$$

To find the net radiative heat exchange between surface 1 and surface 2:

$$\dot{Q}_{1 \to 2} = (A_1 \times \sigma T_1^4 \times F_{1 \to 2}) - \left(A_2 \times \sigma T_2^4 \times F_{2 \to 1}\right) \qquad (W)$$

From the Reciprocity Law we know that $A_1 F_{12} = A_2 F_{21}$ then:

$$\dot{Q}_{1 \to 2} = (A_1 \times F_{1 \to 2} \times \sigma T_1^4) - (A_1 \times F_{1 \to 2} \times \sigma T_2^4) = A_1 \times F_{1 \to 2} \times \sigma \left(T_1^4 - T_2^4\right)$$

Radiation Heat Transfer between Diffuse Gray Surfaces

We start from the definition of Radiosity (J_i):
all the radiation leaving a surface i (emitted radiation + reflecter radiation)

$$J_i = \varepsilon\, E_b \times \rho G$$

We know there is a realtion between absorptivity and reflectivity for opaque surfaces:

$$\alpha + \rho = 1 \quad \rightarrow \quad \rho = 1 - \alpha$$

From Kirchhoff's law we also know that there is a relation between absorptivity and emissivity:

$$\varepsilon(\mathrm{T}) = \alpha(\mathrm{T})$$

This means:

$$J_i = \varepsilon \times E_b + (1 - \varepsilon) G \qquad \left(\frac{W}{m^2}\right)$$

To find the net radiative heat exchange between the surface and the environment:

$\dot{Q}_i = A_i \left(J_i - G_i\right)$ J_i is what it'is leaving and G_i is what it'is receaving

We know that:

$$J_i = \varepsilon \times E_b + (1 - \varepsilon) G \quad \rightarrow \quad G = \frac{J_i - \varepsilon_i \times E_b}{\left(1 - \varepsilon_i\right)}$$

$$\dot{Q}_i = A_i\left(J_i - \frac{J_i - \ \varepsilon_i \times E_b}{(1-\epsilon_i)}\right) = \frac{A_i\,(J_i - \varepsilon_i J_i - J_i + \ \varepsilon_i \times E_b)}{1-\varepsilon_i} = \frac{A_i(\varepsilon_i \times E_b - \varepsilon_i J_i)}{1-\varepsilon_i}$$

$$\dot{Q}_i = \frac{A_i \varepsilon_i}{1-\varepsilon_i} \times (E_b - J_i)$$

Radiative Resistances

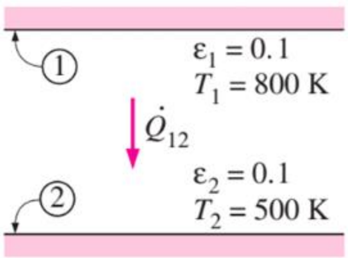
- The radiative resistance is determined by the geometry of the surface that transfer radiation that can be plane, convex or enclosure.
- The energy trasferred by radiation resistance is converted to radio waves (not to heat radiation).
- The electrical analogy is rapresented by :

$$\dot{Q}_i = \frac{E_{b_i} - \mathrm{J}_i}{R_i} \qquad (W) \qquad \rightarrow \qquad R_i = \frac{1-\varepsilon_i}{A_i \varepsilon_i}$$

Between two surfaces:

$$\dot{Q}_{i\to j} = \frac{\mathrm{J}_i - \mathrm{J}_j}{R_{i\to j}} \qquad (W) \qquad \rightarrow \qquad R_{i\to j} = \frac{1}{A_i \mathrm{F}_{i\to j}}$$

1 Find the radiative heat exchange between two parallel plates considering the two emissivities to be 0.1. What can you conclude from the result?



$$A_1 = A_2 = A$$
$$F_{12} = 1$$

$$\dot{Q}_{12} = \frac{A \times \sigma \ \times (T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} = \frac{5{,}67 * 10^{-8} \times (800^4 - 500^4)}{\frac{1}{0{,}1} + \frac{1}{0{,}1} - 1} = \frac{19680{,}57}{19} = 1035{,}82\ W$$

→ from the result I can conclude that lower is the emissivity lower is the heat trasfer between two parallel infinitely large surfaces