*weekly_submission_**05***

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> Write a summary of the topics about radiative heat transfer including the definitions of emissivity, absorptivity and reflectivity, the view factor, the heat exchange between two black surfaces, the heat exchange between the two gray surface and finally the definition of radiative resistance.

EMISSIVITY (ε)

Emissivity is defined as the ratio of the energy radiated from a material's surface to that radiated from a perfect emitter, known as a blackbody, at the same temperature and wavelength and under the same viewing conditions. It is a dimensionless number between 0 (for a perfect reflector) and 1 (for a perfect emitter, black body). The emissivity of a surface is not a constant; it is a function of temperature of the surface and wavelength and the direction of the emitted radiation, $\varepsilon = \varepsilon\,(T, \lambda, \theta)$ where θ is the angle between the direction and the normal of the surface.
Diffuse surface: is a surface which its properties are independent of direction.
Gray surface: is a surface which its properties are independent from wavelength.

ABSORPTIVITY (α)

Absorptivity is defined as the fraction of irradiation absorbed by the surface. It depends on the wavelength and direction of the incident light, type of the material, chemical composition and structure of the material and state of the material and its surface.
It is the ratio of absorbed radiation (G_{abs}) to incident radiation (G). It is a dimensionless number between 0 and 1.

REFLECTIVITY (ρ)

Reflectivity is defined as the fraction of irradiation reflected by the surface. It depends on the wavelength of light, direction of the incident and reflected light, polarization of light, type of the material, chemical composition and structure of the material, and state of the material and its surface.
It is the ratio of reflected radiation (G_{ref}) to incident radiation (G). It is a dimensionless number between 0 and 1.

TRANSMISSIVITY (τ)

Transmissivity is defined as the fraction of irradiation transmitted through the surface.
It is the ratio of transmitted radiation (G_{tr}) to incident radiation (G). It is a dimensionless number between 0 and 1.

The first law of thermodynamics requires that the sum of the absorbed, reflected, and transmitted radiation energy be equal to the incident radiation. That is:

$$G_{abs}+G_{ref}+G_{tr} = 1$$

Dividing each term of this relation by G:

$$\alpha + \rho + \tau = 1$$

RADIATION BETWEEN SURFACES

The total radiation for a unit area of an opaque body of area A_1, emissivity ε_1 and absolute temperature T_1, is:

$$\frac{Q}{A} = \sigma * \varepsilon_1 * {T_1}^4$$

If this is a blackbody, the value of emissivity will be 1, so it becomes:

$$\frac{Q}{A} = \sigma * 1 * {T_1}^4$$

→ **Stefan-Boltzmann's law**

$\dot{Q}_{12}$ net radiation between two surface is:

$$\dot{Q}_{12} = \sigma * A * F * ({T_1}^4 - {T_2}^4)$$

where:
$A =$ area of the surfaces
$F =$ dimensionless geometric factor → view factor or angle factor

If surface A_1 is chosen for A:

$$\dot{Q}_{12} = \sigma * A_1 * F_{12} \ * ({T_1}^4 - {T_2}^4)$$

If surface A_2 is chosen,

$$\dot{Q}_{12} = \sigma * A_2 * F_{21} \ * ({T_1}^4 - {T_2}^4)$$

Where F_{12} and F_{21} are the view factors, surface 1 is the source and surface 2 is the receiver in the first case and vice versa in the second. It means that F_{12} is the amount of radiation interested by body 2 that has been interrupt by body 1 and that F_{21} is the amount of radiation interested by body 1 that has been interrupt by body 2.

Net radiation will be the same so we can put $\dot{Q}_{12} = \dot{Q}_{21}$:

$$A_1 * F_{12} = A_2 * F_{21}$$

<u>VIEW FACTOR (F_{12})</u>

View factor (F_{12}) is defined as the fraction of the radiation leaving surface A_1 that is intercepted by surface A_2. It ranges between 0 and 1 but there are few methods to calculate the view factor:

1) Inspection: you can look at one surface and tell right away how much radiation being intercepted, this is often all of it or not of it;
2) Use the relationship developed for view factor: $A_i * F_{ij} = A_j * F_{ji}$, known as reciprocity relationship
3) Summation rule: $\sum_{j=1}^{n} F_{ij} = 1$

case1: if surface A_1 can see only surface A_2

$$F_{12} = 1$$

case2: if surface A_1 sees a number of other surfaces and its entire hemispherical angle of vision is filled by these surfaces then:

$$F_{11} + F_{12} + F_{13} + \cdots = 1$$

case3: if surface A_1 cannot see any portion of itself (plan surface, convex surface) then:

$$F_{11} = 0$$

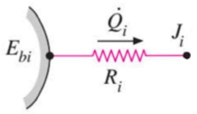
case4: consider a small black body of area A_2 having no concavities and surrounded by a large black surface of area A_1. The factor $F_{21} = 1$ as area A_2 can see nothing but area A_1.

$$F_{12} = \frac{A_2 * F_{21}}{A_1} = \frac{A_2 * 1}{A_1} = \frac{A_2}{A_1}$$

$$F_{11} + F_{12} = 1$$

$$F_{11} = 1 - \frac{A_2}{A_1} \qquad \text{(black surface)}$$

<u>HEAT EXCHANGE BETWEEN NON BLACK BODY</u>



Assume all the surfaces are diffusive and uniform in temperature that reflective and emissive properties are constant over all the surfaces.
G = irradiation = total radiation incident upon a surface per unit time and per unit area
J = radiosity = total radiation which leaves a surface per unit time and per unit area

The net energy leaving the surface is the difference between radiosity and the irradiation.

$$\frac{\dot{Q}_\iota}{A} = J - G$$

$$\frac{\dot{Q}_\iota}{A} = \frac{E_{bi} - J}{\frac{1-\varepsilon}{\varepsilon A}}$$

Further we assume:
Radiosity and irradiation are uniform over the surface.
Radiosity is the sum of the energy emitted and the energy reflected when no energy is transmitted.
$\alpha + \rho + \tau = 1$ but, in this case, $\tau = 0$ so $\rho = 1 - \alpha$
But for black body $\alpha = \varepsilon$ so $\rho = 1 - \varepsilon$

→ **Kirchhoff's law**

J = emitted + reflected
= $\varepsilon * E_{bi} + G * \rho$
= $\varepsilon * E_{bi} + G * (1 - \varepsilon)$

$$\frac{\dot{Q}_\iota}{A} = J - G = [\varepsilon E_{bi} + G(1-\varepsilon)] - G$$

Elimination G we get:

$$G = \frac{J - (\varepsilon E_{bi})}{1 - \varepsilon}$$

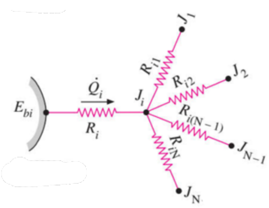
Now by eliminating G we get:

$$\frac{\dot{Q}_\iota}{A} = J - \frac{J - (\varepsilon E_{bi})}{1-\varepsilon} = \frac{J - J\varepsilon - J - \varepsilon E_{bi}}{1-\varepsilon} = \frac{\varepsilon(E_{bi} - J)}{1-\varepsilon}$$

$$\frac{\dot{Q}_\iota}{A} = \frac{(E_{bi} - J)}{\frac{1-\varepsilon}{\varepsilon}}$$

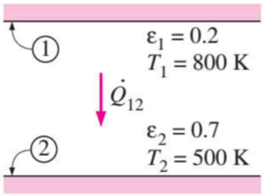
$$Q_i = \frac{(E_{bi} - J)}{\frac{1-\varepsilon}{\varepsilon A}}$$

Driving force
Surface radiative resistance: it is given as $\frac{1-\varepsilon}{\varepsilon A}$ and this value represents the resistance of a surface to the emission of radiation. It is zero for black surfaces.



This can be use for exchange with any number of the opaque diffuse gray surfaces in an enclosure.

RADIATION HEAT TRANSFER IN TWO-SURFACE ENCLOSURES



Consider an enclosure consisting of two opaque surfaces 1 and 2 have emissivities ε_1 and ε_2 and surface areas A_1 and A_2 and are maintained at uniform temperatures T_1 and T_2, respectively. There are only two surfaces in the enclosure, and thus we can write:

$$\dot{Q}_{12} = \dot{Q}_1 = -\dot{Q}_2$$

That is, the net rate of radiation heat transfer from surface 1 to surface 2 must equal the net rate of radiation heat transfer from surface 1 and the net rate of radiation heat transfer to surface 2.

The radiation network of this two-surface enclosure consists of two surface resistances and one space resistance. In an electrical network, the electric current flowing through these resistances connected in series would be determined by dividing the potential difference between points *A* and *B* by the total resistance between the same two points. The net rate of radiation transfer is determined in the same manner and is expressed as:

$$\dot{Q}_{12} = \frac{E_{b1} - E_{b2}}{R_1 + R_{12} + R_2} = \dot{Q}_1 = -\dot{Q}_2$$

or

$$\dot{Q}_{12} = \frac{\sigma({T_1}^4 - {T_2}^4)}{\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1F_{12}} + \frac{1-\varepsilon_2}{A_2\varepsilon_2}}$$

This important result is applicable to any two gray, diffuse, and opaque surfaces that form an enclosure. The view factor F_{12} depends on the geometry and must be determined first.

> Find the net radiative heat exchange between the surface 1 and 2.

According to the formula:

$$\dot{Q}_{net_{1-2}} = \frac{A * \sigma * ({T_1}^4 - {T_2}^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

Assuming A as a unit value, we can solve the problem in this way:

$$\dot{Q}_{net_{1-2}} = \frac{5{,}67 * 10^{-8} * (800^4 - 500^4)}{\frac{1}{0{,}2} + \frac{1}{0{,}7} - 1} = \frac{5{,}67 * 10^{-8} * (4096 * 10^8 - 625 * 10^8)}{5{,}43} = \frac{19680{,}57}{5{,}43} = 3624{,}41\ \frac{W}{m^2}$$

Solve the same problem where $\boldsymbol{\varepsilon_1 = 0{,}1\ ,\ \varepsilon_2 = 0{,}1\ ,\ T_1 = 800\ K,\ T_2 = 500\ K,\ \sigma = 5{,}67 * 10^{-8}\ \frac{W}{m^2K^4}}$.

Assuming A as a unit value, we can solve the problem in this way:

$$\dot{Q}_{net_{1-2}} = \frac{5{,}67 * 10^{-8} * (800^4 - 500^4)}{\frac{1}{0{,}1} + \frac{1}{0{,}1} - 1} = \frac{5{,}67 * 10^{-8} * (4096 * 10^8 - 625 * 10^8)}{19} = \frac{19680{,}57}{19} = 1035{,}82\ \frac{W}{m^2}$$

Comparing the two value found we can conclude that increasing the emissivities, the value of $\dot{Q}_{net}$ increase too.