WEEK 5_ZHU CUILING

TASK1

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

Radiative heat transfer

Radiation is a phenomenon in which energy is transmitted by electromagnetic waves. The process in which radiant energy is emitted due to heat is called thermal radiation.

While scattering the emitted radiant energy, the object will continuously absorb the radiant energy emitted by other surrounding objects and convert it into heat energy. The heat transfer process between the objects that emit radiant energy and absorb radiant energy is called radiative heat transfer. It's a basic way of heat transfer.

Definitions of emissivity

Emissivity is the ability to measure the relative strength of an object's surface in the form of radiation. The radiance of an object is equal to the ratio of the energy radiated by the object at a certain temperature to the radiant energy of the black body at the same temperature. The emissivity of the black body is equal to 1, and the emissivity of other objects is between 0 and 1.

Definitions of absorptivity

Absorption rate refers to the ratio of the heat radiation energy absorbed by an object onto the object and the total heat radiation energy projected onto the object is called the absorption rate of the object. This is the total absorption rate for all wavelengths.

The absorption rate of the surface of the object is related to the nature of the object, the surface condition and the temperature. It is an inherent characteristic of the object itself, and has nothing to do with the external environment.

Definitions of reflectivity

The radiant energy reflected by an object as a percentage of the total radiant energy is called the reflectivity. The reflectivity of different objects is also different, which depends mainly on the nature of the object itself (surface condition), as well as the wavelength and incident angle of the incident electromagnetic wave. The range of reflectivity is always less than or equal to 1 and the reflectivity can be used to judge the properties of the object.

The view factor

A reflection factor is a portion of the energy emitted (radiated or reflected) from an isothermal, opaque, diffusely reflective surface that is emitted directly to another plane (absorbed or reflected by it).

The heat exchange between two black surfaces

Radiation heat exchange refers to the heat exchange process between two objects with different temperatures and not touching each other, which is the total effect of mutual radiation and absorption between two objects.

Black surface will emit a radiation of E_{b1} per unit area per unit time. If the surface is having A1 unit area, then it will emit $E_{b1} \times A_1$ radiation in unit time. The 2nd black body will emit its radiation $E_{b2} \times A_2$ radiation in unit time.

The net heat transfer is the radiation leaving the entire surface 1 that strikes surface 2 subtracts the radiation leaving the entire surface 2 that strikes surface 1.

The formula is: $A_1 \times E_{b1} \times F_1 - A_2 \times E_{b2} \times F_2$

The heat exchange between the two gray surface

Gray surface will reflect or absorb a given fraction of the thermal radiation a blackbody surface would absorb. More importantly, the fraction of graybody/blackbody is independent of radiation wavelength.

How can I find the net radiation heat exchange between surface 1 and 2?

$$\dot{\boldsymbol{Q}}_{\boldsymbol{net\ between\ 1\ and\ 2}} = \dot{\boldsymbol{Q}}_{\boldsymbol{emitted\ by\ surface\ 1\ and\ received\ in\ surface\ 2}} - \dot{\boldsymbol{Q}}_{\boldsymbol{emitted\ by\ surface\ 2\ and\ received\ in\ surface\ 1}}$$

$$\because \dot{\boldsymbol{Q}}_{\boldsymbol{1\to 2}} = \boldsymbol{A_1 \times F_{12} \times \sigma T^4 - A_2 \times F_{21} \times \sigma T^4} \qquad \boldsymbol{A_1 F_{12} = A_2 F_{21}}$$

$$\therefore \dot{\boldsymbol{Q}}_{\boldsymbol{1\to 2}} = \boldsymbol{A_1 \times F_{12} \times \sigma (T_1^4 - T_2^4)}$$

Definition of radiative resistances

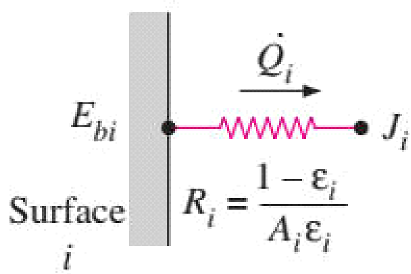
The radiation resistance is part of the feed point resistance of an antenna. The radiation resistance is caused by the radiation of the electromagnetic waves of the antenna; in contrast, the loss resistance usually causes the temperature of the antenna to rise. The radiation resistance and the loss resistance add up to the resistance of the antenna.

Radiosity: radiation leaving a surface

$$j_i = (Radiation\ emitted\ by\ surface\ i) + (Radiation\ reflected\ by\ surface\ i) = \varepsilon_i E_{bi} + \rho_i G_i$$
$$= \varepsilon_i E_{bi} + (1 - \varepsilon_i) G_i \quad (W/m^2)$$

Radiosity of a blackbody: $J_i = E_{bi} = \sigma T^4$

$$\dot{Q}_i = \frac{E_{bi} - J_i}{R_i} \qquad R_i = \frac{1 - \varepsilon_i}{A_i \varepsilon_i}$$



Task2

Find the net radiative heat exchange between the surface 1 and 2 where $A_1 = 1.5m^2$**,** $\boldsymbol{\varepsilon_1 = 0.1}$**,** $\boldsymbol{\varepsilon_2 = 0.1}$**,** $T_1 = 298K$**,** $T_2 = 308K$**,** $\sigma = \mathbf{5.67 \times 10^{-8} W/m^2 \cdot K^4}$**.**

$$\dot{Q}_{net2\to1} = \frac{A\sigma\left(T_2^4 - T_1^4\right)}{\frac{1}{\varepsilon_2} + \frac{1}{\varepsilon_1} - 1} = \frac{1.5 \times \left(5.67 \times 10^{-8}\right) \times \left(308^4 - 298^4\right)}{\frac{1}{0.1} + \frac{1}{0.1} - 1} \approx 4.9823$$

When $F_{1\to2} = 0.01$

$$\dot{Q}_{net1\to2} = A_1 \times F_{12} \times \sigma(T_1^4 - T_2^4) = 1.5 \times 0.01 \times 5.670 \times 10^{-8} \times (308^4 - 298^4) \approx -0.9466W$$

$\because A_1 = A_2$

$\therefore \dot{Q}_{net2\to1} = -\dot{Q}_{net1\to2} \approx 0.9466W$

The value of emissivity would greatly affect the radiative heat exchange between the surfaces.