Week5 Assignment

Task1：

In your own words 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 between two black surfaces, the heat exchange between the two gray surface and finally the definition of radiative resistance.

Summary

Radiative Heat Transfer

The way in which an object transmits energy through electromagnetic waves is called radiation. And electromagnetic radiation due to heat is called thermal radiation. Any objects, as long as the temperature is higher than 0 K, will continuously emit heat radiation to the surrounding space. Thermal radiation can propagate in a vacuum and accompanied by a shift in energy form. Also the radiative heat transfer has strong directionality. Radiant energy is related to temperature and wavelength. The amount of radiation depends on the biquadrate of the temperature.

Emissivity

The ratio of the radiation force of the actual object to the black body at the same temperature is the emissivity. Emissivity is determined by experiments, depending only on the object itself, independent of ambient conditions. The emissivity formula is only for the condition of direction and spectral average. But in fact, the emission capability of true surface changes with direction and spectrum.

Absorptivity

The absorptivity is the ratio of the thermal radiation absorbed by the object to the incident radiation. The value is from 0 to 1. For black body, the $\alpha=1$.

Reflectivity

Reflection is divided into specular and diffuse reflection, related to the roughness of the surface. For gases without particles, the reflectivity is almost zero. It can be seen that the gas with a large absorptivity has a small transmissivity.

The View Factor

View factor is the percentage of radiant energy emitted by on surface falling onto another surface. We can use the relativity, integrity and additivity of the view factor to calculate the view factor.

The Heat Exchange Between Two Black Surfaces

Radiation energy emitted from surface 1 and projected directly onto surface 2.

$$\dot{Q}_{1\to 2} = A_1 E_{b1} F_1$$

Also radiation energy emitted from surface 2 and projected directly onto surface 1.

$$\dot{Q}_{2\to 1} = A_2 E_{b2} F_{2\to 1}$$

Because both surfaces are black, the radiation on their surface will be absorbed by each surface. The amount of direct radiation heat exchange between two black surfaces is:

$$\dot{Q}_{1\to 2} = A_1 E_{b1} F_{1\to 2} - A_2 E_{b2} F_{2\to 1}$$

The Heat Exchange Between Two Gray Surfaces

The ratio of the radiant intensity of all wavelengths of the gray body to the corresponding wavelength of the black body at any temperature remains unchanged. We use irradiation G and radiosity J to calculate the Q between two gray surfaces.

$$J_i = \varepsilon_i E_{bi} + \rho_i G_i = \varepsilon_i E_{bi} + (1-\varepsilon_i) G_i$$

$$Q_i = A_i (J_i - G_i) \Rightarrow Q_i = A_i \left(J_i - \frac{J_i - \varepsilon_i E_{bi}}{1-\varepsilon_i}\right) = \frac{A_i \varepsilon_i}{1-\varepsilon_i}\left(E_{bi} - J_i\right)$$

The Radiative Resistance

The radiative resistance is generally to value the energy that release from resistance which converted to heat radiation. The radiative resistance from one surface to another surface is related to the view factor between the two surfaces.

$$R_{i\to j} = \frac{1}{A_i F_{i\to j}}$$

Task2：

Find the next heat exchange between the surface 1 and 2 where $\varepsilon_1=0.2$, $\varepsilon_2=0.7$, T1=800K, T2=500K

Answer：

$$\dot{Q}_{12} = \frac{A\sigma\,(T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} = \frac{A \times 5.67 \times 10^{-8} \times (800^4 - 500^4)}{\frac{1}{0.2} + \frac{1}{0.7} - 1} \approx 3625.3491A\ (W)$$

While considering the two emissivities to be 0.1, what can you conclude from the result?

$$\dot{Q}_{12} = \frac{A\sigma\left(T_1^4 - T_2^4\right)}{\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1} = \frac{A\times5.67\times10^{-8}\times\left(800^4 - 500^4\right)}{\frac{1}{0.1}+\frac{1}{0.1}-1} \approx 1035.8195A\ (W)$$

Comparing the two results, we can see that the radiative heat exchange between two surfaces is higher while the emissivities of the two surfaces are lower.