Week 5 Radiative heat transfer

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Politecnico di Milano
MSc. Sustainable Architecture and Landscape Design
Fabiola Anahí Mogrovejo León

Task 1

Radiative heat transfer

All bodies, whatever their temperature, emit energy continuously from their surfaces. This energy is called radiant energy and is carried by electromagnetic waves, for this reason, radiant energy can still be transmitted in a vacuum. The continuous emission of radiant energy by a body is called radiation. As a consequence of this phenomenon, two bodies placed in a vacuum that are at different temperatures reach thermal equilibrium because the lower temperature receives radiant energy from the other body of higher temperature. When radiant energy is absorbed by a body, it is transformed into heat; However, radiant energy can also be reflected (diffused) or refracted (propagated) by the bodies.

Definitions:

Emissivity: The emissivity E, of a body, is defined as the amount of heat emitted per unit area and per unit time, in a given direction. The value of E depends fundamentally on the value of λ and T. In general it is expressed by relating it to the emissive power of the ideal black body. The ratio between the emissive power of the body E, and the emissive power of the black body ES, under the same conditions, is called the emissivity coefficient e. That is: e=E/Es. We see that e must be a number, independent of the units in which the emissive power is measured and whose value is between 0 and 1.

Absorbity: The absorbity A of a body is defined as the amount of heat absorbed per unit area and per unit time. Its value depends on λ and T. The ratio between the absorbing power of body A and the absorbent power corresponding to the black body under the same AS conditions is called the absorption coefficient a. a=A/AS, value between 0 and 1. It follows that both aS corresponding to the ideal black body must be worth 1.

KIRCHOFF Law: This establishes that the relationship between the emissive power and the absorption coefficient is a constant for all surfaces at values of λ and T given. If we call E1 and E2 the emissive powers of two bodies whose absorption coefficients are a1 and a2, it must be fulfilled that: E1 = E2. For all surfaces, the emissivity coefficient is equal to the absorption coefficient. Therefore, if a body can emit a radiation λ at temperature T, the same body is also able to absorb it under the same conditions. This phenomenon is known as spectrum inversion.

Reflectivity: ρ, is the fraction of irradiation reflected by the surface.

The view factor: The view factor F12 is the fraction of energy exiting an isothermal, opaque, and diffuse surface 1 (by emission or reflection), that directly impinges on surface 2 (to be absorbed, reflected, or transmitted). View factors depend only on geometry. Some view factors have an analytical expression.

Heat exchange between two black surfaces: Stefan Boltzmann's Law states that the total amount of heat emitted (at all wavelengths), per unit time and per unit area of the black body, is proportional to the fourth power of the absolute body temperature. (As seen before, the amount of total heat emitted is proportional to the area enclosed by the radiation curve: E λ = f (λ). This law can be expressed mathematically:

Where is the total black body radiation coefficient, which can be defined as integral radiation, for all directions and wavelengths transmitted per unit area of the black body, in the unit of time and per ° K of temperature. It is a universal constant. (e(T) = σ T4)

Heat exchange between the two gray surfaces: They are those in which the value of the emissivity coefficient e remains constant for all wavelengths and temperatures. As we saw that e = a, the absorption coefficient must also be constant. In practice there are no gray bodies, since the value of e does not remain constant, however, in most cases the bodies can be considered gray without much error. The emissive power of a gray body will be: E = e*IS. This equation is considered valid for all wavelengths and in a given temperature range.

Radiative resistances: Is a value to measure the energy depleted by loss resistance which is converted to heat radiation; the energy lost by radiation resistance is converted to radio waves.

Task 2

Solve the last example you solved in the class (radiative heat exchange between two parallel plates) awhile considering the two emissivity to be 0.1, what can you conclude from the result?

$$\dot{Q}_{\square} 2 \rightarrow 1 \ = \frac{A\sigma\ (T_1^4 - T_2^4)}{1/\epsilon_2 + 1/\epsilon_1 - 1}$$

$$\dot{Q}_{\square} 2 \rightarrow 1 \ = \frac{1.5\ (5.67\ * 10^{-8})(308^4 - 298^4)}{\frac{1}{0.1_{\square}} + \frac{1}{0.1_{\square}} - 1} = 4.9823\ W$$

Meanwhile, based on this formula

$$\mathrm{F}\ 2 \rightarrow 1 \ = \frac{1}{\frac{1}{0.1_{\square}} + \frac{1}{0.1_{\square}} - 1} = 0.0526$$

When $\mathrm{F}\ 1 \rightarrow 2 = 0.01$

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

$$= 1.5 \times 0.01 \times \ (5.67\ \times 10^{-8}) \times \ (298^4 - 308^4) = -0.9466\ W$$

Comparing the two values of net radiative heat exchange under different situation, is noticed that the emissivity would affect the radiative heat exchange between the surfaces.