Week5_Balaganesan Navaneetha

SUMMARY

Radiative Heat Transfer

Heat transfer through radiation takes place in form of electromagnetic waves mainly in the infrared region. Radiation emitted by a body is a consequence of thermal agitation of its composing molecules. Radiation heat transfer becomes important at high temperatures (above 1000 K) and after collapse of materials, when some structures are in direct view with hot debris located below.

Radiation is modeled in most of the codes, including absorption of heat by steam, but usually the models cannot deal with scattering media (water droplets for example) or large cavities with strong absorption by the gas. Such cases would require multidimensional models that require a lot of computation time. In any case, models for radiation heat transfer, with a relevant estimate of view factors, across rod assemblies or debris, and across large cavities should be available in the code. The lack of appropriate radiative heat transfer models will lead to an incorrect temperature distribution in the vessel.

Definitions of Emissivity

The emissivity(ε) of the surface of a material refers to the effectiveness of the surface in emitting energy as thermal radiation, it is mathematically defined as the ratio of the thermal radiation from the surface to the radiation from an ideal black surface at the same temperature; the value varies from 0 to 1. The greater the value of emissivity is, the closer the surface to a blackbody (ε= 1). The emissivity of a real surface is affected by temperature of the surface as well as the wavelength and the direction of the emitted radiation.

Definitions of absorptivity

Absorptivity(α) of the surface of a material is a measure of the ability of a material to absorb radiation, i.e., its effectiveness in absorbing radiant energy. Like emissivity, value of absorptivity is in the range $0 < \alpha < 1$.

From its definition, a **blackbody**, which is an idealized physical body, absorbs all incident **electromagnetic radiation**, regardless of frequency or angle of incidence. That is, a blackbody is a perfect absorber. Since for real objects the **absorptivity** is less than unity, a real object cannot absorb all incident light.

Definition of reflectivity

Reflectance (ρ) of the surface of a material is its effectiveness in reflecting radiant energy. It is the fraction of incident electromagnetic power that is reflected at an interface. The reflectance spectrum or spectral reflectance curve is the plot of the reflectance as a function of wavelength.

Heat exchange between two black surfaces

A black surface will emit a radiation of Eb1 per unit area per unit time. If the surface is having A1 unit area, then it will emit Eb1*A1 Radiation in unit time. This radiation will go to the other black surface and totally absorb by it but at the same time The 2nd black body will emit its radiation Eb2*A2 per second and it will go to 1st body and totally absorbed by it .The whole process happened simultaneously .So the net heat transfer between these surfaces will be the net heat per second (power) gained by any of the two surfaces (obviously same for both surfaces). 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, which is, in formula: A1Eb1F1-2 - A2Eb2F2-1.

Heat exchange between two grey surfaces

The easiest method to calculate radiative heat transfer between two bodies is when they are assumed to be black bodies. However, in reality most surface are grey bodies. Recall that grey bodies absorb a certain amount of radiation while reflecting a portion of the radiation off of the surface back into space.

The equation below can be used to determine the value for J.

(Eq 1) $J=\varepsilon Eb+(1-\varepsilon)G$
ε = The Emissivity of the Object

$E_{b=}$ The Energy Emitted from a Black Body

Radiative resistance

Radiative resistance 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.

It can be calculated by this formula: $R_1=1-\varepsilon_i/A_i\ \varepsilon_i$

TASK 2

Find the net radiative heat exchange between surfaces 1 and 2 where A_1 = 1.5 m^2, E_1=0.1, E_2=0.1, T_1=298k, T_2= 308 k

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

By introducing the values metioned in the question into the formula,

$$\dot{Q}_{net_{2-1}} = \frac{1.5m^2 \times \left(5.67 \ \times 10^{-8} \frac{W}{m^2 K^4}\right)(308^4 - 298^4)K^4}{\frac{1}{0.1} + \frac{1}{0.1} - 1}$$

$$\approx 4.9823 \, W$$

Meanwhile, under situation, based on the following formula

$$F_{2-1} = \frac{1}{\frac{1}{\epsilon_2} + \frac{1}{\epsilon_1} - 1} = \frac{1}{\frac{1}{0.1} + \frac{1}{0.1} - 1} \approx 0.0526$$

Autem, when $F_{1-2} = 0.01$,

$$\dot{Q}_{net_{1-2}} = AF_{1-2}\sigma(T_2^4 - T_1^4)$$

$$= 1.5m^2 \times 0.01 \times \left(5.67 \ \times 10^{-8} \frac{W}{m^2 K^4}\right)(298^4 - 308^4)K^4$$

$$\approx -0.9466 \, W$$

$$\because A_1 = A_2, \qquad i.e., \qquad \frac{A_1\sigma(T_1^4 - T_2^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} = -\frac{A_2\sigma(T_2^4 - T_1^4)}{\frac{1}{\epsilon_2} + \frac{1}{\epsilon_1} - 1}$$

$$\therefore \ \dot{Q}_{net_{2-1}} = -\dot{Q}_{net_{1-2}} \approx 0.9466 \, W$$

Considering the two values of net heat exchange under different situations, it is seen that the value of emissivity will have affect greatly the radiative heat exchange.