Lab 7

ME 326 Heat and Mass Transfer Laboratory

Experiment RD3: View Factor

Written by:
<name>

Submitted to Dr. Bednarz

10/31/12

Abstract:

This experiment investigated the view factor for a rectangular aperture. Experiment was compared to theory by inspection which yielded a reasonable match.

Introduction:

The view factor is a quantity that relates the fraction of the radiation leaving surface *i* that is intercepted by surface *j*. The relationship is purely geometric and can be found analytically for simple cases. For complex cases the relationship is often found numerically or by experiment. This experiment investigated the view factor for a flat, black plate, and the radiometer.

Procedure and Experimental Data:

This experiment used the Radiation Heat Transfer Apparatus. The black plate was placed 50 mm from the radiation source. The adjustable aperture plate was placd 200 mm from the radiation source. The radiometer was placed 300 mm from the radiation source. The radiation source power was set to ~60%. This caused the steady-state temperature of the black plate to be 107 degrees Celsius. The ambient temperature was 22 degrees Celsius. Once steady-state was reached radiometer readings were taken for multiple aperture widths. The experimental data is in Table 1 below.

Table 1: Experimental Data

Aperture Width (mm)	60	55	50	40	30	20	10	0
Radiometer Reading (W/m^2)	70	70	70	64	52	40	28	15

Results, Discussions, and Analysis:

For an arbitrary shape and arbitrary size, the view factor is given by equation 1 (Kalim):

$$F_{ij} = \frac{1}{A_i}\int_{A_i}\int_{A_j}\frac{\cos\theta_i\cos\theta_j}{\pi R^2}dA_i dA_j \tag{1}$$

Equation 1 is difficult to use in many situations. For this situations, the view factor can be written in terms of radiation heat transfer (Kalim):

$$q_{12} = F_{1-2} A_1 \epsilon_1 \sigma (T_1^4 - T_2^4) \quad (2)$$

Because the emissivity of the black plate is unity and the temperature of the radiometer is constant and close to room temperature, equation 2 can be simplified to (Kalim):

$$q''_{12} \approx F_{1-2} \sigma (T_1^4 - T_a^4) \quad (3)$$

Solving this equation for the view factor yields:

$$F_{1-2} = \frac{q''_{12}}{\sigma (T_1^4 - T_a^4)} \quad (4)$$

Equation 4 was used to calculate the view factor for this situation. The value for q''_{12} is 5.59 times greater than the reading obtained from the radiometer. This relationship was given by the lab maual. The calculations for the view factor for each aperture width is in Table 2 below.

Table 2: View Factors

Aperture Width (mm)	60	55	50	40	30	20	10	0
Source Power	391	391	391	358	291	224	157	84
View Factor	0.520	0.520	0.520	0.475	0.386	0.297	0.208	0.111

Sample Calculations

Source Power: $391W = 60 * 5.59$

View Factor: $0.520 = \frac{391}{5.67(10)^{-8} * ((107+273)^4 - (22+273)^4)}$

Various solutions to equation 1 are tabulated in Table 13.1, page 865 (Incropera, Bergman, Lavine, DeWitt). The solution for this problem is given by the parallel plates with midlines connected by the perpendicular case (equation 5).

$$F_{ij} = \frac{[(W_i + W_j)^2 + 4]^{1/2} - [(W_j - W_i)^2 + 4]^{1/2}}{2W_i} \quad (5)$$

$$W_i = \frac{w_i}{L}; W_j = \frac{w_j}{L} \quad (6)$$

Where w_i is the width of the aperture, w_j is the width of the black plate, and L is the distance between the aperture and the plate. This theoretical relationship was compared to experiment by graphing the experimental view factors as a function of aperture size. This is in Figure 1 below.

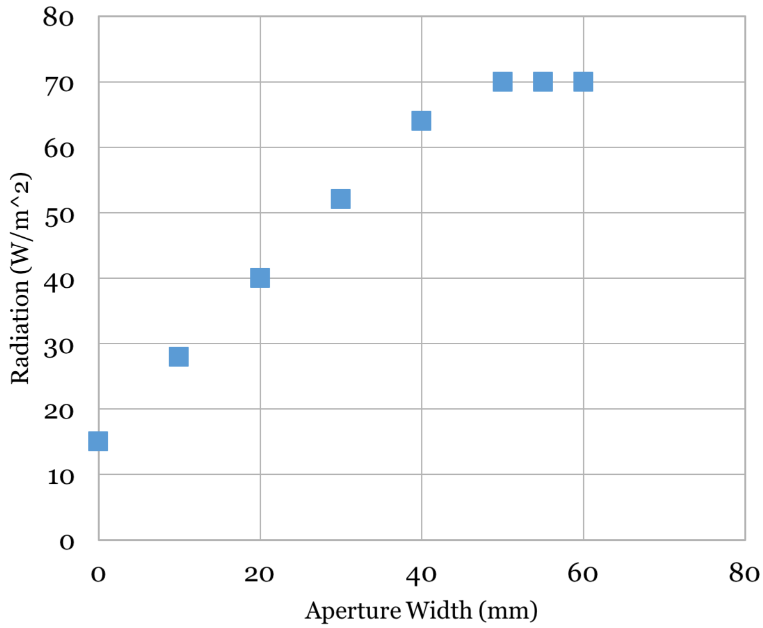

Figure 1: Radiation as a Function of Aperture Width

Figure 1 indicates an approximately linear relationship between and aperture size of 0 to 50 mm with a limiting value of 70 W/m^2 for values greater than 50 mm. Equation 5 is approximately linear for sufficiently large w_i and w_j and has a limiting factor of 1. Although the limiting factors are different, equation 5 and Figure 1 behave similarly. This suggests equation 5 is fair model for this situation.

Finally, the view factor for an enclosure can be shown to equal 1 by the the conservation of energy. The view factor represents the fraction of received radiation to the fraction of emitted radiation. For each surface in an enclosure:

$$F_{ij} = n, Where 0 < n < 1 \tag{7}$$

However, by conservation of energy the emitted radiation in an enclosure must be equivalent to the absorbed radiation in the enclosure. If the emitted radiation is assumed to be 1 W/m^2, the absorbed radiation must be 1 W/m^2. Because the view factor represents the fraction of this 1 W/m^2 each surface receives and the total radiation received must be 1 W/m^2, it follows from the conservation of energy that:

$$\sum_{i=1}^{n} \quad F_{ij} = 1 \tag{8}$$

Practical Applications:

The view factor is important for the design of forges and furnaces. These devices operate at high temperatures and radiative heat transfer is the primary method of heat loss. Furthermore, these devices require doors to allow the loading of material. These doors act like the apertures investigated in this experiment. Their shape will dictate their view factor. A knowledge of view factors will allow forge and furnace doors to be designed that minimize the view factor for a given shape. This will minimize the radiation losses from the doors and reduce the operating costs of the forges and furnaces.

Conclusions:

This experiment examined the view factor for radiation through a rectangular aperture. The view factor was calculated for each aperture width. The received radiation as a function of aperture width was plotted and this was compared to equation 5 by inspection.

References:

[1] Incropera, Frank P., Theodore L. Bergman, Adrienne S. Lavine, and David P. DeWitt. *Fundamentals Of Heat And Mass Transfer*. 7th ed. Hoboken: Wiley, 2011. Print.

[2] Kalim, Perwez. *Heat and Mass Transfer Lab Laboratory Manual*. 5th . Wilkes-Barre, PA: Wilkes University, 2011. Print.

Comments:

1. In the procedure, the "Radiation Heat Transfer Apparatus" was called out but no reference to a description was given. In a formal report a citation or other reference allowing the reader to find a description is normally needed, perhaps just reference [2].
2. The tables used seem to be images. These were originally in an .odt document, and may have been converted on conversion, which is not a problem for the original.
3. The Figure 1 title was correct in the original (an .odt document) but was messed up when transferred to Word. That was not a problem in the original.
4. Connected data points for Figure 1 seem preferable.
5. This laboratory exercise seems at first more of a characterization than experiment. Statement of the hypothesis before procedure and data, would help. As it is, the hypothesis first appears in the results section.
6. The conclusion does not say anything about to what extent the experimental data was consistent with the hypothesis.