HAMT

Heat and Mass Transfer

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2.1 Radiation

The net radiation heat flux from surface 1 to surface 2 using grey body radiation can be calculated as

$$\dot{Q}_{1\to 2} = A_1 F_{1\to 2} E_1 - A_2 F_{2\to 1} E_2. \tag{2.1}$$

using the formula for emission of grey bodies

$$E_i = \epsilon_i \sigma T_i^4 \tag{2.2}$$

and the reciprocity rule for configuration factors $A_1 F_{1\to 2} = A_2 F_{2\to 1}$ we can write

$$\dot{Q}_{1\to 2} = \sigma A_1 F_{1\to 2} \left(\epsilon_1 T1^4 - \epsilon_2 T_2^4 \right) \tag{2.3}$$

and $\dot{Q}_{1\to 2} = -\dot{Q}_{2\to 1}$. Given two line segments as seen in Fig. 2.1

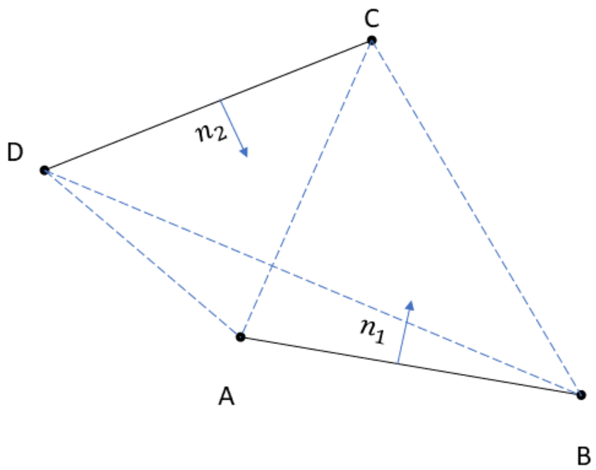

Figure 2.1: Radiation.

the configuration factor from surface $\overline{\mathrm{AB}}$ to surface $\overline{\mathrm{CD}}$ can be calculated as

$$F_{\overline{\mathrm{AB}}\to\overline{\mathrm{CD}}} = \frac{\overline{\mathrm{AC}} + \overline{\mathrm{BD}} - \overline{\mathrm{AD}} - \overline{\mathrm{BC}}}{2\overline{\mathrm{AB}}} \tag{2.4}$$

where $\overline{\mathrm{XY}}$ is the distance from X to Y. The total heat flux from or to a single surface is the sum of the heat fluxes to other surfaces plus the heat flux to the background

$$\dot{Q}_{tot} = \sigma A_1 \left\{ \epsilon_1 T_1^4 \sum_i F_{1\to i} - \sum_i \epsilon_i F_{1\to i} T_i^4 \right\} + \dot{Q}_{backgr} \tag{2.5}$$

In terms of boundary conditions we ca write

$$\lambda \left(\vec{n} \cdot \nabla T \right) = \frac{\dot{Q}_{1\to 2}}{A_1} = \sigma F_{1\to 2} \left(\epsilon_1 T1^4 - \epsilon_2 T_2^4 \right) \tag{2.6}$$

and using a Taylor series

$$\mathrm{T}\left[T^4 \right] \approx T_0^4 + 4T_0^3 \left(T - T_0 \right) = 4T_0^3 T - 3T_0^4 \tag{2.7}$$

and the shorthand $\tilde{\epsilon}_i = \epsilon_i \sigma F_{1\to 2}$ we get

$$\lambda \left(\vec{n} \cdot \nabla T \right) - 4\tilde{\epsilon}_1 T_{1,0}^3 T_1 + 4\tilde{\epsilon}_2 T_{2,0}^3 T_2 = 3\tilde{\epsilon}_2 T_{2,0}^4 - 3\tilde{\epsilon}_1 T_{1,0}^4 . \tag{2.8}$$

Bibliography

[1] Hans Dieter Baehr and Karl Stephan. *Wärme- und Stoffübertragung*. Berlin, Heidelberg: Springer Berlin Heidelberg, 2019. ISBN: 978-3-662-58440-8 978-3-662-58441-5. DOI: `10.1007/978-3-662-58441-5`. URL: `http://link.springer.com/10.1007/978-3-662-58441-5` (visited on 10/20/2024).