Transient Conduction Lab

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1. Figure and Tables

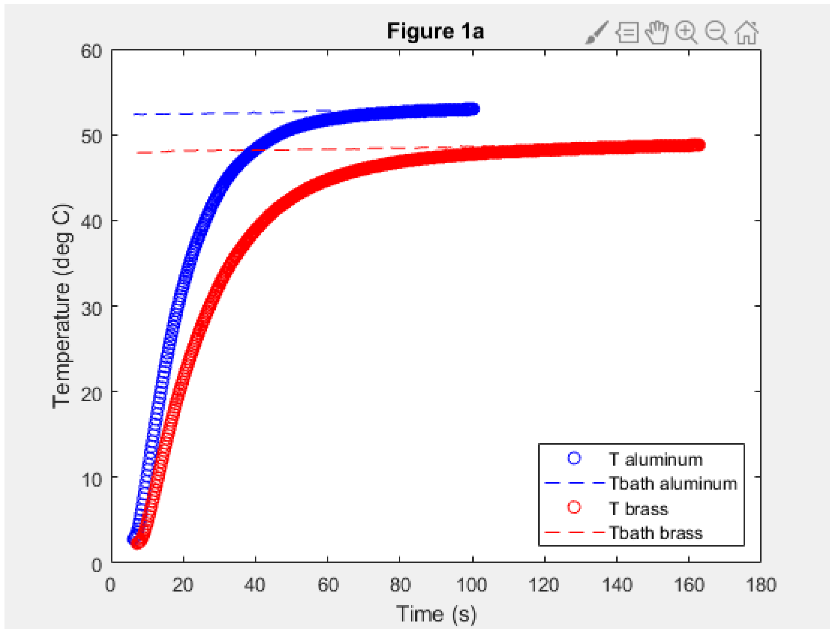

Figure 1a. Center temperature T and bath temperature Tbath each a function of time t of both experiments involving aluminum and brass spheres.

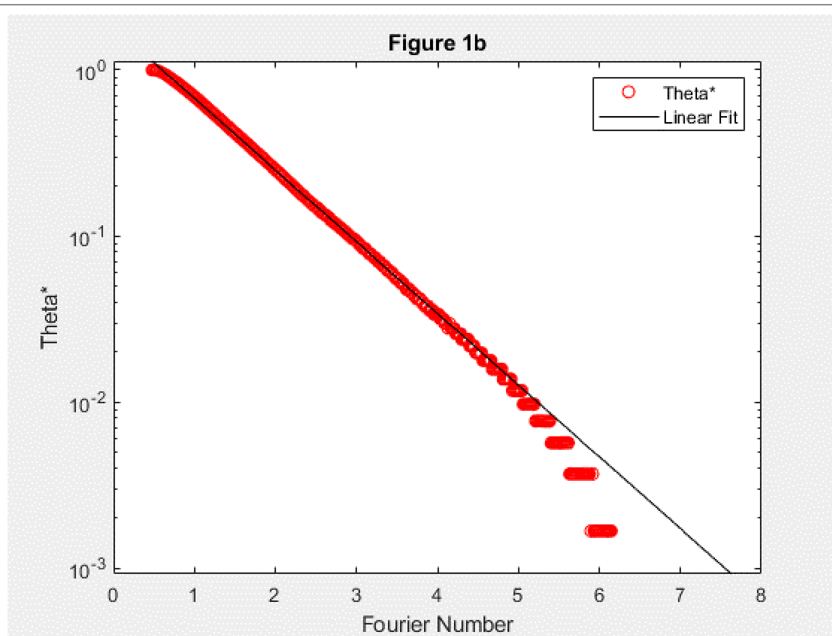

Figure 1b. Dimensionless Temperature Distribution and Fourier Number during the experiment with aluminum.

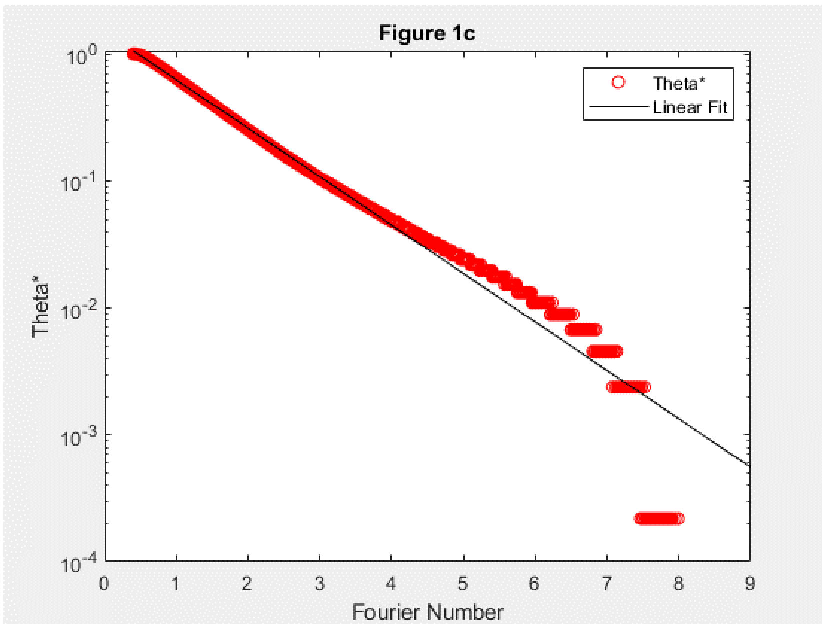

Figure 1c. Dimensionless Temperature Distribution and Fourier Number during the experiment with brass.

Table 1d. Table of the Bio Number, Heat Transfer, time constant, and heat transfer coeffiecients. The variance included with the time constant and heat transfer coefficient are within 95% confidence interval. LC represents the Lumped Capacitance method and ES represents the one-term approximate solution.

Sphere	Bi	Q (J)	τ (s)		h (W/m^2-K)	
			LC	ES	LC	ES
Aluminum	0.3313	-2.169e+04	13.21± 0.0521	20.63± 0.9911	1.583e+03± 12.48	1.060e+03± -86.26
Brass	0.2929	-6.851e+04	20.58± 0.0952	28.40± 0.9027	1.337e+03± 6.776	1.013e+03± -57.07

2. Short Answer Questions

a) *State the percent difference, ϵ_h, between the heat transfer coefficients for the brass and aluminum spheres obtained using the one-term approximation to the exact solution,*

$$\epsilon_h = \frac{|h_{\text{brass}} - h_{\text{alum}}|}{\frac{1}{2}(h_{\text{brass}} + h_{\text{alum}})} * 100\%. \tag{52}$$

Based on your engineering judgment, is this difference reasonable? Briefly discuss any ideas you have for why there is an observed difference. Offer at least one suggestion for improving the experiment (either the apparatus or procedures) in order to increase the accuracy of the h values obtained. [4-6 sentences].

The percent difference between the heat transfer coefficients for the brass and aluminum spheres obtained using the one-term approximation is 4.5493%. A reason for this is because heat transfer coefficient varies with materials. To increase the accuracy of the h values obtained, the data used to calculate the hES should be filtered from 0.2 < Fo < 4 to exclude inaccurate thermocouple data at Fo > 4.

b) *State the "goodness-of-fit" (R^2 values, using 5 significant digits) for your curve fits to the Lumped Capacitance model for each test specimen. Interpret these R^2 values and comment on what these indicate about the quality of your curve fits. Note, your goodness-of-fit calculations should be placed in your Matlab code with the output displayed to the screen. [2 sentences]*

The R^2 values obtained for the linear fits of aluminum and brass are -7.6841e-04 and 0.0020 respectively. The goodness of fit for aluminum is nonsense as R^2 should only vary from 0 to 1. The R^2 value for brass, however, is sensible and indicates that the goodness of fit of the linear fit is very bad as it is very close to 0. A possible reason for such a bad R^2 is that the linear fit is only valid for Fo < 0.4 as observed in Figure 1c.

c) *Based on your experimental results, explain why it is or is not appropriate to use the Lumped Capacitance Model to calculate the heat transfer coefficient h from your experimental data. Note, your response should indicate the magnitude of the Biot number calculated for each test. Describe how you could modify the experiment to reduce the Biot number even further to better ensure that the Lumped Capacitance Model remains valid for a wider range of test specimens. Your statement must be specific and must include a justification. For example, if you suggest decreasing the size of the specimen, then state the exact dimension you would use (assuming the material composition is brass or* *aluminum). If, instead, you suggest changing the material composition of the specimen (e.g., by 3D printing the specimen), then state which material you would use and justify this choice. Other changes could be made as well, e.g., altering the flow speed. [2-4 sentences]*

The Bi values obtained for aluminum and brass are 0.3313 and 0.2929 respectively. Since both Bi values are well above 0.1, the Lumped Capacitance model is not appropriate for calculating the heat transfer coefficient. If we are adamant on using the Lumped Capacitance Model, the radius of the sphere needs to be reduced to 0.0379 m for aluminum and 0.0335 m for brass.

d) *Electric resistance heating, like the type used to heat the recirculating water bath, is 100% energy efficient in the sense that all of the supplied electric energy is converted to heat. Based on this knowledge, state how much power (in Watts) was consumed by the heating element during the two experiments in order to maintain the bath temperature at* T_∞ *.Include a separate estimate for each test specimen. Explain any observed discrepancies between the different test specimens. [2–3 sentences]*

The power consumed by the heating element during the experiment is 216.41 W for aluminum and 420.95 W for brass. The discrepancy observed may be due to the thermal different thermal conductivities of the materials. Brass has a lower thermal conductivity than aluminum, resulting in more energy used to increase the temperature of the brass sphere.