MECE-606 Systems Modeling

Computer Project #4: *Coffee Cup Thermal Model*

Goal: Develop a model of the thermal dynamics of two different types of commercial coffee cups. The model parameters should be estimated based on cooling of near boiling water and validated on the warming of near freezing water to a room temperature ambient condition. Use the cup data to estimate the convection coefficient (h). Apply the developed models to the validation data sets.

Measurement: Temperature data is collected using a National Instruments USB-TC01 and a MicroDAQ MSR-145.

Figure 1: Coffee Cup Thermal Test Setup

System: The mugs used in this experiment have the following geometry: *Ceramic* - OD=8.5cm, thickness=0.4cm, height=12cm; *Styrofoam* - top OD=9.3cm, bottom OD=6cm, thickness=0.3cm, height=12cm. Assume a nominal OD=7.65cm for the Styrofoam cup. Both mugs are pre-treated prior to the experiment with a similar temperature water used in the test to initialize the mug material to a common starting temperature. The thermocouples are immediately placed inside the center of the cup with one inch thick Styrofoam plates on the top and bottom. This is intend to reduce this problem to a 1-D radial thermal problem by assuming zero heat transfer axially. The following table is provided to maintain a consistent source of material data.

Table 1: Fluid & Material Properties

Parameter	Density (ρ)	Thermal Conductivity (k)	Specific Heat (C_p)
Units	*kg/m*^{3}	*W/(m*^{o}*K)*	*J/(kg*^{o}*K)*
Water	1000	0.609	4187
Ceramic	2400	1.5	1070
Styrofoam	100	0.033	1300

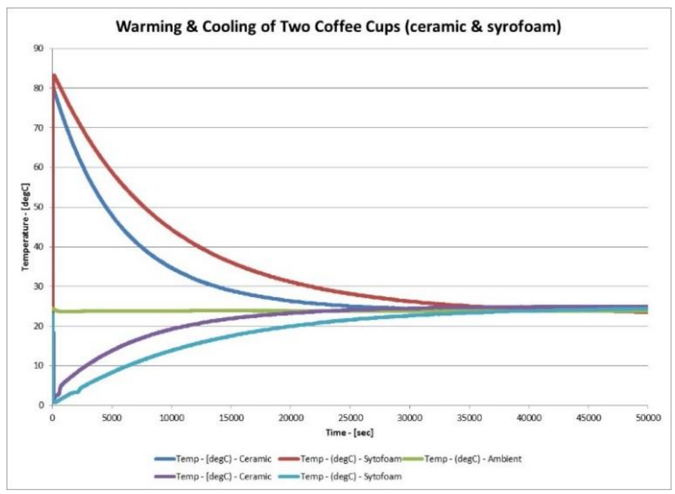

Figure 2: Warming & Cooling of Two Coffee Cups

Considerations: First, approximate the initial start time of the test from the data by estimating the initial steady-state temperature of the water. Check Biot number. Is discretization necessary? Develop **<u>four</u>** models: (1) a 1st order empirical model lumping cup and water; (2) a 2nd order "half-cup" non-radial model with states (T_{water}, T_{cup}); (3) a 2nd order radial model with states (T_{water}, T_{cup}); (4) a higher order non-radial model satisfying the Biot condition (assume h=10J/kgK, and the inner radius of the water is 0.25in). For all models do not consider conduction of the water just the cup. Estimate convective coefficient (h) using optimization methods discussed in class. Does your answer for h make sense? Consistent between cup types? Is the radial model better? Plot all states. Is the higher order model better? How does the cooling model fit compare versus the (warming) validation data sets? Be sure to compare all models against each other.

Deliverable: A concise <u>three</u> page (max.) report on the modeling approach with full derivation of all equations from first principles (i.e. F=ma) through final model <u>including</u> control volume depictions. A discussion of the final results related to quality of the model fit of the data is critical including a quantification of the error (RMS, etc.). The number of plots should be kept to a minimum but be of high quality and description (legends, captions). A portion of the grade is reserved for the quality of the written report. Please submit all of your Matlab/Simulink code <u>separately</u> and consolidate it to as few pages as possible.

Due Date: Two weeks after the assigned date.