Preliminary Housing Thermal Modeling

Andrew Motz

10 June 2024

1 Purpose

Following the previous modeling of the Reefscan Deep housing, we now look at the available data for the Reefscan Transom to evaluate the model. The current design of the transom is smaller and contains significantly fewer electronic components, however it contains an embedded temperature sensor from the camera which is logged with the photo data. This data was aggregated from all available log files from since September of 2023. The results will be compared to the first-principles model discussed previously and evaluated for consistency.

2 Data

Temperature sensor data was pulled from "photo_log.csv" files from all available trip data from September 2023 through this date. There were 141 csv log files from samples not labeled "rubbish". Of these files an additional nine files were excluded due to issues with the contents being processed. Four files threw a "NaN" error and would not load on the Google Collab file explorer. Five files had erroneous dates for their start time in 2021 or 2001 for portions of their data. All other files imported properly and were within a reasonable timescale for legitimacy.

3 Analysis

The models were visualized graphically as a function of sensor temperature as a function of elapsed time for each run. Elapsed time was determined by the filename_string column time stamps from the first recorded time. Temperature data was pulled directly from the "sensor_temperature" column. They were then plotted using matplot on Google Collab. The resulting visualization is Figure 1.

The majority of the runs saw start temperatures ranging from around 40 °C to 60 °C. The overwhelming trend also shows an asymptotic approach to a steady state temperature around 58 °C, regardless of starting temperature. It should be noted that much of the data is of such short duration that a precise asymptotic approximation is not possible, however they still display behavior supporting the long-term behavior of longer data. There were three cases of outlier data with maximum temperatures exceeding 62 °C and with positive slope. More examination of these specific files may reveal explanations and they remain a small fraction of the observed data.

4 Model Validation

The previous first-principles thermal model consisted of a housing of a Delrin tube with a glass dome on one end and an aluminium end cap on the other. The thermal resistance was calculated for the convection between air and material, conduction through the material, and convection with the sea water. A block diagram is illustrated in Figure 2. Using values from the CAD file for the most recent version of the Transom camera housing, the model was solved with

$\dot{W}_{elec}$	$4.5W$	K_{glass}	$1.38\frac{W}{m \cdot K}$
A_{glass}	$0.0162m^2$	h_{water}	$75\frac{W}{m^s \cdot K}$
A_{cap}	$0.00319m^2$	h_{air}	$20\frac{W}{m^2 \cdot K}$
T_{sea}	$30°C$	L_{glass}	$0.005m$
K_{alum}	$235\frac{W}{m \cdot K}$	L_{alum}	$0.015m$

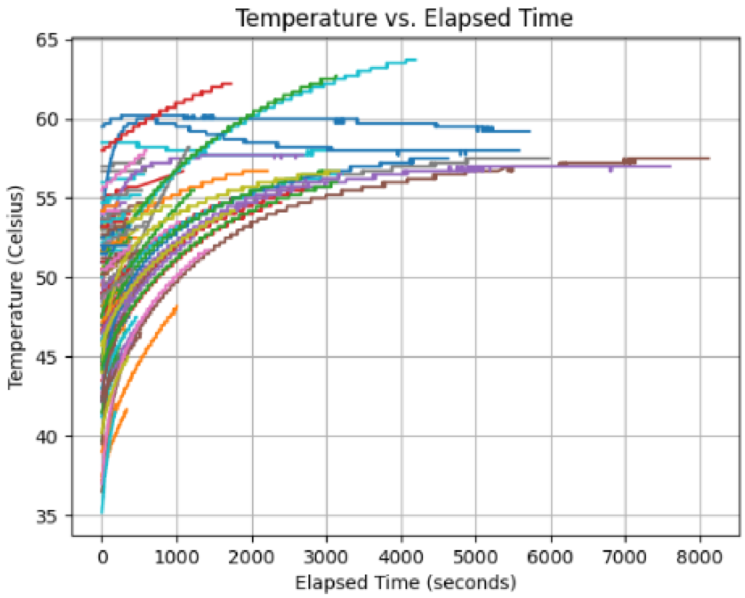

Figure 1: Sensor temperature versus elapsed time for 132 runs since September 2023

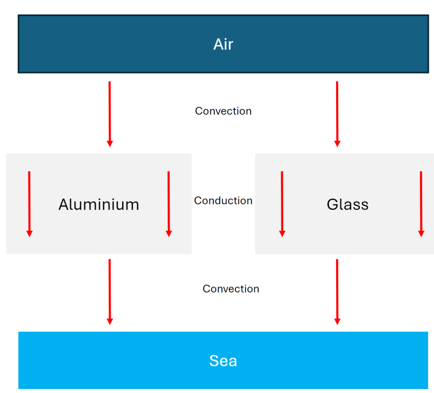

Figure 2: Thermal Model of Housing

The resulting T_{air} is 45.4 °C. This value is not consistent with the observation of the experimental data. The heat is not dissipated as effectively as expected with the given parameters. If an assumption is made that the convection is not as effective as anticipated, a consisted solution of $T_{air} = 58.5$ °C can be obtained with the coefficients $h_{water} = 50\frac{W}{m^s \cdot K}$ and $h_{air} = 10\frac{W}{m^2 \cdot K}$.

Using the new coefficients, we can re-run the model with the measurements from the Reefscan Deep. With the aluminium end cap, T_{air} **= 151.9 °C**. With an aluminium tube, T_{air} **= 50.8 °C**. The predicted steady state values are substantially higher than the original prediction, especially the the aluminium end cap only. The aluminium tube still maintains the temperature within the operational limits making it a significantly better design choice. With an aluminium end cap, h_{air} would need to increase to $80\frac{W}{m^2 \cdot K}$ to drop the steady state temperature to 64.7 °C.

5 Takeaways and Next Steps

The data from the Reefscan Transom showed that the model was an overestimate for the heat dissipated by the housing. After recalculating relevant coefficients to be consistent with observed data, it is even more apparent that producing the cylinder of the housing out of aluminium is the best design choice. A Delrin tube for the body of the housing risks significant overheating.

Next steps to continue this study include:

- Examining the three outliers to determine probable cause for the temperature readings
- Investigation to the actual sea water temperature for each of the trials as locations and time of year varied greatly
- Comparison of the plotted data to the corresponding solution to the differential equation for temperature as a function of time based on the initial sea water temperature and sensor temperature
- Experimentation on actual housing and electronics components to determine heat generated and convection coefficients