TRUNNION SHRINK-FIT PROCESS TIME

EXPERIMENTAL PROJECT #1

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Project Summary

This report outlines the methods used to determine minimum time needed for a shrink-fit process on a bridge trunnion. Shrink-fit processes are used to contract the trunnions size so that it can be fit into the bridge structure. The trunnion is placed in an ice water bath until it cools to the same temperature of the water, referred to as the steady state temperature. Since this is the coldest the trunnion will become under these conditions, the time corresponding to when it reaches steady-state temperature will be when it experiences the largest contraction. This time was found to be 88 minutes.

Engineering Model

The heat transfer process from the trunnion was modeled as a lump capacitance transient heat transfer problem. In order to balance the energy in the system, this method states that the rate of heat loss through convection will equal the rate that energy is stored by the trunnion (Kaw 2008).

The rate of heat loss through convection is given by the equation:

$$hA(T - T_\infty)$$

Where,

h = Heat Transfer Coefficient ($W/m^2 °C$)
A = Immersed Surface Area (m^2)
T = Temperature of the Trunnion (°C)
T_∞ = Temperature of the Ice Bath (0 °C)

The rate at which heat is stored is given by:

$$mC\frac{dT}{dt}$$

Where,

m = Mass of the Trunnion (kg)
C = Specific Heat of Trunnion(J/kg °K)

The energy balance for the system would give the following differential equation:

$$hA(T - T_\infty) = mC\frac{dT}{dt}$$

Since initially (at time=0) the trunnion is at room temperature, the following condition is true:

$$T(0) = T_0$$

Where,

T_0 = Initial Temperature of the Trunnion, or Room Temperature (23 °C)

The solution to this equation using the above condition is,

$$\frac{T - T_\infty}{T_0 - T_\infty} = e^{\frac{-hAt}{mC}}$$

Since our concern for this project is determining cooling time, this equation was solved using MATLAB for time:

$$t = \frac{mC \times log\frac{T_\infty - T}{T_\infty - T_0}}{-hA}$$

Trunnion Specifications

The dimensions of the trunnion as well as its material properties are necessary to complete the engineering model.The trunnion itself was represented as a hollow cylinder with the following dimensions:

Table 1: Trunnion Dimensions

Outer Diameter (m)	0.6096
Inner Diameter (m)	0.4572
Length (m)	1.524

We know that the trunnion will be made from steel. Material properties for standard steel are given by Ashby (1999) as:

Table 2: Material Properties of Steel

Density (kg/m^3)	7850
Specific Heat (J/kg °K)	446

Based on the above tables and the trunnion's geometry, the mass was found to be 1527 kilograms, and its surface area was 1.7535 meters. These values are necessary for our final equation of the engineering model.

Experimental Conditions

The following conditions were used for the remaining variables listed in the engineering model:

Table 3: Conditions for Engineering Model

h (W/m^2 °C)	400
T_∞(°C)	0
T_0(°C)	23
T (°C)	0.01

Note: Heat transfer coefficient came from Incropera (2007). All other values were assumed within the model.

Since steady state temperature is desired, the T used for temperature of the trunnion was very close to that of the ice water bath: 0.1°C. This will give the time it takes for the trunnion's temperature to reach within a hundredth of the ice water bath. This time was found to be 88 minutes.

Recommendations

Through the model discussed in the previous section, the time needed to reach the near maximum contraction was 88 minutes. This model was developed conservatively, using steady-state temperature as 0.1°C, to give a decent estimation of the minimum time needed for each shrink fit process. Since we are very close to the steady state temperature, the trunnion is close to its maximum contraction value. Therefore, the recommended minimum time for the trunnion to stay immersed in the ice bath is 88 minutes. If this time needs to be further minimized the amount of contraction the trunnion must achieve would need to be known.

References

Ashby, M. (1999).Materials Selection in Mechanical Design.Butterworth-Heinemann Publishing, Woburn, MA.

Incropera, F., Dewitt, D., Bergman, T., &Lavine, A. (2007). Introduction to Heat Transfer.Wiley & Sons, Inc., Hoboken, NJ.

Kaw, A. (2008). Cooling a Aluminum Cylinder in Iced Water. *Holistic Numerical Methods Institute.* Retrieved from http://numericalmethods.eng.usf.edu/experiments/