Group 8: Stator Insertion Machine Redesign

3rd Deliverable Product Specification

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Contents

Introduction

The fundamental task of the design project is to redesign the current method for heating compressor housings. The housing is cast from A356 T6 aluminum. Currently a large convection oven is used to heat four housings at a time. Heating time is roughly 30 minutes at a temperature of 300 °F. Before the housing can continue through production it must cool for approximately one hour. The primary goals are as follows:

- Minimize the overall size of the heating/insertion mechanism to maximize floor space
- Reduce overall heating time
- Lower overall part temperature
- Decrease total cooling time
- Eliminate batch processing to allow 'just in time' order processing

Product Specifications

The principle components of the project are the heating element and the stator insertion component. Initially the heating element is used to heat the housing to the desired temperature. Once the required temperature is reached based on temperature reading from a thermocouple the heating element retracts. After heating, the stator is inserted into the housing and the part is cooled either in ambient air or by other means. The heating of the housing should be completed in less than 8 minutes. The heating should not introduce any thermal stresses that cause the housing material to yield. The exterior of the housing should remain at 200 °F or less. The final dimensions should be no more than 6ft X 4ft X 8ft. The parts will be cycled through the mechanism one at a time.

Heating Element Calculations

The stator utilizes an interference fit with the housing. The required clearance for this fit is based on the clearance fit section of the Machinist Handbook. The insertion process utilizes a basic shaft into hole free fit, the appropriate clearance for this is approximately 50 microns. The temperature needed to reach the desired clearance is calculated using the thermal expansion relationship (Equation 1). This calculation utilizes the maximum material conditions fit.

$$\Delta \boldsymbol{L} = \boldsymbol{L_o} * \boldsymbol{\alpha} * \Delta \boldsymbol{T} \qquad \textbf{(1)}$$

Based on the supplied drawings the smallest diameter of the housing is 0.1715m, the maximum stator dimension is 0.1716m. The coefficient for thermal expansion for aluminum A356 is 0.000023 m/m*°C. Ambient temperature is considered 25°C. Using this information the clearance between the two parts is calculated based on temperature change (FIG 1). From the graph the final temperature of the part should be approximately 85 °C (185°F). This temperature is an idealized temperature. We will use this temperature as a starting point for experimentation. Once the desired temperature is found the total energy needed is calculated using a simplified version of the second law of thermodynamics (Equation 2). The density of aluminum A356 T6 is

2670 kg/m^3. The specific heat capacity is 963 J/kg*°C. From a CAD model of the housing, the volume is 0.0126m^3. Using these properties the required heat input was plotted as a function of ending temperature (FIG 2). To reach the desired temperature of 85 °C, approximately 2000 kJ will be needed. This is just a baseline calculation to achieve a starting point for experimentation. There will be heat losses within the system regardless of the heating method.

$$\boldsymbol{Q = \rho * V * C * \Delta T} \quad \textbf{(2)}$$

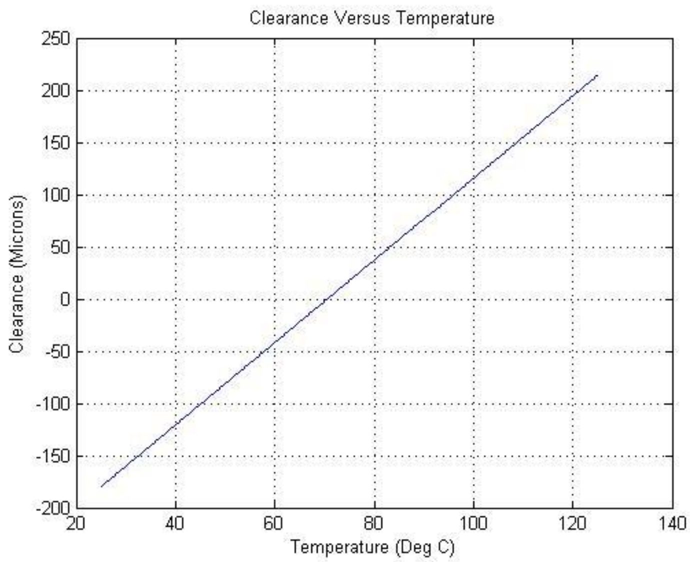


Figure 1

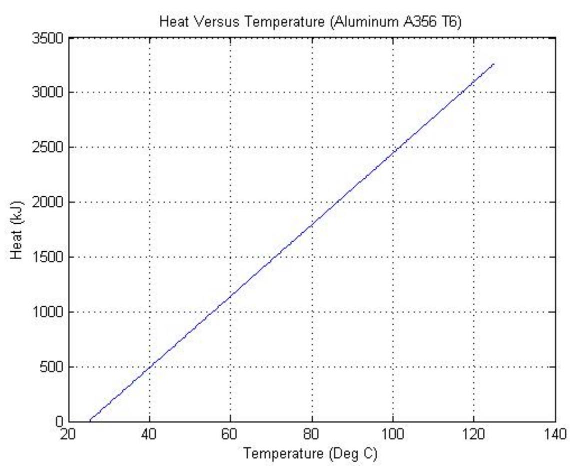
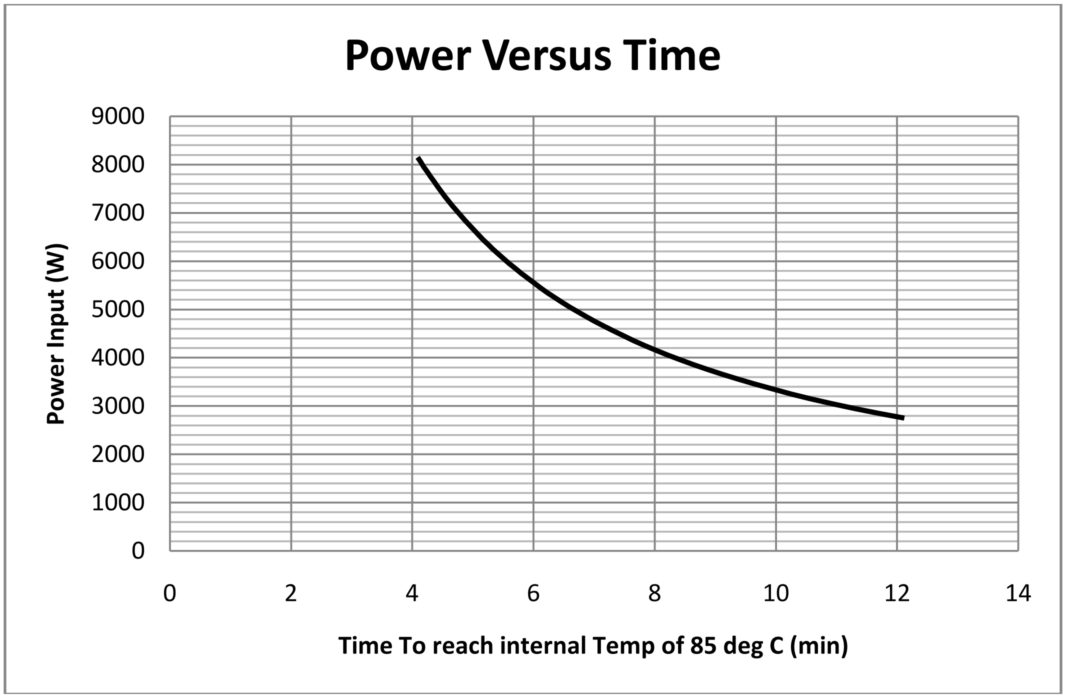


Figure 2

For selection of the heating element, power input must be considered. The total heating time is calculated using the input power and the required energy (Equation 3). This power input does not reflect losses within the heating system. Losses will be reflected in a longer than calculated heating time and determined through experimentation. Calculations show that to achieve our target time of 8 minutes the heating power must be at least 4200 Watts (FIG 3).

$$\boldsymbol{Heating\ Time} = \frac{\boldsymbol{Q}}{\boldsymbol{P}} \quad \textbf{(3)}$$



Environment

The finished design will be implemented on the production floor at Danfoss Turbocor. The assumed temperature of the manufacturing facility is assumed 25 degrees Celsius. All housings are assumed to be stored in this facility at this ambient temperature.

Stator Insertion Device

Currently the stator is inserted into the housing using a linear actuator. Once the housing comes out of the oven it is moved to a separate table. A technician maneuvers the housing into alignment pins and inserts the stator. The only change to the insertion mechanism will be integrating it into the heating platform. This will provide less loss from convective heat transfer before the stator is inserted, thus lowering the initial housing temperature.

Housing Material

The compressor housing is cast from aluminum A356 with a T6 heat treatment. Material properties are presented in Table 1. These properties will be used extensively throughout the project.

Table 1: Material Properties Aluminum A356 T6

Property	Metric	English
Tensile Strength Ultimate	234 Mpa	34000 psi
Tensile Strength Yield	165 Mpa	24000 psi
Modulus of Elasticity	72.4 Gpa	10500 ksi
Shear Modulus	27.2 Gpa	3950 ksi
Shear Strength	143 Mpa	20700 psi
Specific Heat Capacity	0.963 J/g-°C	0.230 BTU/lb-°F
Thermal Conductivity	151 W/m-K	1050 BTU-in/hr-ft^2-°F
Linear expansion Coefficient	22.2 (10^{-6}m/m-K)	12.3 (10^{-6} in/in-°F)

Bibliography

MatWeb.(n.d.).Retrieved 10/1/2010, Material Properties Aluminum A356 T6: http://www.matweb.com/search/DataSheet.aspx?MatGUID=d524d6bf305c4ce99414cabd1c7ed070&ckck=1

Engineering Toolbox,(n.d). Retrieved 10/1/2010, Linear Expansion Coefficients for Various Materials:http://www.engineeringtoolbox.com/linear-expansion-coefficients-d_95.html

Appendix

Sample Calculations

Calculating Clearance

$T_1 := 25°C$ $\quad$ $D_h := 0.171450m$

$T_2 := 85°C$ $\quad$ $D_s := 0.171630m$

$\Delta T := T_2 - T_1$ $\quad$ $\alpha := 0.000023\frac{m}{m \cdot K}$

$\Delta L := \pi \cdot D_h \cdot \alpha \cdot \Delta T$

$$D_{new} := D_h + \left(\frac{\Delta L}{\pi}\right)$$

$Clearance := D_{new} - D_s$

$\boxed{Clearance = 56.601micron}$

Calculating Energy Needed

$\rho := 2760\frac{kg}{m^3}$ $\quad$ $C_p := 963\frac{J}{kg \cdot K}$ $\quad$ $V_h := 0.0126m^3$

$Q := \rho \cdot V_h \cdot C_p \cdot \Delta T$

$\boxed{Q = 2.009 \times 10^6 J}$

Calculating Power needed to heat in 8 minutes

$Time := 8min$

$$P := \frac{Q}{Time}$$

$\boxed{P = 4.186 \times 10^3 W}$