Danfoss Turbocor: Stator Insertion Redesign
Mechanical Engineering Senior Design Team 8

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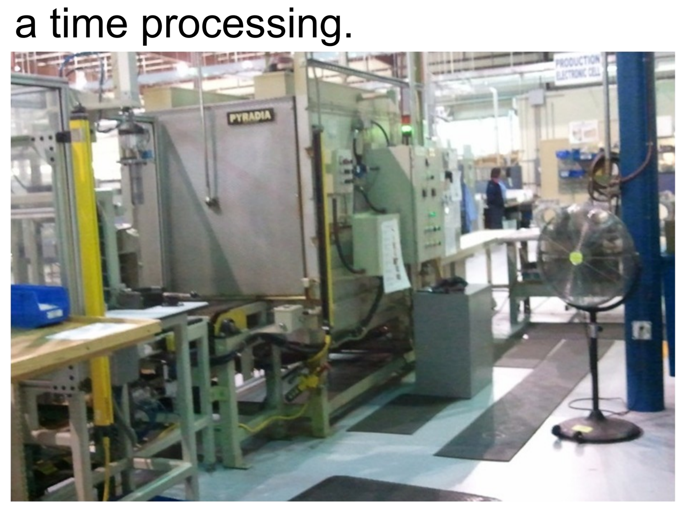
Justification and Background

Danfoss Turbocor makes state of the art compressors that utilize magnetic bearing technology. One of the key steps in manufacturing the compressor is inserting an oversized stator into an aluminum outer casting. The stator is held in place using an interference fit. Batches of housings are loaded into a large electric oven four at a time. The parts are then heated for approximately forty-five minutes. After heating the housing is moved to a secondary station where the stator is inserted. Once the stator is inserted the part must cool for a long time before workers can continue assembly. The batch method of heating does not allow for rush orders to be completed in a timely manner. This two step system uses extensive floor space that could be used for other manufacturing processes. Streamlining the process into one station reduces floor space and allows one housing at a time processing.



Left: Current oven used to heat housings four at a time **Right:** Current stator insertion station. This introduces slop when inserting stator.

Problem Statement

Design a more efficient way of heating the aluminum housing for stator insertion. Once the housing is heated the outside surface should be easily handled without needing excessive protective equipment. The heating and insertion process should be completed in a timeframe to allow increased production. The finished product should be considerably smaller than the current heating equipment.

Engineering Requirements

- Reduce heating time to less than 15 minutes
- Lower final housing temperature
- Smaller size
- Thermal expansion must allow for 60 microns clearance
- Method for aligning stator and housing for thermocouple insertion
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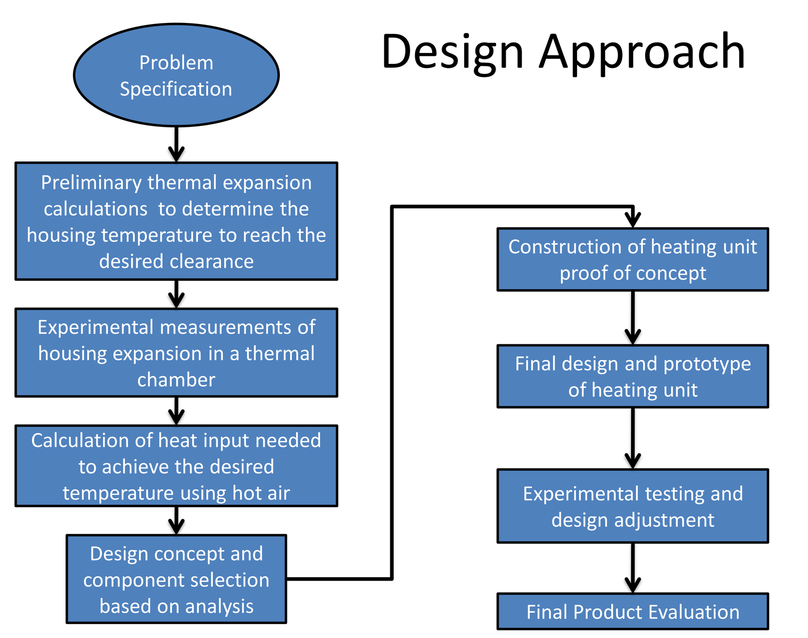
Design Approach

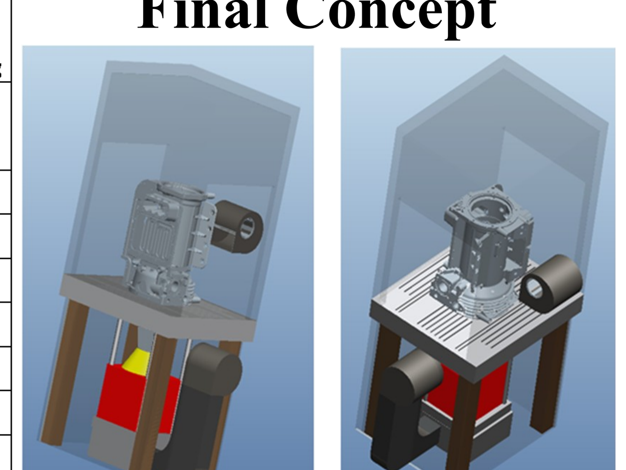


Concept Selection										
		Convective Oven		Oil bath		Internal Resistive		Induction Heating		
Selection Criteria	Weight	Rating	Weight Score	Rating	Weight Score	Rating	Weight Score	Rating	Weight Score	
Performance	30%	4	1.2	5	1.5	3	0.9	3	0.9	
Complexity	20%	4	0.8	3	0.6	2	0.4	2	0.4	
Size	20%	3	0.6	2	0.4	4	0.8	3	0.6	
Durability	15%	3	0.45	4	0.6	1	0.15	2	0.3	
Cost	10%	2	0.2	2	0.2	3	0.3	3	0.3	
User Friendly	5%	3	0.15	1	0.05	3	0.15	3	0.15	
Total		3.4		3.35		2.7		2.65		
Ranking		1		2		3		4		

Concept Selection

Based on the decision matrix it was decided that Concept A – Convective Oven was chosen as our final design. Although Concept B was very close in ranking, after presenting the choices to the customer the oil bath was eliminated because the compressor housing must remain dry.

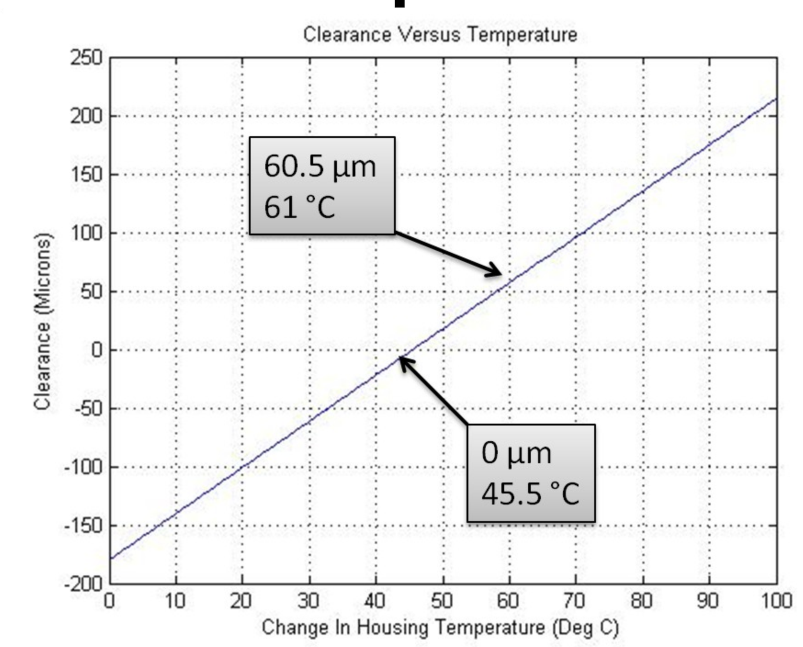
Final Concept



- Insulated sliding hood
- Slotted base plate for circulation of air
- Heater to raise air temperature
- Blower to circulate air through unit
- Alignment technique for stator alignment

Theoretical Analysis: Linear Expansion

Linear expansion equation is valid due to the fact that the only dimension of interest is the inner diameter of the housing. The linear expansion equation plotted using the coefficient of thermal expansion for Aluminum A356. Graph based on the maximum material condition of both the housing and the stator.



$$\Delta L = L_o * \alpha * \Delta T$$

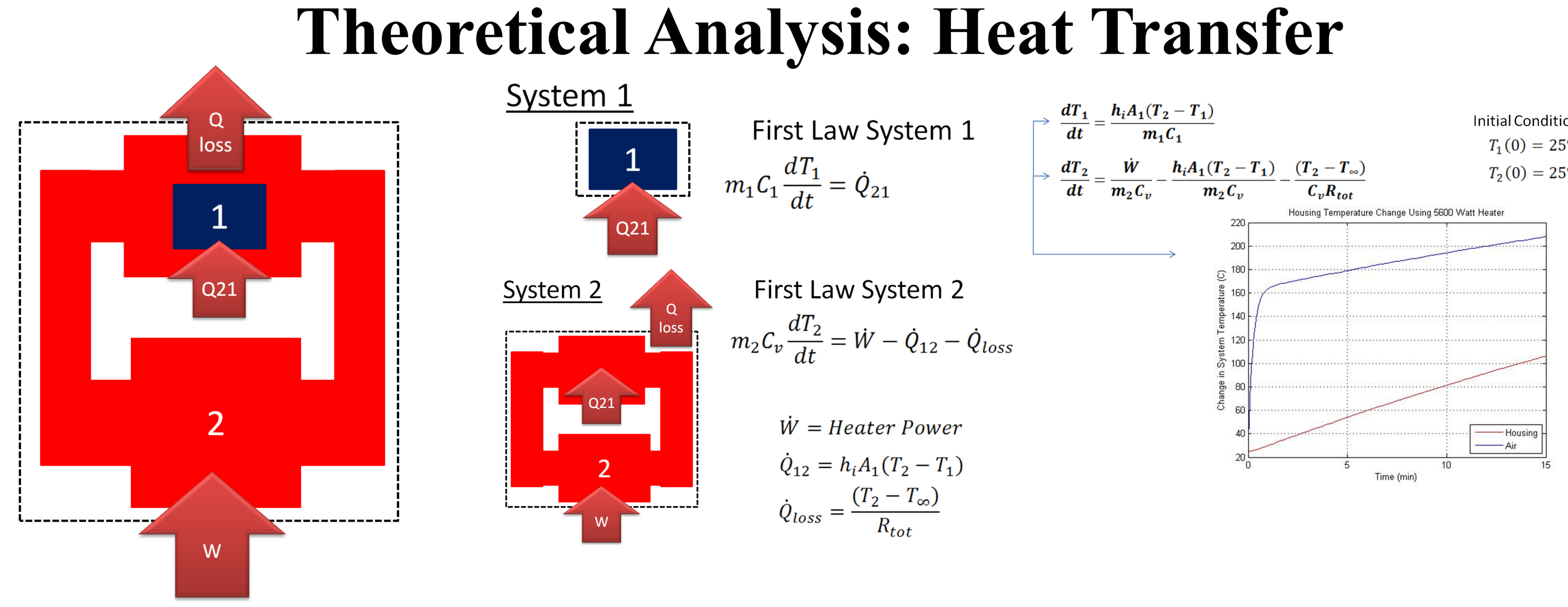
ΔL = Change in length

L_o = Initial length

α = Thermal expansion coefficient

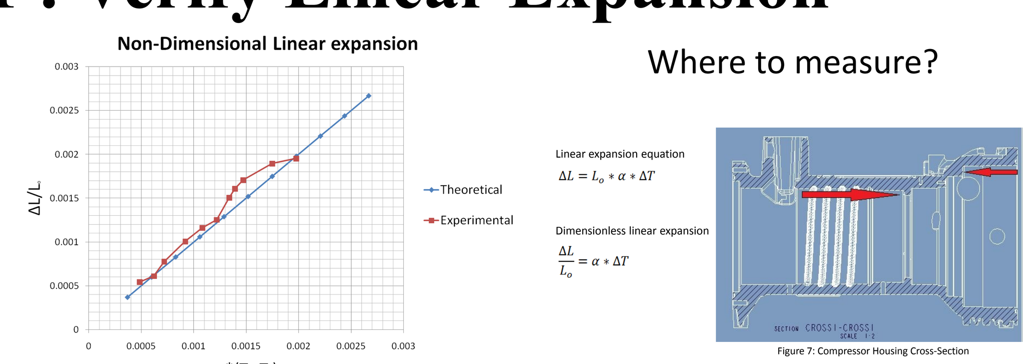
ΔT = Change in temperature

Theoretical Analysis: Heat Transfer



Experiment 1 : Verify Linear Expansion

Steps:
- Heat Housing to maximum Temperature
- Take diameter measurement as housing cools
- Plot experimental data versus theoretical data



Experiment 2: Proof of Concept Testing

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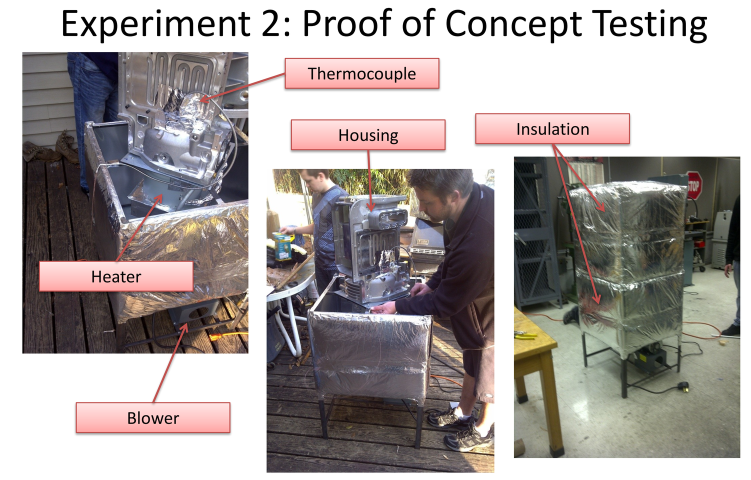
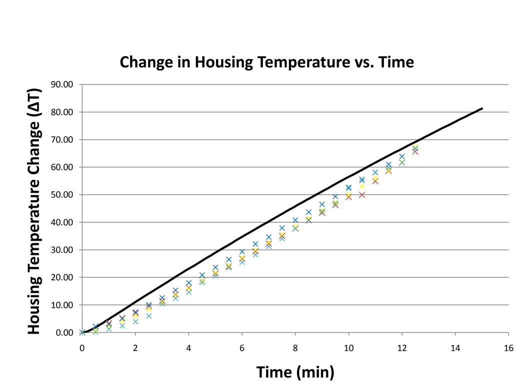
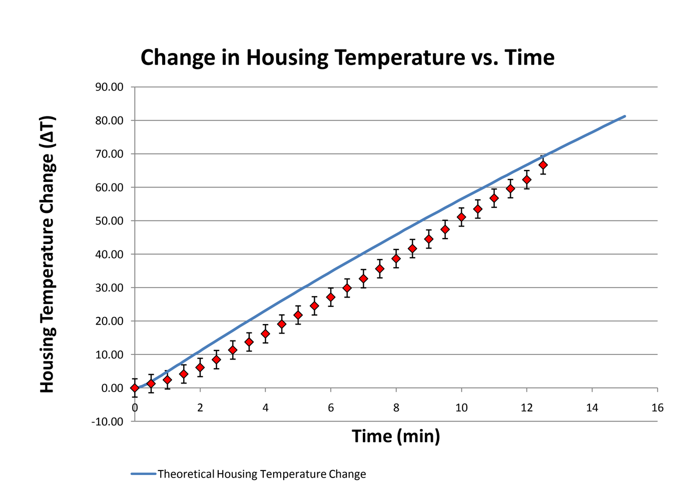


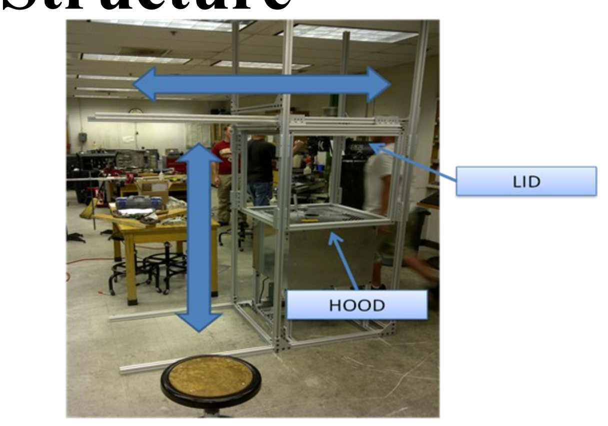
Steps:
- Assemble proof of concept heating chamber
- Attach thermocouple to housing to monitor temperature
- Record temperature at set time intervals
- Plot data and compare to heat transfer model
- Verify data follows expected trend



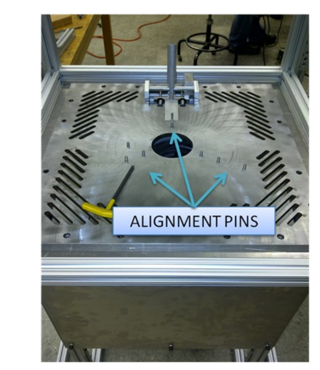


Final Design: Main Structure

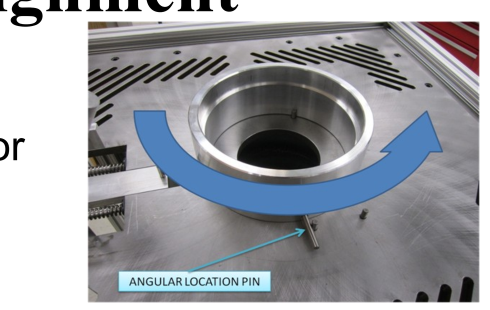
- Main structure assembled utilizing Engineering Extrusion 80/20
- Hood lowers and closes using sliding Teflon bearings
- Lid slides to the open and closed position using Teflon bearings
- Pneumatic actuator using expanding mandrel to insert stator into housing

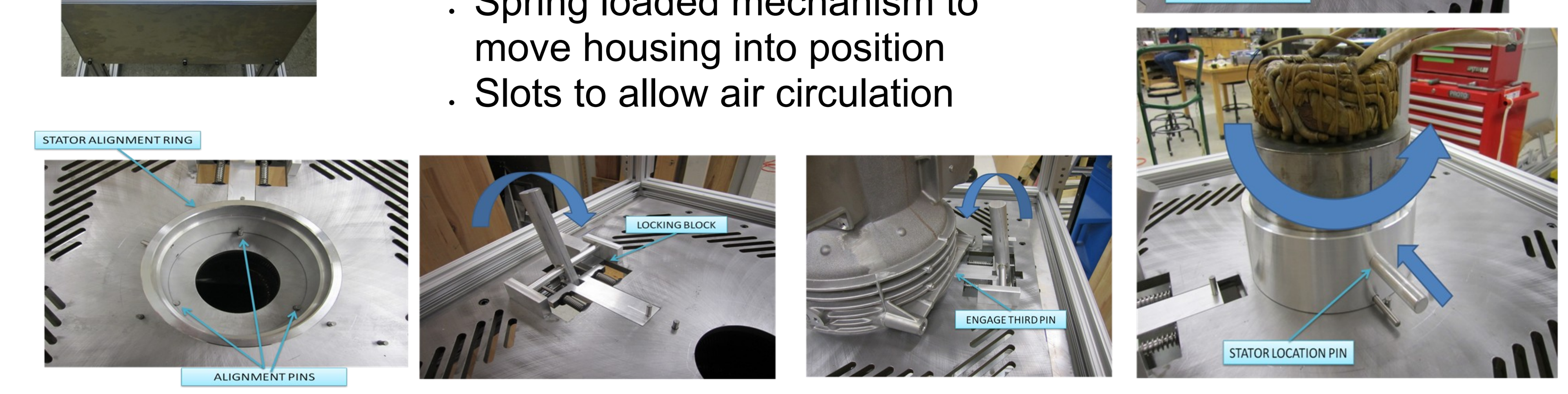


Final Design: Stator Alignment



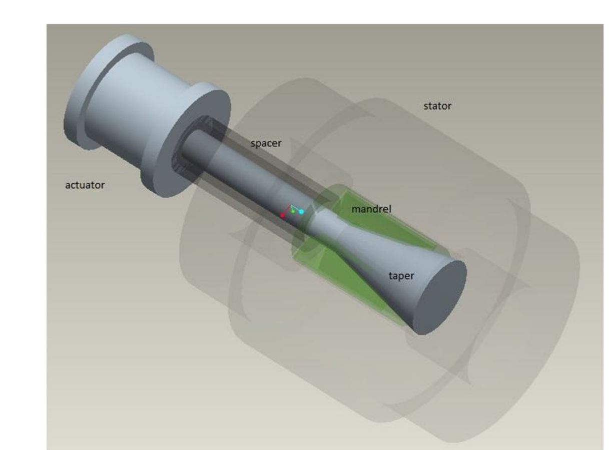
- Location pins to locate stator alignment ring
- Single pin to locate stator to stator alignment ring
- Pins to locate housing
- Spring loaded mechanism to move housing into position
- Slots to allow air circulation



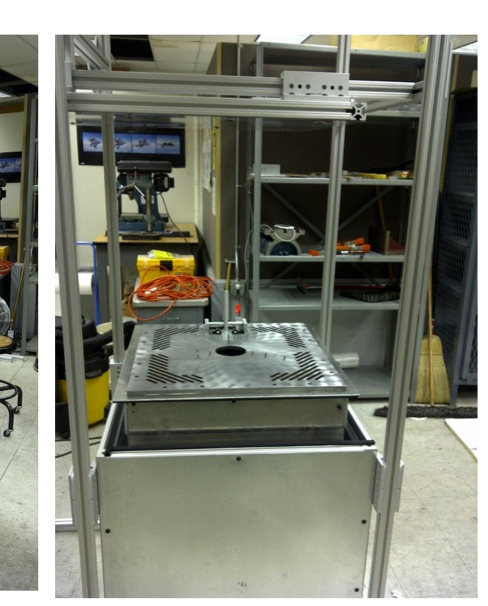


Final Design: Stator Insertion

- Short stroke actuator pulls wedge into expanding mandrel
- Outside of mandrel grips inside stator surface
- Long stroke pneumatic actuator pulls the smaller actuator above the lid into the load position during heating cycle
- Once heated the stator is placed into housing and the mandrel is released



Final Assembly Pictures



Conclusion

The use of convection heating in the compressor manufacturing process is a feasible solution for Turbo Corr. The assembled design successfully heated the housing to the required temperature in just under 14 minutes. The selected heater was the most powerful heater available of the shelf. A specialized more powerful heater could be implemented in order to increase the time. Due to the lower final temperature the housing cooled to a safe handling temperature in 20 minutes. The total heating, insertion,

Acknowledgments

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