Labyrinth Seal Test Rig
Danfoss - Turbocore

Interim Design Presentation
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Overview

- Introduction
- Design Concept
  - Basic Design
  - Shaft Concentricity measurement
  - Pressure Differentials
- Numerical Modeling
- Material Selection
- Cost Analysis
- Future Work
- Conclusion

Introduction

The Problem

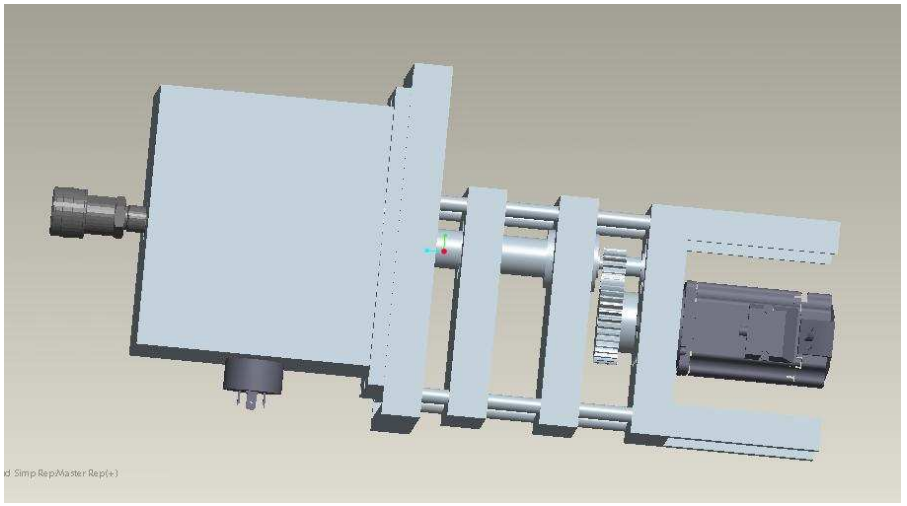
Design and build a device that can determine the amount of leakage through various designs of labyrinth seals so that the best design can be determined.

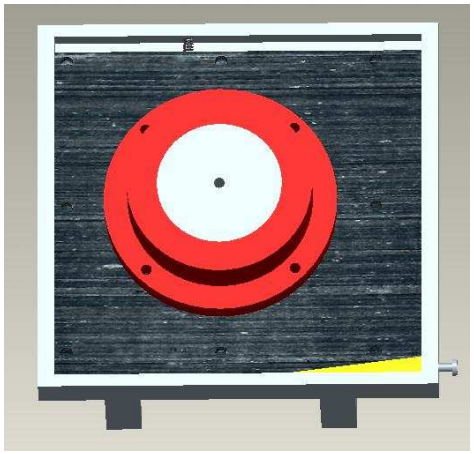
Customer Needs	Product Specifications
Environmentally friendly	Replace R134a w/ air
Accurately model conditions in compressor	Numerical analysis to match Re of both fluids
Vary shaft concentricity	Differential threading
Measure leakage through seal	Pressure gauges in conjunction w/ Pitot Probe
Interchangeable labyrinth seals	Multiple removable seal plates

Conceptual Design

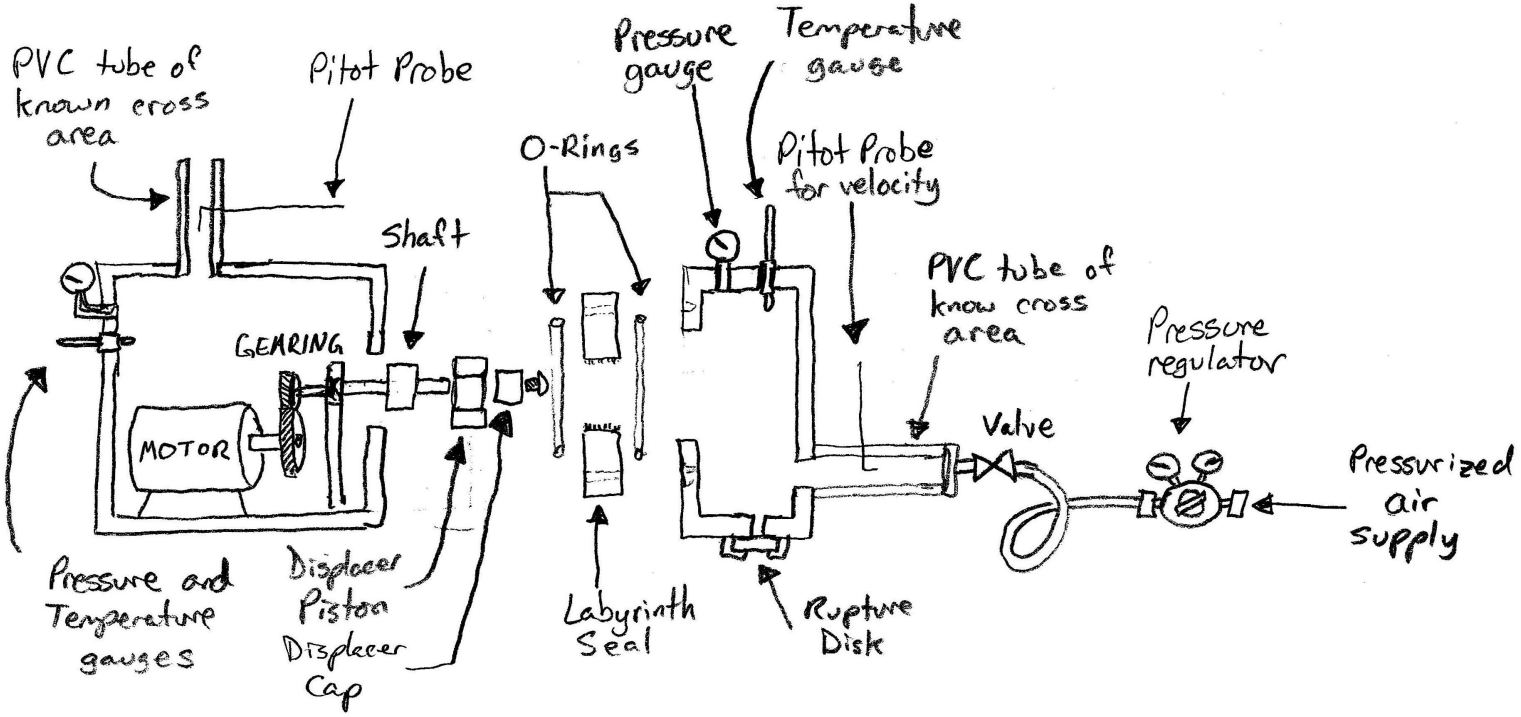
Design consists of:

- High pressure side box
  - Pressurized air provided via compressor
  - Regulator used to control incoming pressure
  - Pressure transducer inside box measures controlled pressure
- Seal Plates
  - Interchangeable, each one containing a different size seal
- Intermediate low pressure box
  - Open to the atmosphere
  - Exiting air escapes through a known diameter
  - Pressure gauges in this stage measures leakage pressure
  - Pitot Probe in tube exit



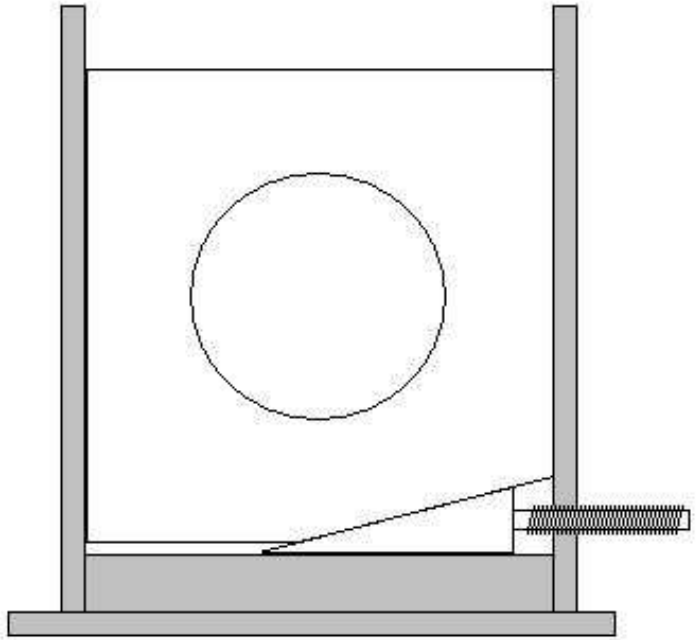


Conceptual Design: Pictures



Conceptual Design: Shaft Alignment

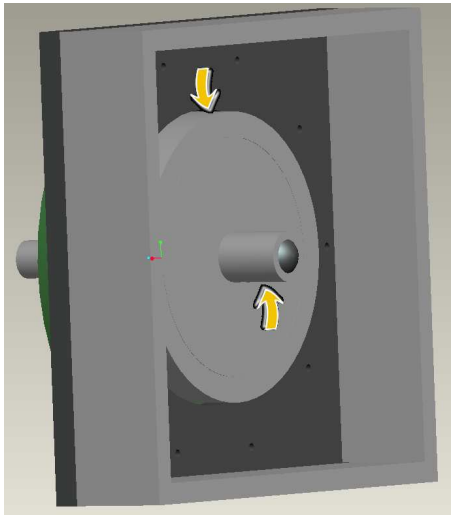
- Precision Jacking bolts will be used to change concentricity of the shaft
- As bolts are turned a wedge is pushed under seal plate to raise or lower seal in relation to the shaft.
- Wedge-Bolt system gives greater precision and control of movement

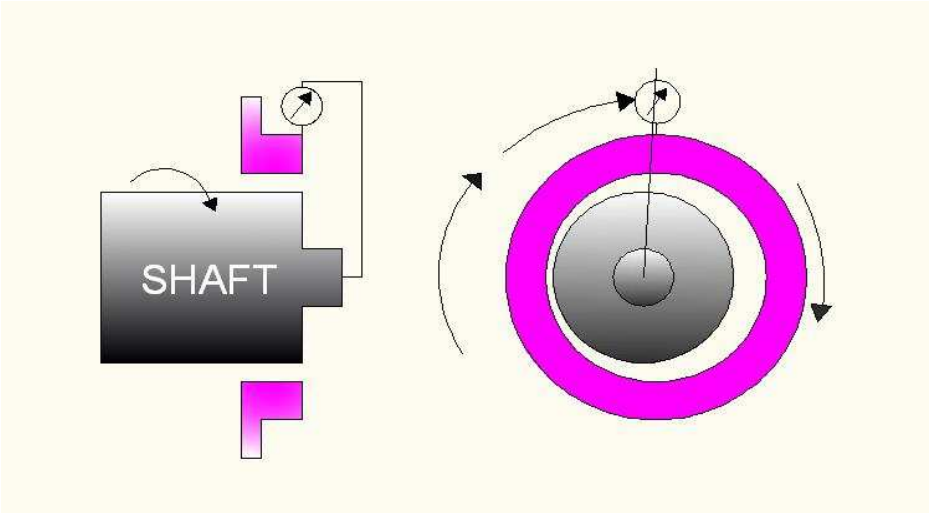


Conceptual Design: Concentricity Measurement

2 methods utilized for measuring concentric alignment:

- Micrometers used to measure distance from shaft to seal wall
- Dial gauge attached to shaft used to verify concentric alignment





Conceptual Design: Safety

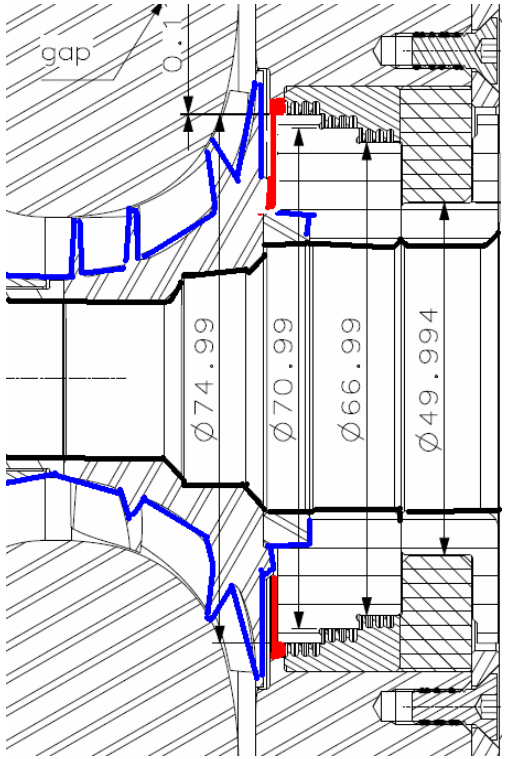
- Over designed thickness of high pressure side box to withstand above expected internal pressures
- Rupture Disk built into to high pressure side
- Shatter proof plexiglass on the low pressure side box
  - Shaft and gearing enclosed in low pressure side box

Numerical Analysis: Replacing R134a w/ Air

- To accurately represent R134a using air, the Re of both fluids must match
- Used Tangential Velocity as the dominant velocity of the fluid

$$\mathrm{Re} = \frac{Vd}{\nu} \qquad V = V_T = r\omega$$

- This Assumption was WRONG!
- The pressure gradient is the driving velocity



$$\frac{\dot{m}^2}{A^2} = \frac{\gamma}{\gamma - 1} 2g \frac{P_0}{V_0} \left[\left(\frac{P_1}{P_0} \right)^{\frac{\gamma}{2}} - \left(\frac{P_1}{P_0} \right)^{\frac{\gamma+1}{\gamma}} \right]$$

$$\left(\frac{\dot{m}}{A} \right)^2 = \frac{g\left(P_0^2 - P_N^2\right)}{P_0 V_0 \left(N + \log_e P_0 / P_N \right)} = \frac{g\left(P_0^2 - P_N^2\right)}{N P_0 V_0}$$

Material Selection

- **High Pressure Side Box : Steel**
  - In order to withstand high internal pressure
- **Low Pressure Side Box: Plexiglass**
  - Does not need to withstand pressures
  - Allows for observation of internal pressure gauges and motor & shaft operation
- **Exit Tube: PVC piping**
  - PVC piping has an assumed surface roughness of zero so viscous effects can be neglected
- **The following parts are all manufactured in house by Danfoss - Turbocore:**
  - Seal Plates: Steel
  - Shaft: Steel
  - Seals: Steel

Cost Analysis

Material Costs

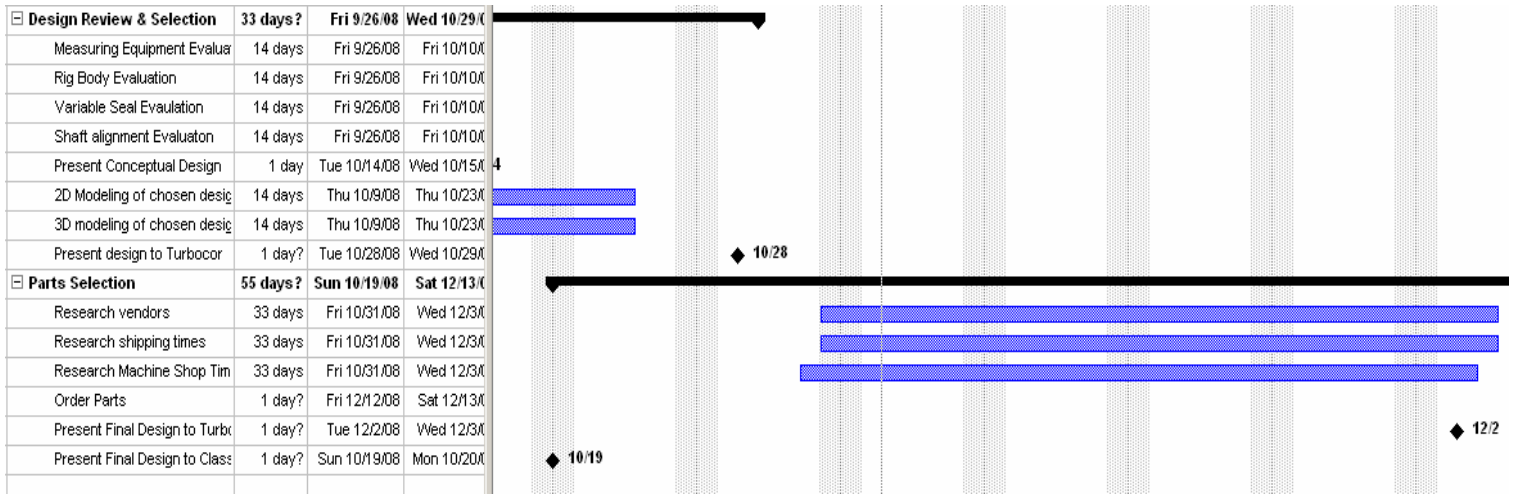
- The seals, seal plates and shaft will be provided by Turbocore at no cost
- Steel: $354.70
  - $59.11 per plate (1.5' **x** 1.5')
- Plexiglass:$339.12
  - $56.52 per plate (2'**x** 2')

Measurement & Equipment Costs

- Pressure Gauges: Free
- Pressure Regulator: Free
- Pitot-Probe: $120.00
- Micrometers: $140.00
- Dial Gauge: $100.00
- Motor: $200.00

Future Work (Fall Semester)

- Rework Reynolds number calculations to determine required pressure
- Use corrected Re calculations to determine internal pressure forces
- Finalize design dimensions and material selection with client
- Order materials
- Write Final Design Report



Conclusions and Summary

- An open system design will be used
- Leakage through the seal will be determined based on pressure measurements
- The shaft concentricity will be varied using precision jacking bolts
- The driving velocity of the fluid is caused by the pressure gradient across the seal
- The majority of the test rig will be made of steel and plexiglass
- The estimated cost of the test rig is $1253.82

Questions?

References

- www.Amazon.com
- http://www.discountsteel.com/index.cfm/go/main.itemDisplay/itemID/29.htm
- Piotrowski, John. Shaft Alignment Handbook. Danbury: NetLibrary, Incorporated, 1995.
- http://www.professionalplastics.com/PLEXIGLASS-ACRYLICSHEET-EXTRUDED