Needs Assessment & Project Scope

Team #1
Danfoss-Turbocor

Team Members
Will Chapman
Giovanni Dinitto
Justin Mariniak
Kristin Scheel

Submitted: September 16th 2008

Needs Assessment

Danfoss-Turbocor manufactures state of the art compressors for air conditioning systems, and a crucial part of their compressors is a labyrinth seals that prevents the refrigerant from leaking from the high pressure compression stage into the low pressure portion of the compressor. The company has implemented different labyrinth seal designs, but each design has failed to provide conclusive efficiency results. Danfoss-Turbocor needs a test rig which will be able to provide quantitative results on the amount of leakage that is encountered at this labyrinth seal. The test rig should be adjustable to fit various seal sizes, shaft alignments, and testing conditions (ie different temperatures, pressures etc). It has also been requested that the working fluid of the test rig be air instead of R134A in order to minimize test costs. In addition to the test rig, Danfoss-Turbocor would like us to provide theoretical calculations and mathematical modeling of the leakage rates through this specific seal. Danfoss-Turbocor also inquired about a possible use of a CFD (Computational Fluid Dynamics) analysis of the seal, but this analysis was revoked from the requirements, due to a lack of experience of this type of software use.

Project Scope

Problem Statement:

The focus of this project will be to design and build an apparatus that will allow various sizes of labyrinth seals to be tested for leakage under similar operating conditions that they would experience inside a Danfoss – Turbocor brand compressor. Once the test rig is built a study will be conducted on various seals to determine the most effective seal design. Once these results are collected, they should be compared against the mathematical modeling of the leakage rates.

Background

According to Flitney and Brown [1], a labyrinth seal operates on following two methodologies; rotating radial faces cause centrifugal separation of liquid or solid from air and a series of restrictions followed by a clear volume creates expansion of a gas and hence reduces the pressure. These seals use a very small gap in between the seal and the rotating shaft, and then grooves are machined into the seal in order to disrupt the flow. A general design of a labyrinth seal is shown in figure 1 [2]. It can be seen that the fluid is prevented from leaking through the seal, by disrupting its flow through the use of turbulent inducing grooves across a very small clearance area. According to Boyce [2], a labyrinth seal has the following advantages: simplicity, reliability, tolerance to dirt, system adaptability, very low shaft power consumptions, material selection flexibility, minimal effect on rotor dynamics, back diffusion reduction, integration of pressure, lack of pressure limitations, and tolerance to gross thermal variations. Boyce [2] further claims disadvantages associated with this type of seal are the following: high leakage, loss of machine

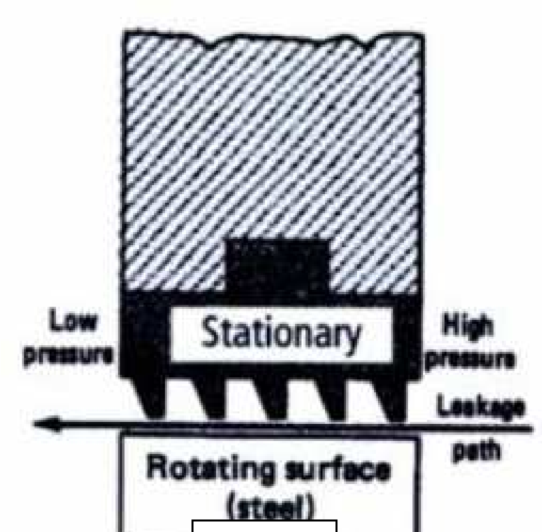

Figure 1

efficiency, increased buffering costs, tolerance to ingestion of particulates with resulting damage to other critical items such as bearings, the possibility of the cavity clogging due to low gas velocities or back diffusion, and the inability to provide a simple seal systems that meets OSHA or EPA standards. The current design of the labyrinth seal in use at Danfoss-Turbocor consists of three steps each with three groves. Much research has been preformed regarding the labyrinth seal, but engineers at Danfoss-Turbocor still question which combination of the following will reduce the amount of leakage: number of teeth, number of steps, tooth thickness, and spacing.

An experiment was conducted at Texas A&M University in order to determine the most effective configuration of teeth in a labyrinth seal. Figure 2 [3] represents the test rig used in their study, but it should be noted that their study dealt with a labyrinth seal and a non-rotating shaft, whereas our experiment will study the leakage rates through the seal while a rotating shaft is present. Nevertheless, the results provided by this experiment should be compared to any theoretical and experimental calculations that are conducted by our team.

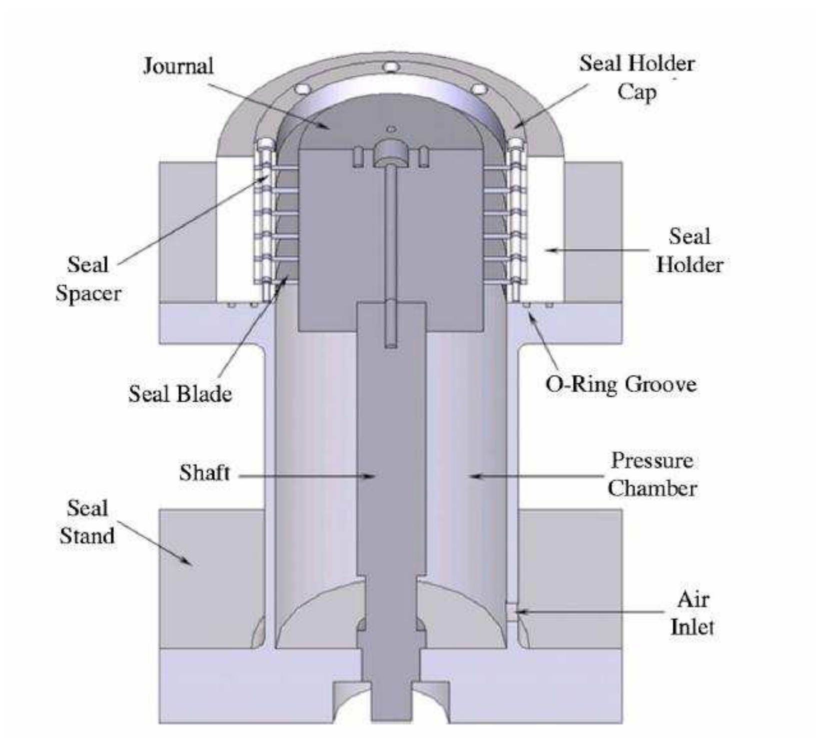

Figure 2

Objective

In order to satisfy the requirements given by Danfoss-Turbocor, our progress will be updated through scheduled design presentations. The main objective for this test rig is to quantitatively measure flow rate through the seal. The final design will be presented to the company and school no later then December 4^{th}, 2008. Prior to this date, we will perform our conceptual design and interim design presentations, which will be scheduled no later then October 16^{th}, 2008 and November 4^{th}, 2008. On the date of the interim design presentation, our mathematic model should be made available.

Methodology

The first step that will be taken in this design process is background research. The research will center on several key areas: fluid properties, Labyrinth seal designs, fluid flow patterns through labyrinth seals, and material costs. The properties of R134A and air are currently being researched and compared so that the test rig can be built to produce the conditions needed to allow air to represent R134A with minimal differences. The results of this research will define the capabilities of the test rig. The sizes and designs will also affect the rig design in that an adapter that can be fit to all of the test seals must be made. Finally material costs need to be investigated so that it is known what can feasibly be built under the budget. Material costs will most likely be researched after a very basic design of the test rig has been created.

Once the necessary background research has been performed, various designs for test rigs will be evaluated on several criteria: ability to effectively test various seals for leakage, manufacturability, ease of use, and cost (both initial and cost per test). Different types of precision measuring equipment will also be evaluated at this time. Once the design has been chosen a 3D computerized model will be created in Pro-E and submitted to Danfoss – Turbocor for a final design approval. It is hoped that a final detailed design will be completed prior to the end of the fall semester so that materials and parts may be ordered before the winter break.

If the design is approved and the parts are ordered on schedule, the spring semester will be dedicated to the building and fine tuning of the test rig. Once the test rig is working properly a study on the effectiveness of seal design will commence. The labyrinth seals supplied by Danfoss – Turbocor will each be evaluated and compared to see which seal most effectively stops leakage as well as which seal is the most cost effective and which seal best fits the needs of Danfoss – Turbocor. Upon completion of the study a report complete with the test rig specifications, results of the study, and seal design recommendations will be submitted to Danfoss – Turbocor.

Constrains

There are several limiting factors that will need to be taken into account over the course of this project. The most important constraint is the working fluid. It has been asked that air be substituted for R134A as the working fluid. The substitution was made in order to reduce the cost of testing as well as to decrease the complexity of the test rig. A budget of $1,500 will also play a limiting factor in that it will affect level of precision in the measurement instruments that are purchased. The budget may also affect the size of the test rig due to material costs.

Expected Results

By the conclusion of this year, a detailed design of the test rig will be prepared and ready for manufacturing. In addition to the test rig, mathematical models of the leakage through the seal will be complete.

References

[1] Flitney, R. and Brown, M., 2007, “Seals and Sealing Handbook”, Elsevier, pp. 238

[2] Boyce, M., 2003, “Centrifugal Compressors: A Basic Guide”, PennWell Books, pp. 453-455

[3] Gamal, A., Vance, J., April 26, 2007, “Labyrinth Seal Leakage Tests: Tooth Profile, Tooth Thickness, and Eccentricity Effects”, Journal of Engineering for Gas Turbines and Power