Design of the GLARE Tool
A Grease Lubrication Apparatus for Research and Education

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Summary
The GLARE: Grease Lubrication Apparatus for Research and Education was designed as a fourth year thesis project with the University of Ontario Institute of Technology (UOIT). The purpose of the apparatus is to train Ontario Power Generation Nuclear (OPGN) staff to properly lubricate bearings with grease and to help detect early equipment failures. Proper re-lubrication is critical to the nuclear industry as equipment may be inaccessible for long periods of time. A secondary purposefor the tool is for UOIT research and undergraduate laboratories.This abstract provides an overview of the project and its application to the nuclear industry.

1. Introduction

In any power plant there is a heavy reliance on grease lubrication for electric motors, motor operated valves, and fan shafts. The nuclear industry faces an added difficulty of having equipment that is inaccessible for long periods of time while the reactor is operating. During maintenance outages, it is critical to have reliable knowledge on the condition of the bearing and of the lubricant. This is considered to be a form of Predictive Maintenance (PdM); a condition-informed method of machine maintenance. This allows for more efficient use of spare parts and avoids unnecessary maintenance, while allowing for the early detection of component failures. This early detection can be useful to the nuclear industry to avoid a forced outage situation when a component fails in an inaccessible area. In the field of bearings, this can also be applied to determine the correct amount and frequency of lubrication required; something which is particularly difficult with grease.Being a non-Newtonian fluid, grease lubrication is generally less understood and less controlled than oil lubrication.

A need was defined by our client, Ontario Power Generation, to provide a training tool for the proper lubrication and condition assessment of a rolling element bearing. An additional requirement was identified to provide the University of Ontario Institute of Technology (UOIT) with a laboratory apparatus for potential graduate level research and undergraduate laboratory use. The apparatus could also be useful for the evaluation of new re-greasing technologies such as grease meters, auto-greasers, and grease relief fittings.[1]This is the genesis of the GLARE: Grease Lubrication Apparatus for Research and Education tool.

2. Design Process

The GLARE project was divided into two main segments, one for each term – the paper design for the first term and constructing and operating the apparatus for the second term. The design process began with a series of conceptual design meetings between the UOIT design team and the client (OPG). These meetings led to the creation of the initial set of tool requirements that would be followed throughout the process.

2.1 Design requirements

The design requirements were defined as follows:

1. The tool must operate in both a vertical and horizontal shaft configuration.
2. The tool must be capable of using a variety of grease types to demonstrate the effects of different thickeners, base oils or additives
3. The bearing housing must be interchangeable to allow for different housing configurations to be employed (i.e. grease flow path through bearing vs. flow across bearing).
4. The bearing shaft speed must have at least three variations.
5. Radial bearing loading should be available, if feasible to design.
6. Grease chamber must be accessible for grease sampling purposes.
7. Grease chamber must be visible to observe grease mixing.
8. Instrumentation must be provided such that:

- Vibration measurements can be taken in three axes.
- Motor current analysis can be performed to determine motor loading.
- Ultrasonic (acoustic emission) measurements can be taken.
- Bearing outer ring temperature can be recorded.

2.2 Pre-existing Design Evaluation

The next step in the design process was to research pre-existing bearing test rigs which have been created for many different purposes in the past. Every effort was made to review these designs for the purpose of conceptualizing a design that meets this project's requirements. One finding in the review is that most bearing test rigs are created for a single purpose, whereas the design required by the client is for multiple applications. The designs considered relevant were:

MRG Laboratories (R. Wurzbach)
The design team had the opportunity to personally observe this test rig in action and have had some support from the designer throughout the design phase. This test rig makes use of a slightly modified outboard end bell from an industrial motor. The end cap of the end bell has been removed and replaced with a Plexiglas cover to allow for viewing into the grease reservoir and the unshielded side of the bearing. The end bell is mounted on a metal frame with a ¼ HP

motor configured with a coupled shaft to an adapter which is fitted to the bore of a grease-lubricated NTN 6311C3 Deep Groove Ball Bearing. The design can be flipped for vertical shaft operation.

Tokyo University of Agriculture and Technology and Japan Ministry of Trade and Industry (T. Yoshioka et al.)
This test rig was built in Japan for the purpose of investigating the acoustic emission generation in a rolling element bearing. This setup is of interest to this project for two purposes. It uses a unique cantilevered dead-weight radial loading system, which is a consideration for this design. The other purpose is to give some indication of where an appropriate position exists to mount a vibration sensor on the bearing housing.[2]

The Timken Company, Canton, Ohio (M.Hoeprich)
This test rig was built for the purpose of obtaining internal temperature measurements on oil-lubricated rolling element bearings. This rig uses an opposing pair of taper roller bearings, with a hydraulic piston providing a constant axial load. One aspect of interest in this design was the use of thermocouples threaded into the outer race of the bearing to measure the temperature profile across the outer race.[3]

2.3 Conceptual Design Evaluation

The first concept developed by the team was in essence a revision of the R. Wurzbach design to suit the project requirements. The changes that were made to the design were the addition of variable tension belt loading device between the motor and the demonstration bearing. Also, a Direct Current (DC) motor was used to provide variable speed. A design review meeting was held with the client where it was decided that there were three significant shortfalls:

- The loading mechanism would put excessive load on the drive-end bearing of the motor.
- Having a coupler on the shaft will reduce rigidity and diminish the loading effect of the belt on the demonstration bearing.
- A variable speed DC motor was considered to be cost prohibitive for this project.

The second concept was developed with feedback from the design review. This concept uses a single speed AC motor with a stepped pulley system to drive a parallel shaft at variable speeds. The shafts are connected with a V-belt whose tension can be varied to provide load on the secondary shaft. The motor is mounted on a hinge-type mount with adjusting screws to provide tension on the V-belt. The secondary shaft is driven in the centre and is supported by two deep groove ball bearings, one at each end. This allows for two bearing housing configurations to be demonstrated at once. It also has the benefit of demonstrating both the top and bottom housing for a vertical shaft orientation. The problematic coupler is also removed from the design, increasing the rigidity of the system. Two issues were identified with this concept:

- Guarding for the belt will be difficult to construct for this design.
- Excessive complication in construction.

The third concept builds on the second, while making use of readily available parts to save construction time and cost. This concept uses a conventional bench-top drill press as the drive mechanism. This solves the guarding issue, as a guard already surrounds the drive belt. Also, the drill press is driven by a set of stepped pulleys and a V-belt, thus saving some construction time. The stock base will be removed, and the drill press will be mounted by the column to the base plate. Two options exist for driving the bearing in this design. The drill press table can be used to mount a flange-type bearing housing. In this configuration, loading can be applied by simply rotating the table around the column. One disadvantage of this concept is the use of forced misalignment for the loading of the bearing, which results in additional axial load on the bearings.

3. Final Design

The final design is based off of the third concept from the previous section. This design makes use of a common bench-top drill press as the main drive mechanism. The stock base from the drill press is removed and it is mounted to a fabricated aluminum base plate. A flange-mount bearing housing is bolted to the table on the drill press column. The bearing is driven by a custom drive shaft from the spindle of the drill press. A dead-weight loading system is employed to add a radial load to the demonstration bearing.

The bearing type and size used in this apparatus were designed based on both client-specifiedrequirements. The demonstration bearing must be large enough that grease flow can be readily observed. The intent of the project was that the bearing should be representative of ones found in Ontario Power Generation's equipment. It was determined that a 40 mm bore bearing would be adequate size for visual observation and is a typical bearing found at OPG. Several types of bearing were considered in the early design phases, however deep groove ball bearings were of primary interest to the OPG as they are most commonly found in motors that are grease lubricated. These requirements made the decision for the common 6208 size bearing to be selected for one housing.

One concern that arose from the selection of a deep groove ball bearing was the method of loading. This design uses a forced misalignment loading mechanism, which will exert an axial load on the bearing of which deep groove ball is not designed to handle. The decision was made to use a self-aligning ball bearing for any experiments requiring sustained loading. The 2208 bearing has the same bore and outer diameter, but is 5 mm wider than the 6208 deep groove ball. Both design basis bearings havea normal internal clearance.[4]

An additional requirement of this device is the ability to operate with different bearing housing configurations. This is met by designing the bearing housing to be readily removed with common tools for replacement with an alternative. For the purposes of this project, two housings were designed to demonstrate different aspects of grease lubrication. Each housing is designed to contain either of the two design basis bearings. When installed, the housing has a 5.59 mm thick Plexiglas cover on each side. This allows for safe visual observation, while maintaining the cleanliness of the grease inside, and the equipment outside of the housing. This also adds one safety barrier in the extreme case that an experiment should cause a bearing failure to occur.

The first housing design has the grease inlet (Zerk fitting) on the same side of the bearing as the drain. This configuration is commonly seen in outboard motor bearings or installations where the bearing has one side shielded.The second housing is designed to have the grease flow path to pass through the bearing. This is typical of an inboard bearing configuration with unshielded bearings.

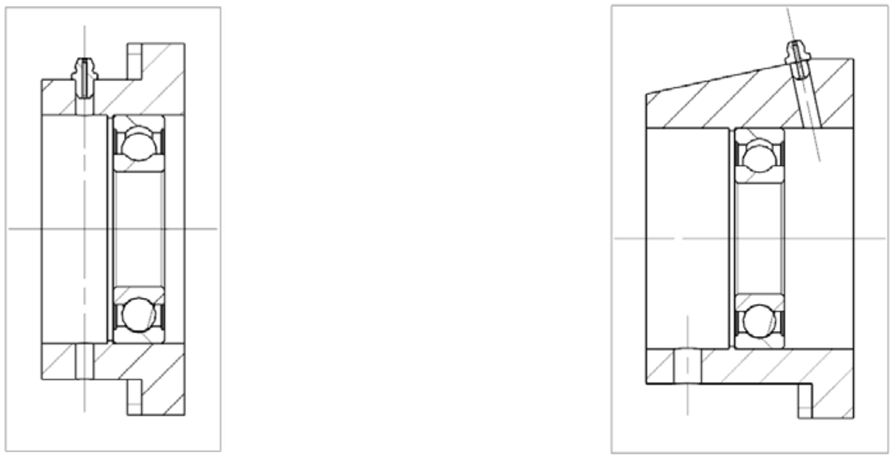

Figure 1 - Bearing Housings 1 and 2 (left and right respectively)

4. Construction and Operation

The GLARE tool was constructed in February and March of 2012 by volunteer staff members from OPG based on 3D CAD models produced by the Design Team. The tool was set up in a laboratory at the Energy Research Centre at UOIT in Oshawa, ON. During the latter half of March and April, experiments were run by the Design Team testing the suitability of the tool with four PdM technologies (vibration, ultrasound, IR thermography, and motor current analysis). Experiments were also performed using special coloured greases to observe grease mixing and flow within the bearing.

5. References

[1] Maintenance Reliability Group, "Nuclear Maintenance Applications Centre: Effective Grease Practices," EPRI, York, 2010.

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[4] SKF Canada Limited, *925 Bearing Catalog*. Canada, 2006.

6. Acknowledgements

Without the support of many individuals and corporations, this project would not have been a success. The credit for the GLARE project belongs with the following:

Design Team (UOIT):	Kale Stallaert Brad Rawlings Jim Dermarkar Bryan Beamish
Faculty Supervisor (UOIT):	Dr. Ali Keshavarz
Subject Matter Expert (OPG):	Dr. George Staniewski
Construction Team (OPG):	Mohamed Ali John MacFarlane
With Support From:	Ontario Power Generation (OPG) University of Ontario Institute of Technology (UOIT) Society of Tribologists and Lubrication Engineers (STLE) Jennifer Moritz, SKF Canada Limited Wayne Mackwood, Chemtura Canada Co. Rob Milner, FLIR Systems Limited Gus Velaquez and Allan Rienstra, SDT North America Rich Wurzbach, Maintenance Reliability Group