Chapter 4: Conclusions and Future Considerations

4.1 Conclusions

This design synthesis presented in this thesis evolved from a design problem statement, through a large group of design concepts to design evaluation and testing. The end result is a small group of functioning designs. It was not the intent of this design process to conclude with one specific design to solve a given problem, but to narrow the design ideas to a group of feasible solutions and to explore the process used for solving such a problem. In doing so, however, a design for implementation was developed and two concepts that are promising for future consideration were also developed. It is hoped that this thesis will now serves Torrington as an aid in finding solutions for double row ball bearing assembly problems. The resulting group of designs consisted of a stepped support arm, a soft foam insert and an assembly technique of rotating the assembly station through 90^o. The sponge foam insert, through design synthesis, fabrication and testing proved to be the easiest to implement and functions as dictated by the design specifications. The other two design concepts are candidates for implementation when consideration is made for automation of the bearing assembly process.

The result of this thesis is that removal of the rubber O-ring in the Torrington 5203 double row ball bearing and replacing it with a ball supporting assembly aid can be accomplished. Research shows that this may be the only published non-proprietary discussion of the double-row bearing assembly problem. Even though solutions have been proposed, the designs are not immediately production ready. Because of this, further evaluation within Torrington may be needed. This thesis, along with the assembly station and prototypes will be presented to Torrington for further development and subsequent implementation. The following sections make suggestions for future considerations.

4.2 Future Work

Future work includes the possibility of immediate implementation of the most effective design concept and the reevaluation of a few of the design concepts presented in this thesis, especially when consideration is made for assembly automation. With this reevaluation, modification of the assembly station may be needed. In particular, this may include developing a device for producing the required support arm motion. Also future work may delve into the possibility of complete bearing redesign. The following sections introduce these considerations and may serve as a foundation to build further design synthesis.

4.2.1 Implementation

The design synthesis resulted in a design that functioned most effectively as the requirements dictate, and thus has potential for immediate implementation. This design was the sponge support insert. Implementation of this design concept would ideally add no time to the current assembly process. Implementation would only consist of obtaining the proper material, a closed foam polymer, and cutting it to the proper dimensions as described in Table 3.2.

4.2.2 Further Evaluation of Support Arm Design

Further evaluation of the support arm design can consist of reevaluating the stepped support arm and the rotated assembly station assembly technique. They could both be considered for the next generation of assembly aids for the double row ball bearing and approached as manual processes or included in the design synthesis for an automated assembly process. If they are to be implemented into the current assembly process, the assembly station needs slight modification. In addition to the assembly station modifications, a motion device needs to be developed.

4.2.2.1 Assembly Station Modifications

To implement the stepped support arm the assembly station will need modification to allow insertion from the bottom of the workbench. The access hole will need to be at least 1.3 inches in diameter to accommodate the current diameter of the support arm. If the rotated assembly station assembly technique is to be implemented, the assembly station will need to be fitted with a pivot about the axis perpendicular to the line worker to allow for the required 90^{o} rotation. In addition to the assembly station modifications for the rotated assembly station assembly technique, a ball feeding tube will need to be fabricated. Extended analysis of these designs may show that further alterations to the assembly station may be necessary.

4.2.2.2 Motion Device

As often mentioned, the motion of the support arm structure is a vital part of its design and subsequent implementation. It was concluded that a more discrete motion sequence is easier to apply to an automated assembly system than a complex motion sequence, such as that used in the Torrington screw design concept. A straight arm that rotates about the center axis of the stepped support arm can be designed to perform the needed rotation then axial motion required to move the arm into its ball supporting position. This motion requires that the initial position of the support arm's horizontal arm be internal to the bearing at the height at which it can pass over the inserted lower balls.

No motion device would necessarily be needed for the assembly station rotation assembly technique. With the proper placement of the assembly station pivot, the only components needed would be a handle and a locking system to maintain the original and rotated assembly station positions.

4.2.3 Consideration for Bearing Redesign

Even though bearing redesign would take considerable research and development, it could have a significant effect on the assembly process. As with many bearings manufactured today, multiple inner rings could be considered for a design configuration. Because of the involvement of such alterations, the bearing designers would not only need to meet the current bearing specifications but would need to meet, if not exceed the needs of the current and potential customers.

4.3 Optimization Summary

The optimization process presented in this thesis must be evaluated. For the bearing assembly problem, optimization is defined by a set of optimization goals, many of which are difficult to quantify. Nevertheless, it is important to reflect upon the success of the proposed in meeting these goals.

4.3.1 Optimization Goals

Embarking upon this thesis, the following optimization goals were defined.

- Replacement of the rubber O-ring with a ball support device.
- Reduction or removal of extraneous force and/or awkward positioning of fingers and hands to accomplish assembly. Reduce potential for repetitive motion injuries.
    - Inner ring tilting force
    - Inner ring depression force
- Removal of unnecessary assembly steps.
- Reduction of assembly cost.
- Reduction of assembly time.
- Increase potential for assembly automation.

4.3.2 Optimization Solutions

This thesis attempted to produce an optimized approach to assembly through process analysis and design synthesis. Even though “reduction” and “increase” are difficult to quantify the solutions presented in this thesis have shown the potential for improvement relative to each of the goals defined above. Table 4.1 presents a summary of the optimization results.

Table 4.1 Optimization Problems and Solutions

Optimization Problems	Optimization Solutions
Replacement of the rubber O-ring with a ball support device.	Design of sponge foam insert to support upper balls during insertion.
Reduction or removal of extraneous force and/or awkward positioning of fingers and hands to accomplish assembly. Reduce potential for repetitive motion injuries. – Inner ring depression force	Use of sponge foam insert and removal of rubber O-ring allows for elimination of spring actuated plunger to support inner ring during assembly.
Removal of unnecessary assembly steps.	No inner ring depression required for insertion of lower balls. Machining of groove and insertion of rubber O-ring eliminated from pre-assembly process.
Increase potential for assembly automation.	Introduction of other ball support devices (rubber O-ring replacements) with potential for implementation in an automated assembly process.

Unfortunately, all of the optimization goal could not be met within the constraints of the problem, however, thought was given to addressing the other optimization goals and, in some cases the groundwork for their solution was established. The remaining optimization goals are presented in section 4.3.3.

4.3.3 Extended Optimization

Several optimization goals were outside of the scope of this thesis. As presented in section 4.3.1, the remaining assembly problems include, inner ring tilting force reduction or removal, reduction in assembly cost, and reduction in assembly time. The foundation for removal or reduction of the inner ring tilting force was established in its analysis presented in section 1.5. Solutions could include a counterbalance to aid in the required force applied, a slight increase in the bearing deformation during assembly, pneumatic assistance for inner ring tilt or bearing assembly automation. Reduction in assembly cost will have to take into consideration several assembly components. It should also consider such complex factors as the cost associated with repetitive motion injuries. Reduction of assembly components costs include evaluation of groove machining and the rubber O-ring compared to the sponge foam insert and assembly station modification for process changes and possible automation. The reduction in assembly time needs a detailed comparative analysis of the current assembly method compared to the assembly process using the sponge foam insert. This analysis would not only include time of assembly of the bearing but would also include the time for machining of the O-ring groove and placement of the O-ring onto the inner ring.

4.4 Thesis Closure

This work is unique in that this may be the only published work dealing with assembly techniques for double row ball bearings. The double row bearing market is a considerably profitable market based on the number of companies producing them and the potential for their increased production. Because of this, this thesis, even though not a final solution, has opened new directions and explored some existing ideas. It may serve as the originating resource for future double row ball bearing assembly research and innovations.