Ball Nut Ball Bearing Injection System

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***Abstract*—This multiphase project for the senior design capstone program at the College of Engineering and Engineering Technology at Northern Illinois University was proposed by Rockford Ball Screw (RBS), an industry leader of ball screws and linear guide rails. The goal of this project was to design and fabricate an electromechanical workstation system which can be utilized by their team to aid in and increase the efficiency of the final assembly steps of their ball screw products. The aim of this design was to assist in the loading of ball bearings into ball screws while maintaining flexibility of usage for a range of their full line of products. To meet specifications the system features interchangeable components as well as ball bearing count control with programmable logic and implements safety and user-friendly features as daily use is expected. The system was designed in Solidworks®, validated with analysis software and hand calculations, and fabricated with machined and 3D printed parts.**

I. Introduction

The ball screw is a mechanical actuator that translates rotational motion to linear motion using ball bearings. Ball bearings are driven helically in either an internal, external, or other circuit type between the threads of the screw and nut, permitting for translation with little friction and the ability to withstand high thrust loads. They have many applications where precise linear motion of high loads is desired. Currently, assemblers at Rockford Ball Screw load ball bearings into their ball nut products by hand. This process is done by loading ball bearings into unique steel tubes which hold a specific size and amount of ball bearings depending on the nut. The nut is then fed the ball bearings via a circuit channel entrance while the screw is turned through the nut, drawing in the appropriate amount of ball bearings. The main problem with this process is that it is timely which increases labor costs and slows down production. Also, it induces repetitive motions in the loading of the tubes and turning of the screw which could lead to strain or joint injury over a long period of time.

The solution is the Ball Nut Ball Bearing Injection System which administers a specific amount of ball bearings with accuracy and does so while maintaining flexibility of usage for a range of ball diameters. As the design is to be used as a workstation tool, features of safety, ease of use, and handleability were implemented. This includes a ladder logic control system that uses a panel interface for accessible usage by the RBS team after minimal training. One of the primary goals of the project was to design something to be time efficient, specifically, faster than the current assembly process. Therefore, the system was designed to translate ball bearings in a rapid manner, is capable of many ball nut loadings before a refill is required, and has purge capabilities for when product demand changes throughout a workday.

II. Design Overview

The system consists of a hopper, handheld administration portion, and a control interface, shown in Fig. 1. It is mainly built from various 3D printed sections for containing and conveying ball bearings along with steel and plastic tubing. Electrical devices controlled with a PLC are also utilized in the design and are responsible for actuating components for ball bearing conveyance, output control, and safety. Although the system is made to be suitable for a range of ball bearing sizes by utilizing interchangeable components, for the sake of this prototype two ball sizes were selected to build around.

Figure 1: From front to back; handheld piece, hopper, and control system portions

A. Mechanical

The hopper is made of multiple components that make up the whole hopper portion. The hopper motor housing is the main containment unit for the ball bearings and houses a motor which actuates a rotary feeder. Attached to the motor shaft is a feeder shaft connector, the hopper motor housing and feeder shaft connector are noninterchangeable components of the hopper. The feeder shaft connector is designed for quick change out of the remaining interchangeable ball bearing translation components of the hopper. The rotary feeder takes in the feeder shaft connecter for rotational actuation from which ball bearings are drawn with gravity through the part by way of a through channel. The rotary feeder output shaft connects to a bearing which sits within a section that connects to the feeder unit base, said part connects to the hopper motor housing unit with fast access locks as this is the point of manual changeout. All the hopper components were 3D printed; the rotary feeders used stereolithography and the remaining components were fabricated with fused deposition modeling printers to save on cost.

The hopper nozzle tip connects to a length of interchangeable plastic tubing which translates the ball bearings single file to the handheld nozzle portion. Like the hopper the handheld portion of the system is made of multiple 3D printed parts with some machined and electrical components. The plastic tubing from the hopper connects to an interchangeable piece of steel tubing which mimics the steel tube assemblers at RBS currently use. This tube sits within the rest of the handheld portion and features machining which accounts for the position of the tube, allows for the actuating escapement pin element to interrupt the flow of balls, and the pass-through sensor to detect and count ball bearings as they pass through. The case for the handheld portion is made up of halves that interlock and is where the output control elements are housed, the bottom portion is where the user grips the machine.

The control interface enclosure houses the power supply, central processing unit, and the human machine interface Fig. 2. It was machined to fit these components and presents the control interface off axis from tabletop to the user for ease of use.

Figure 2: Control interface and enclosure

B. Electrical

The electrical components of the system are a motor, actuating element, sensor, safety sleeve, and the control system. The system operates under 24 volts direct current, the electrical components work in tandem via the user operated control system.

III. RESULTS

The system was determined to achieve the focal requirements as requested by the client. The final prototype showed reliability and ease-of-use for daily implementation with minimal operator strain. Several areas of improvement have been specified to the client regarding the physical design. The handheld portion will require a modified interlocking mechanism due to clearance issues in the initial prototype. Additionally, manufacturability options will require consideration with respect to weight and component adjustability.

In testing it was determined some modifications were required of the control program to maintain accuracy, once these changes were made the system dispensed ball bearings to the setpoint more frequently. It was also determined that when testing with a larger diameter ball bearing the choice of element for flow interference was underspecified, a new part was selected to replace the original. Once these changes were implemented the system showed reliability for the task it was designed for.

IV. CONCLUSION

Overall, to enhance production in the assembly steps of Rockford Ball Screw's ball screw products a novel system has been conceptualized, designed, and prototyped to meet the demands described. The optimal design chosen is a gravity fed ball bearing dispensing system that consists of hopper, nozzle, and control system subunits. The system is operator controlled and works to feed ball screws with ball bearings in an accurate and controlled manner. The team succeeded in producing a functional prototype of this system. Further iterations of the design are recommended before full scale application of the product.

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