Automatic Piston Pin Internal Diameter Defect Detection

Jacob Gholson, Mario Gallardo, Wesley Triphahn.
Department of Mechanical Engineering, Northern Illinois University, DeKalb, IL 60115

Faculty Advisor: Dr. Zinger
Department of Electrical Engineering
College of Engineering and Engineering Tech., NIU
DeKalb, Illinois, United States
dzinger@niu.edu

Industry Client: Elisa Sorrentino
Department of Quality Engineering
Burgess-Norton Manufacturing Co., Inc.
Geneva, Illinois, United States
easorrentino@burgessnorton.com

***Abstract*—Inner diameter inspections of piston pins are manually performed via a GO/NOGO plug gage inspection. Automation of this physical process may be achieved through the implementation of an appropriately controlled and situated linear actuator. To accommodate for varying piston pin sizes, the physical architecture of the design is constructed such that the design may be changed manually prior to a production run. To minimize complexity during adjustments, all physical adjustments are based around placing the center of the piston pin into a recurring target position. Since this target position does not change, the prototype maintains the capability to adjust itself across three different axes to account for the length of the pin, the vertical center of the pin, and the horizontal center of the pin.**

I. Introduction

Burgess-Norton Mfg. Co. is a manufacturer of powder metal parts and is the world's leading manufacturer of piston pins. Millions of piston pins are supplied every year to major automotive industry partners. These pins must meet rigorous international standards and customer specifications in order to be safe for automobile use.

In fiscal year 2019, Burgess-Norton spent in excess of $100,000 on internal sorting labor costs. Current sorting activities are manual, highly operator dependent, and have extremely inefficient cycle times. As a result, many internal key performance metrics are negatively impacted, including customer on-time-delivery, expedited freight charges, and unplanned overtime.

To alleviate these costs, a prototype was developed to automate a high-impact sorting activity, inner diameter (ID) plug gage inspections.

Critical criteria of inner diameter inspections revolve primarily around ensuring that there are not pins from separate production orders being mixed in. Given the variety of pin sizes produced by the client and similarity between externally measurable criteria (such as length and outer diameter), an inspection of the inner diameter is necessary to ensure that mixing has not occurred. Inspectors employ a simple GO/NOGO gage called a plug gage that is inserted into the ID. Several customers of the client require that mixed pins are inspected for in every shipment, resulting in an ongoing demand for automation of this process. Due to the inherent nature of the process, pins will sometimes become mixed on accident. In these unpredictable instances, a plug gage sorting may be necessary. Automation of a plug gage insertion and subsequent reading of the GO/NOGO gage depth will eliminate currently required manual labor. This same method of inspection is also employed for other related issues such as detecting out-of-tolerance ID dimensions or inspecting for a collapsed ID (a potential defect in the piston pin manufacturing process). Ultimately, plug gage insertion automation and processing will cover a wide range of inspections.

II. Methods and Materials

All structural components are fabricated from 1/4-inch 1018 steel to ensure structural integrity and ease of manipulation for potential future adjustments deemed necessary. For initial prototyping purposes, an Arduino was utilized to demonstrate a basic level of automation over one of the features of the prototype, an automatic gate/rejection/acceptance subassembly. This physical feature is rotated by an Oriental Motors PK299-03BA Stepper-Motor that is controlled by a CSD2145T Driver and an Arduino Uno R3. For scaling beyond a prototype, a PLC will be required for industrial-level control systems engineering. The linear actuator is a pneumatic system that will be using a solenoid bank and air pressure supply in accordance with the industry client's in-house systems. The actuator is similarly controlled by a PLC.

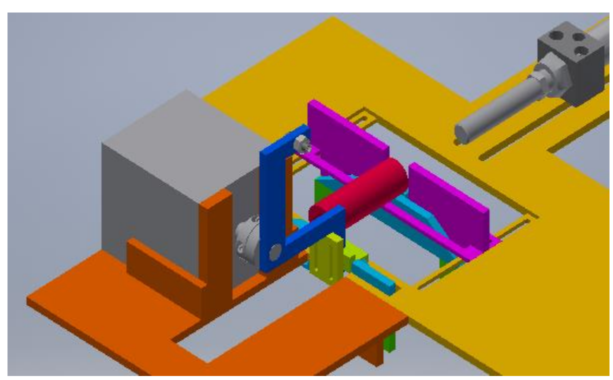

Fig. 1 An overview of the entire system. The piston pin that is inspected is the red cylinder.

All methods of securements for adjustable aspects of the design involve screw fasteners and nuts and for locking in place. The method of holding varying sized plug gages was solved by modifying a pre-existing design that enables a wide range of plug gages to be used via a simple setup procedure. An additional minor modification also made fastening of this component to the front face of the actuator functionally effective. For the physical architecture of the project, a three-axis piston pin positioning is utilized.

III. RESULTS

The prototype design is capable of maintaining the necessary points of contact to ensure smooth piston pin motion while also allowing the necessary three-axis level of maneuverability. With a plug gage inspection, numerous different types of inspections may be performed depending on the situation. The system is appropriately setup to allow mixed pin inspections (where adjustment of the actuator is unnecessary) as well as collapsed ID inspections (where adjustment is necessary). The design will function for piston pins within an ID, OD, and length varying 0.2-0.6 inches, 0.5-1.25 inches, and 0.5-4 inches respectively. One considered obstacle was that minor variance in the tolerances of the piston pins would result in making a recurring target position too difficult to achieve. Initial experimentation revealed that the amount of deflection permissible in the pin is a matter of the distance of the chamfer on the end face of either the plug gage or the pin. The variance permitted in the relevant end face components of the piston pin are, at worst case scenario, two orders of magnitude lower than the minimum machinable chamfer length on the plug gage.

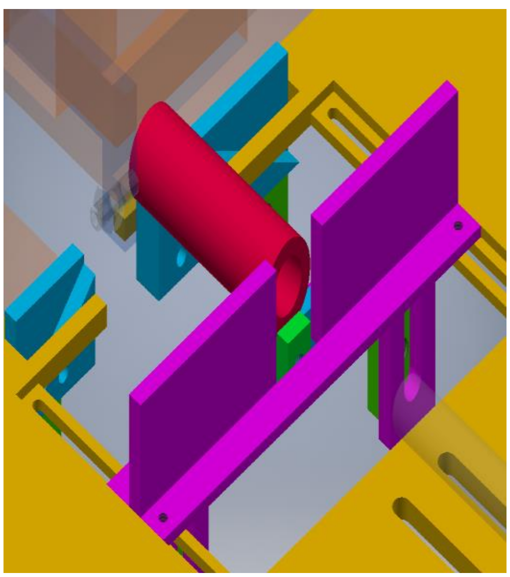

Fig. 2 The three-axis positioning system from the perspective of the side of the pneumatic actuator. The purple Adjustment Holder component is responsible for adapting to different piston pin widths, while the separate ramp components are adjustable for the pin's vertical positioning.

IV. DISCUSSION

A successful, production-ready implementation will depend on several extrinsic and intrinsic factors of the project. The tested cycle of time of a single inspection will be a major influence on the future of the external aspects of the design such as the chosen location to implement the design within the client's facility. Subsequently, the method of material introduction and removal will also vary based on the chosen location. If chosen to be in a pre-existing production line - implying a sufficiently fast cycle time - the cost of implementation outside of a PLC's relevant components is insignificant. If the reverse is true, then most methods of material introduction or removal will present significant costs. Periodic manual introduction could present a desirable medium between these cost scenarios.

Several steps have been taken to mitigate potential issues that may occur during testing or production runs. In considering the potential variance in the center of a piston pin's ID, a chamfered plug gage is utilized to ease in the deflection of the piston pin. Additionally, instructions are provided to intentionally offset the target position of the system so that the piston pin does not deflect downward or forward into a solid surface. To prevent the possibility of jamming, a double-acting linear actuator was selected with the operating psi suggested at relatively low pressures.

V. CONCLUSION

Future incarnations of this prototype should seek a means to increase the cycle time of a single inspection without sacrificing the pressure applied during a manual plug gage inspection. In addition to this development, an inexpensive and innovative means of introducing piston pins into the system should be researched or developed to further the feasibility of the design in a production-ready environment. Implementation of a PLC to fully coordinate the system is also a must.

Of perhaps the most significance during this prototyping phase is the development of an inexpensive and piston pin based three-axis positioning system. The end goal of the project to conduct an automated plug gage inspection necessitated such a system, and consequently this design may be repurposed outside the region of plug gage inspections that could not previously be automated due to the lack of such a system. Research into further automation stemming from the core of this design could save the industry client significant time in inspections that today are performed manually.

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