MEEN 401 DR1 Initial Report

Zachary Walker

MEEN 401-900 Bray Team – Embedded Valve and Actuator Sensors

UIN: 330003562

Due Date: 10/2/2023

On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work.

Signature: _Zachary Walker_

Introduction

Bray International, Inc. is a large manufacturer of flow control and automation products. Bray has facilities located in many countries and serves customers in many industries, including semiconductor, energy, chemical, HVAC, municipal utility, pharmaceutical, food, and mining [1]. Their main types of manufactured products include valves, actuators, sensors, solenoids, and filter regulators [1]. Like all other companies, Bray is continuously looking to improve their products through continuous innovation and design upgrades. The senior design team working with Bray is comprised of Zachary Walker, Cody Sims, Locke Lehmann, Avery Haynes, Michael Hager, and Travis Carlson. All six are senior mechanical engineering majors working on this project through their capstone design course.

Bray sponsored this team to work together on a product design improvement project titled "Embedded Valve and Actuator Sensors". The central problem that this project will focus on is that valve and actuator assemblies, bought by Bray's customers and used in their respective fields, can and will degrade over time to the point where they fail to work properly and meet the customer's needs. This can be a result of both or one of the following causes. First, the actuator's capacity to provide torque can decrease over time due to mechanical wear or material buildup that contaminates its components. Second, the torque required to operate the valve can increase over time due to these same factors. As the required valve torque increases and the available actuator output torque decreases, the assembly may reach a point where the actuator is no longer sufficient to operate the valve as desired, so preventative maintenance must be performed to clean, re-calibrate, or replace the parts. Bray's goal is for the project team to develop a method for determining valve position and actuator output torque in real-time so that this maintenance can be predictable and planned and so that Bray and customers can monitor the performance of their products in real-time so they can make more informed decisions about valve and actuator design, service life, and usage.

Currently, Bray must anticipate valve or actuator failure without having all the necessary data and must manually check the assembly to determine the cause of the failure. Having this data on position and torque will allow Bray or their customers to see how these parameters are trending, determine when and why components are going to fail, and identify other possible design improvements to study based on the most common trends seen in the performance of their parts. Bray has developed a product known as the IOT Torque Bracket for determining the torque on a valve, but combining the data from the bracket with the solutions they are still looking for would provide a much more complete solution to the problem. An embedded sensor would be a better solution for Bray's customers than one that is positioned outside of the assembly like the IOT Torque Bracket is. The IOT Torque Bracket is sold as an attachable assembly to an actuator, and an embedded design would not require any additional space or customer assembly of parts, making it easier for customers to implement it into their systems without any additional work. Due to the modular design of Bray's valves and actuators, the sensors or other methods for measuring position and torque must be independent of the other parts of the assembly, so that, for example, a valve position measurement is not dependent on the actuator that the valve is connected to. This would allow Bray's components to continue being sold individually, which is a benefit for customers who would like to order more cost-effective solutions instead of having to order an entirely new assembly if something breaks.

Background Research

Bray manufactures several different types of valves, including ball valves, butterfly valves, knife gate valves, and check valves. This project will mainly be focused on valves of the butterfly and ball variety, as decided by the company. Butterfly valves consist of a thin disk that can be turned on a rod running down its center to open or close a fluid line. While butterfly valves are lightweight and easy to manufacture, they have some downsides, including an ever-present possibility of leakage [2]. Due to their thin design, just a small accidental turn can cause a valve to open when it is not supposed to. Their turning ability is also affected by the pressure of the fluid being controlled, and the fact that the open disk remains in the fluid stream can cause unwanted pressure changes in the fluid. Ball valves are metal spheres with holes drilled through them to allow fluid flow depending on position. The hole can either be straight through, at a 90-degree angle, or anywhere in between. Ball valves are more secure than butterfly valves, due to the tight seal that the ball makes with the fluid vessel (with a wider margin for leakage error) and allow complete passage of the fluid with no obstructions [2]. However, they are more expensive to manufacture and are larger and heavier than butterfly valves [2]. Both butterfly and ball valves function in a fully open or fully closed state most of the time, so position data is important for tracking potential flow disruptions. Adding a sensor or some other method of measuring valve position will help Bray monitor if their valves are ending up at a position between open and closed, which would hurt valve performance and may be an indicator of excessive wear or buildup on the valve. **Figures 1** and **2** show these valves.

Figure 1: Ball valve example [2].

Figure 2: Butterfly valve example [2].

Actuators, like valves, come in many different types. This project will mainly focus on rack-and-pinion style and scotch-yoke style actuators, both of which are manufactured by Bray [3, 4]. Both of these kinds of actuators come in assemblies that are roughly shaped like rectangular prisms and have a shaft extending down from their lower center to connect with the stem of the valve and turn it. Scotch-yoke actuators transfer lateral mechanical motion into rotational motion that opens or closes the valve. Their torque curve is not linear, because as the yoke turns around its center, the length of the moment arm changes as the spring compresses [3, 4]. Rack-and-pinion style actuators use compressed air to expand two plates connected to springs away from each other. These plates are linked to a gear in the center of the actuator which turns to move the valve [5]. Rack-and-pinion actuators have a linear torque curve, meaning that the actuator provides the same torque at all points in its rotation [3, 5]. Both of these types of actuators can be designed to be either normally open or normally closed, meaning that if there is a power failure or some other sort of disruptive event, the actuator will revert the valve to being either open or closed, depending on safety protocol [5]. The torque that the actuator provides can degrade over time, so receiving that data as the actuator is in operation can help identify issues before they become detrimental to valve operation or fluid flow. **Figure 3** and **Figure 4** below show the internal workings of the rack-and-pinion and scotch-yoke actuators from Bray that this project will deal with.

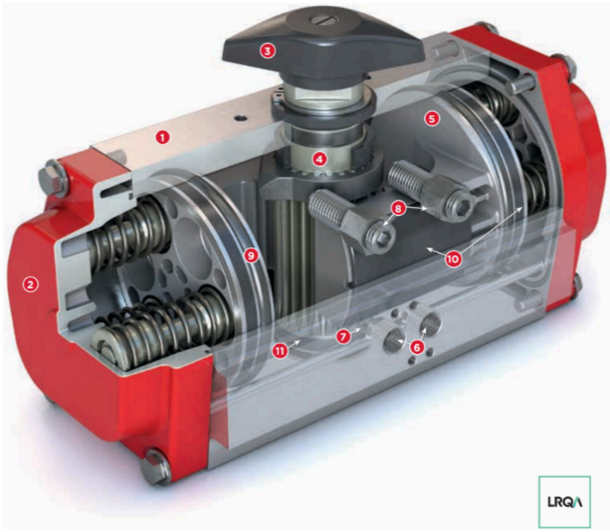

Figure 3: Rack-and-pinion actuator [3].

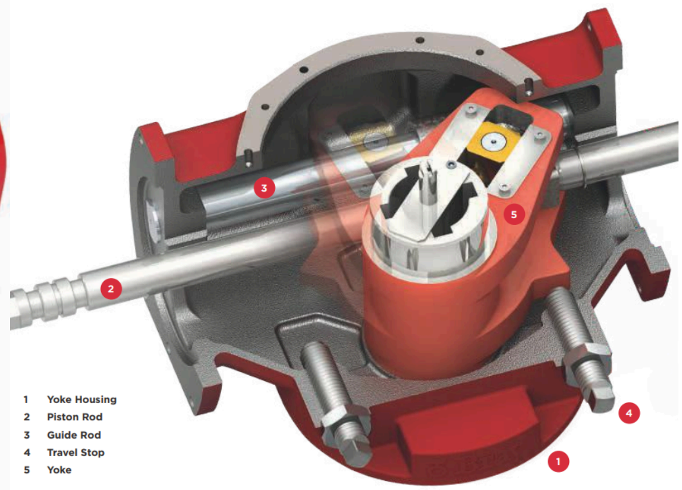

Figure 4: Scotch-yoke actuator [4].

Bray's current solution for measuring torque, the IOT Torque Bracket, measures reaction torque from the valve to the actuator. However, this does not predict when the actuator will fail to operate the valve since it does not measure the maximum capacity of the actuator. Bray and their customers care about actuator torque since a failed actuator will cause valves to be stuck in the wrong position, which could interfere with whatever system the valves are a part of. An external or embedded solution is necessary because pneumatic actuators such as the two displayed above are non-digital, meaning they have no built-in method of recording and transmitting data. An embedded sensor to measure actuator output torque, independent of reaction torque from the valve, would enable Bray and their customers to monitor actuator performance over time to determine when an actuator needs to be replaced. The IOT Torque Bracket is available as an attachable assembly to an actuator, and while it is functional, it could be improved upon as described in the introductory section. Further details of the problem statement and the requirements of the solution are explained below.

Problem

This section of the report will be dedicated to the explanation of the following solution-neutral problem statement: Develop a method to internally measure valve position independent of an actuator, measure actuator output torque, and detect fluid leakage to increase the service life of the valve.

These are three issues related to the central problem of live monitoring of valve performance. An issue that can develop in valve-actuator systems over time is a failure to completely close or open due to hysteresis. Hysteresis is an error resulting from a change of direction. In this specific application, error results from the fact that there is some looseness in the stem between the actuator and the valve, so the actuator and valve may not always be in the same position. Since the actuator may turn a few degrees before the valve begins to turn, due to this hysteresis, the valve may open to 87 or 88 degrees when it is supposed to turn a full 90 degrees. This produces an issue when the fluid flow is interrupted and does not flow as the customer expects it to. Hence, Bray would like to know the angle at which their valves are positioned so they can quickly identify hysteresis errors and work on correcting them. As mentioned earlier, material buildup can cause the valve to become more difficult to open over time, so knowing the trends in position data can help Bray know how long it takes their valves to degrade and what timeline they must implement for preventative maintenance or cleaning.

While these first two issues are the most critical for Bray to solve (due to their direct impact on valve and actuator function), there is a third issue of valve leakage that is a separate issue from the first two. There are several points on the valve that fluid may leak from, and this will be discussed further in the next section. Bray would like a method for determining the location of valve leakage so that they don't need to wait for a problem to occur down the line after the leak has already been going on for some time. The valve leakage portion of the problem statement was more vaguely defined by Bray than the other two and could be considered a "stretch goal" for this project. The team will focus its resources more heavily on the first two goals. The main constraint on the problem is that the sensor or measurement method must be embedded into the actuator or the valve itself, separate from the other parts of the assembly so that the components can still be sold separately.

Bray has given clear statements of the problem, but avenues for creativity still exist within the given boundaries. Some opportunities for innovation here are the open-endedness of the problem statement regarding the type of sensors used, the possible location of the sensors (although they must be embedded to represent a step forward from the IOT Torque Bracket), and how the data is recorded and sent to a computer. Additionally, it is not required that these three parts of the problem have three separate products as solutions, but the possibility of combining two solutions into one will be determined as feasible or not further into the problem-solving process. The inherent underlying issue with these pneumatic actuators is that they are operated by compressed air, which is a physical means, not an electronic one, so they have no built-in method of recording and transmitting data. A solution for measuring torque and position would help Bray to analyze this section of their products in the same way they can see real-time data from their digitally operated valves. Some potential conflicts with this design process include differences in the data that Bray is interested in versus what data their customers are interested in from the valves and actuators, which will be explained further in the next section. Another potential conflict is lead times for parts that may need to be ordered to create the solution, which could be done in Bray's research and development facilities. Parts with shorter lead times will be preferable since the project is limited to the duration of this school year.

Customer Needs

Bray has several criteria for the product, some more important than others. Since Bray makes valves and actuators of varying sizes, the solutions must be scalable, meaning they must be able to be made larger or smaller while maintaining the same performance. This requirement is important because it would not be very cost-effective to endure the entire design process for every valve size. The solutions must be able to operate at a temperature range of between -40 and 300 degrees Fahrenheit and must be able to withstand a maximum pressure of 740 psi. These requirements are not as important as the previous one, because the majority of Bray's valves and actuators are not subjected to extreme environments. The solutions for torque and position measurement must be embedded into the valve/actuator, which is not necessarily critical for their operational success, but is important in that a non-embedded sensor would not be a step forward for Bray and would just be more of the same from a design perspective. Bray already has non-embedded sensors like the IOT Torque Bracket and is trying to advance their technology further.

The solution must work for both ball and butterfly valves, but Bray stated that ball valves are a higher priority to them, as they assigned a specialized ball valve engineer to the project but not one for butterfly valves. The solution must work for various types of fluid media that flow through Bray's valves, but it may or may not come into contact with the fluid, so this is not a very high priority. Bray would like the position and torque solutions to have a precision of +/- 2 degrees and within 5% torque, respectively.

All of these needs were stated by Bray during the team's meetings with Bray's representatives for the project, both over Microsoft Teams and during the team's visit to Bray's facility in northwest Houston. Since Bray has customers in many different industries, it would be very difficult and time-consuming for the A&M team to interview all of them. The interview with Bray served as a substitute for an interview with customers since Bray communicated to the team the needs and wants of Bray's customers. Bray's summarized needs of their customers for the three solutions are ranked into groups below in **Table 1**.

Table 1: Ranked needs of Bray's customers.

Need	Importance (least 1, most 4)
Embedded design into actuator/valve	1
Scalable for physical size	3
Records and transmits sensor data	1
Works in a wide range of temperatures and pressures	4
Works for various fluid media	3
Measures values within specified margins of error	1
Relatively short part lead times	2
Works for both hydraulic and pneumatic actuators	3

A potential conflict exists here in that Bray is interested in true valve position, leakage, and torque, but their customers are not necessarily interested in valve position. This is because failures related to leakage and low output torque could cause valves to fail or not perform up to their required specifications, while a slightly inaccurate position placement would only have a small effect on valve performance. Bray is interested in monitoring valve position because it could help them better design their actuators to compensate for the inherent hysteresis in a twisting valve stem, even though their customers (other manufacturing corporations and the like) would not necessarily know this is a problem or be interested in improving it. Bray's customers care about a solution for leakage and output torque because it directly affects whatever process they are using Bray valves for, while Bray also cares about true valve position because knowing that data could help them produce more accurate and reliable actuators and valves.

Conclusions

In summary, Bray would like the A&M project team to develop embedded sensors for valve position and real actuator output torque and a method to detect fluid leakage from a valve. These desires arise from the fact that non-digital valves have no built-in method of monitoring live valve performance. Wear and tear on the assembly over time can cause the actuator to fail to operate the valve, and knowing the trends in this data ahead of time would allow Bray and their customers to better predict valve failure and schedule more accurate preventative maintenance procedures. Bray and their customers' most important needs include the embedded nature of the solution, its ability to transmit data in real-time, and its accuracy within the decided-upon margins of error. Less important but still ideal needs include the scalability of the solution, its ability to work with extreme temperatures and pressures, and its usage in different fluid media. Successful design of solutions for the three issues would be one more step towards real-time, complete data acquisition from these assemblies.

References

[1] "About". *Bray International, Inc*, 2023, https://www.bray.com/about. Accessed 11 September 2023

[2] "A Comprehensive Guide on Butterfly Valve Vs Ball Valve". *Dombor Valve*, 2021, https://www.dombor.com/ball-valve-vs-butterfly-valve/. Accessed 11 September 2023.

[3] "Pneumatic Actuator: Series 92/93 Rack & Pinion Pneumatic". *Bray International, Inc*, 2023, https://www.bray.com/valves-actuators-controls/actuators/pneumatic-actuator/series-92-93-pneumatic-actuator. Accessed 11 September 2023.

[4] "Scotch Yoke Pneumatic Actuator: Series 98". *Bray International, Inc*, 2023, https://www.bray.com/valves-actuators-controls/actuators/pneumatic-actuator/series-98-scotch-yoke-pneumatic-actuator. Accessed 11 September 2023.

[5] "Fluid Power Actuators Explained". *Rotork Fluid Systems*, May 2016, https://www.rotork.com/uploads/documents-versions/24733/1/pub010-024-00_0516.pdf. Accessed 11 September 2023.