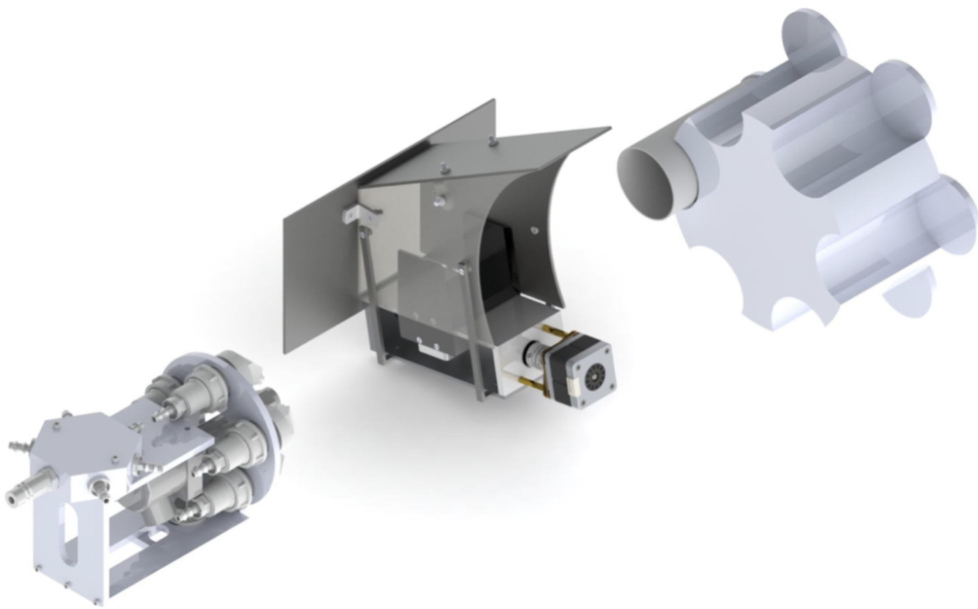
Ball Corporation

Robotic Automation of Cleaning Production Equipment



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Team 1

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Project Background

In the production of consumer aluminum cans, the Ball Corporation sprays a coating inside the cans before they are filled with beverages. The spray coating builds up overtime on an air manifold and the nozzle tip is used to spray the cans, negatively affecting the functionality of the machine. Our team has created an automated two-part cleaning system using compressed air nozzles to remove coating from the coating nozzle tip and a linear-actuator driven scraper to scrape built-up coating into the vacuum/ disposal box.

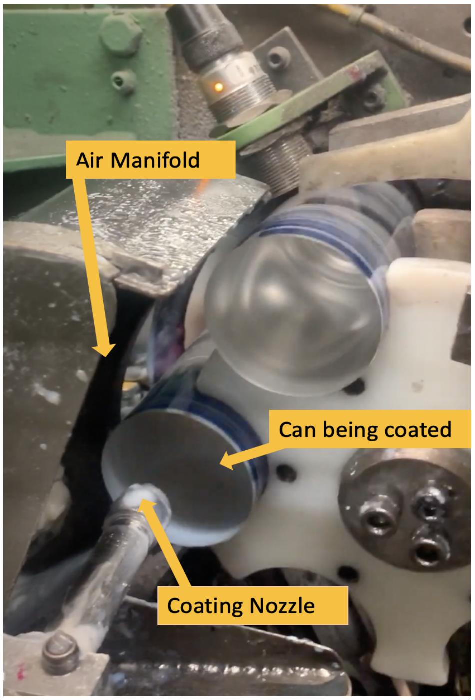


Figure 1: Can coating process

Currently in the Ball factory a technician must stop the can coating process once per hour to clean the nozzle tip and air manifold, contributing to 20 minutes of machine downtime per 12 hour shift. Our automated solution would cut downtime to 6 minutes per 12 hour shift. A single machine produces 250 cans per minute, so our device will allow Ball to produce 7000 additional cans per day on each of its machines.

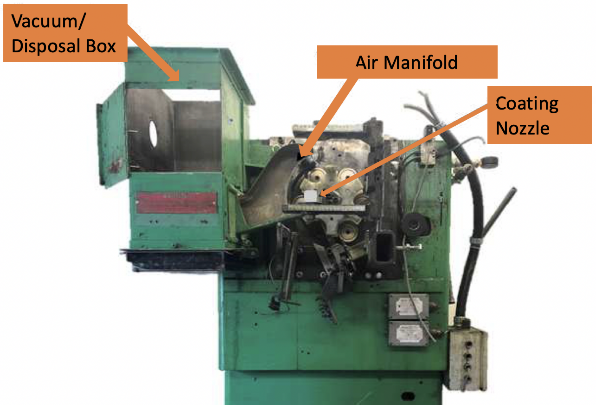
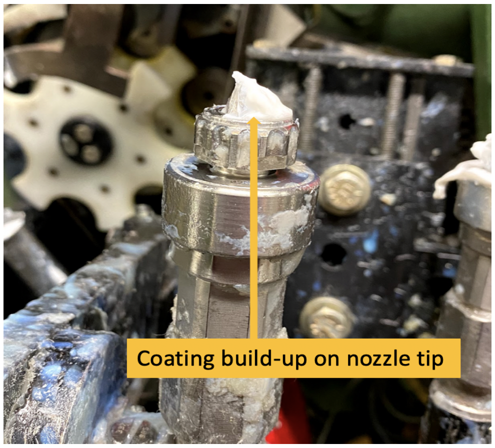


Figure 2: Coating machine

Our team spent a lot of time determining the operating conditions of the current industrial process, and examining alternative solutions, before finalizing our two-part design which we believed would be the most functional while integrating most seamlessly into a well established industrial environment.

Design Priorities and Requirements



1. Effectively Clean Production Equipment

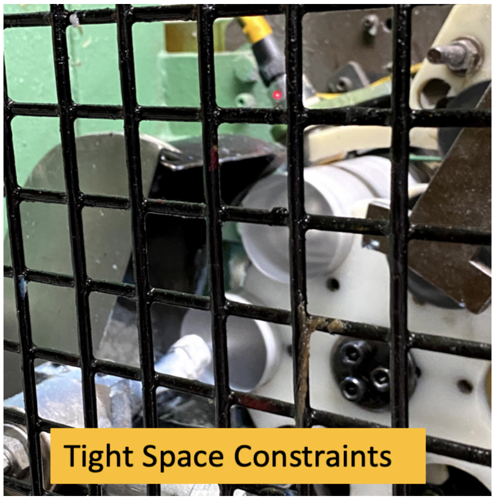
Coating must be removed effectively form the spray nozzle tip and air manifold so buildup does not interfere with the quality of cans in production

Figure 3: Factory nozzle buildup

2. Reduce Machine Downtime

Cleaning time should be reduced to a maximum of 6 minutes per 12 hour shift, approximately 25% of original time, with less manual cleaning required by a factory technician

Figure 4: Factory manifold buildup



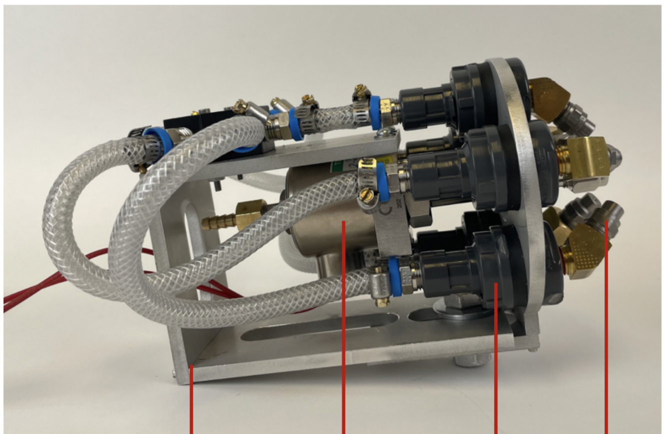
3. Fit within the confines of existing machinery

Our design must not interfere with existing production equipment or produce additional waste streams. Our device will operate at existing voltages supplied by the machine, and a compressed air pressure currently being supplied on the factory floor.

Figure 5: Factory space constraints

Design Overview

Compressed Air Nozzle



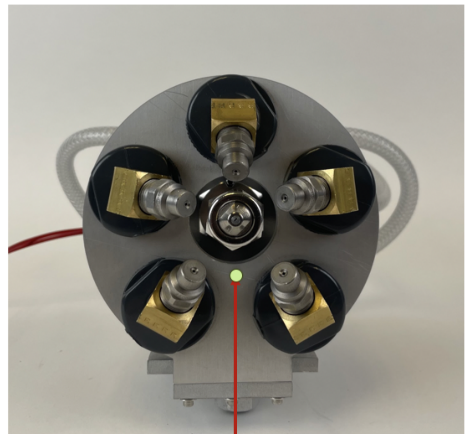


Figure 6*: Compressed air cleaner side*

Figure 7*: Compressed air cleaner front*

The compressed air nozzle system cleans by directing five different streams of pressurized air at the tip of the IC nozzle. Air nozzles are mounted in a ring around the IC nozzle, so streams of air remove buildup from all sides, directing it forward away from the nozzle tip.

The nozzle cleaning system was designed using compressed air because 90 psi air is supplied directly to the factory floor, and using steam cleaning or brushes were determined to interfere too greatly with the production process. Five air nozzles were used as this was the maximum that could be mounted due to size constraints on the mounting ring, and would provide air streams from each direction. We selected Al 6061 for the mounting superstructure in order to be robust, corrosion resistant, and easily manufacturable on a mill. The harsh conditions in the factory meant our device would accumulate excess coating blowback overtime, so we designed our system without moving parts that could become bound up. The flow of compressed air through the cleaning nozzles is controlled by a solenoid and air pressure regulator.

Scraper and Manifold

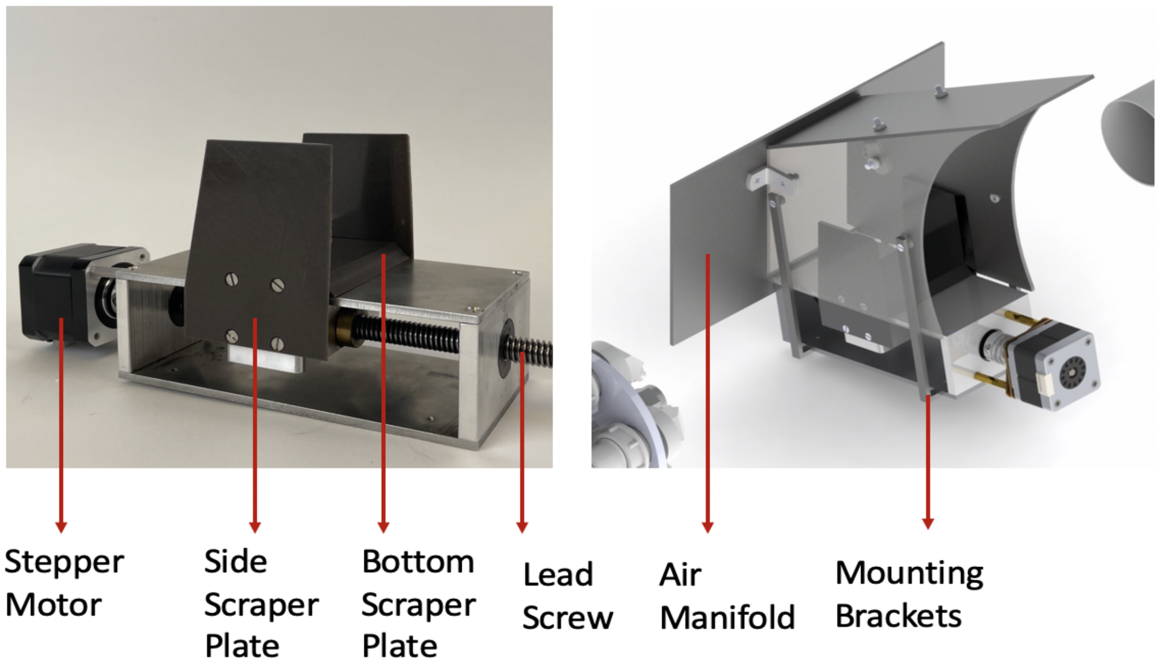


***Figure 8**: Scraper without manifold*

***Figure 9**:Scraper with manifold*

The scraper mounts underneath the air manifold, and is designed to scrape built up coating off of the manifold sides and out the back where it will fall into a disposal container. Our scraper was modified from a design created by a previous group working on this project with Ball Packaging that showed high efficacy in cleaning. Improving upon that design, we designed a new air manifold with simpler geometry and larger contact area between the scraper plates and the manifold sides. Our final design mounts the scrapers to the sides of the moving block, so built up coating does not come into contact with the lead screw, a critical component which must remain clean for the scraper to move.

The scraper plates are manufactured from delrin to be durable and flexible while interfacing with the steel manifold sides. The scraper subsystem mounts to the manifold using L brackets, and tight tolerancing was required to ensure that the scraper plates were touching the manifold sides, but not compressed inward by the manifold walls, creating more friction on the scraper than torque the motor could supply. Many adjustments were made during testing to achieve the proper clearance.

Control system

The electronic control of our prototype uses an Arduino Uno to actuate the motors and solenoids. The stepper motor is controlled by an Easy Drive Motor Controller and powered by an external 12V power supply. The programmed action of the motor is on a timer, but can be activated manually by a button mounted to the manifold. The flow of compressed air is controlled by a solenoid operating on a 24V power supply, timer and button activated. A relay allows the arduino, supplying 5V, to control the 24V solenoid. For testing purposes, we constructed a third system to control the 24V solenoid which regulates the spray of the coating through the nozzle.

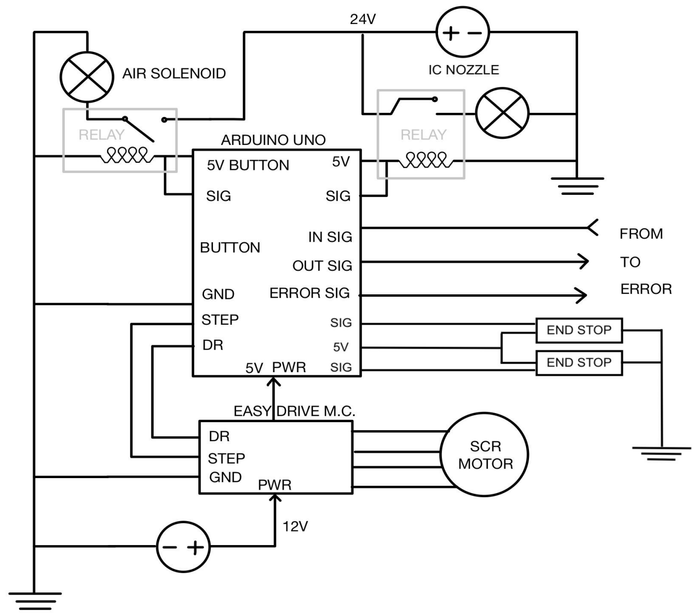


Figure 10: *Control system diagram*

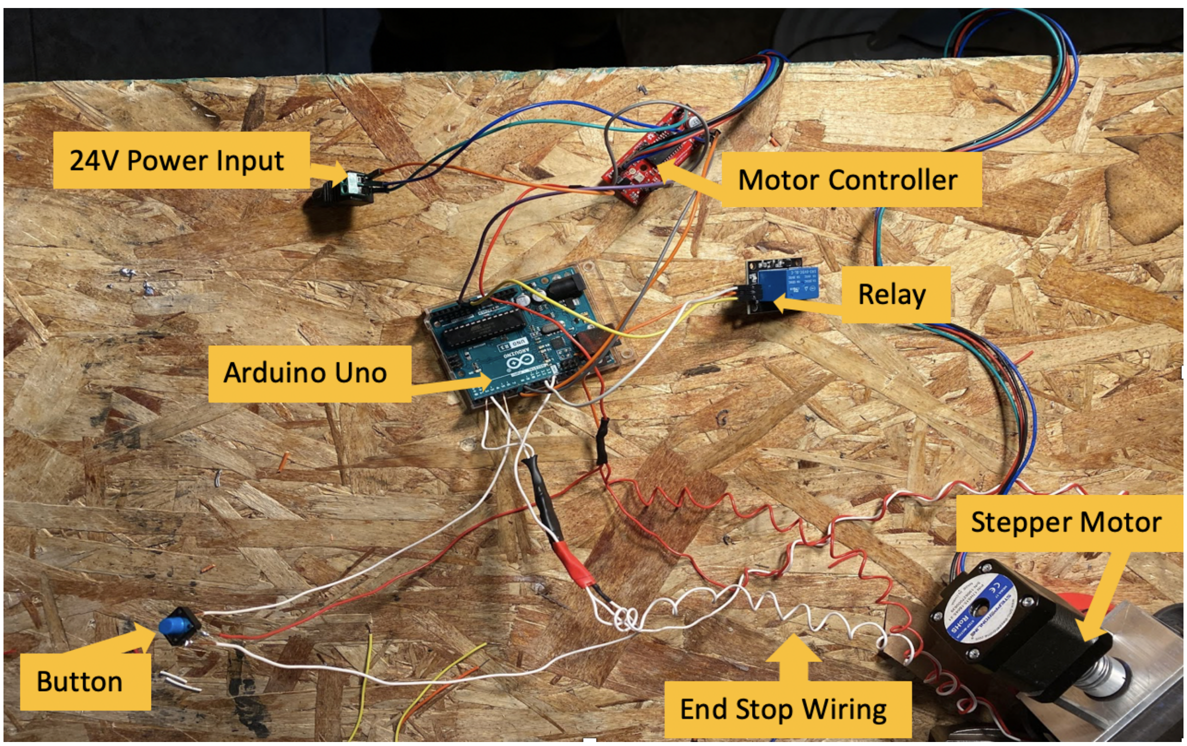


Figure 11: *Control system for both manifold and compressed air cleaner*

Challenges

At home testing

Our team made the decision to conduct our testing at home due to limited availability of testing equipment and space for team members to gather. A secondary part of our project became building a test rig to simulate factory conditions with a pressurized coating tank and a spray booth. We had to conduct our testing outside due to coating fumes and general mess of spraying coating over long periods of time. This made it hard to standardize the testing procedure due to inconsistent conditions such as weather changes and debris entering the testing area.

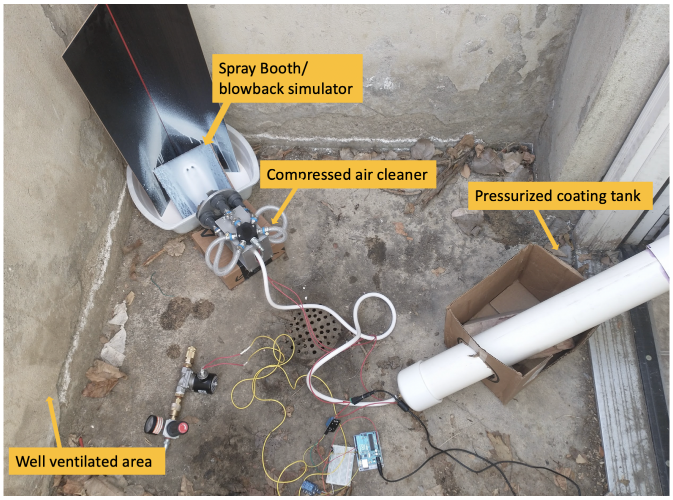


Figure 12: At home testing system

Confirmation of A successful clean

At the factory, technicians assess the cleanliness of the sprayer and manifold through a visual inspection only. Because no physical parameters are used, our team had to rely on visual and qualitative measurements to assess the efficacy of our two-part cleaning system.

Extreme operating conditions

Once implemented in the Ball factory, our device would have to be able to withstand constant use as each machine operates roughly 23 hours per day. The factory has high humidity levels, and our device will be constantly exposed to coating, requiring daily cleaning. To address this, we have created a simple design which protects moving components such as the motor and lead screw and vulnerable mechanisms like our control system from being directly contacted by the spray coating.

Test Results

Compressed Air Nozzle

The testing showed that the compressed air nozzles cleaned the coating nozzle to a high degree of success. When tested at the appropriate focal distance, all 5 nozzles concentrated on the tip of the nozzle and efficiently cleaned wet or lightly tacky coating. Once the coating was fully cured, the compressed air was not powerful enough to remove the coating as seen in Table 1. Based on these results, we found the ideal duration of air spray time for each cleaning was determined to be a 3 second burst of air at the nozzle tip after every 20 minutes of normal operation.

Figure 13: *Coating nozzle before cleaning*

Figure 14: *Coating nozzle after cleaning*

Dry Time / Spray Time	10 min	20 min	1 hour
1 sec	Fully clean	Some residue	Not clean
3 sec	Fully clean	Fully clean	Not clean

Table 1: *Compressed air cleaner effectiveness over dry time*

Scraper and Manifold

Testing of the manifold and scraper involved varying the time the coating was allowed to accumulate and dry inside the manifold before the scraper was run. When the coating is allowed to dry, it becomes very tacky causing the motor to bind as it does not have enough torque to move the scraper. Therefore, we recommend running the scraper once every 5 minutes to remove coating before it dries, while not cycling the motor more than necessary to prevent wear.

Figure 15: *Manifold before cleaning*

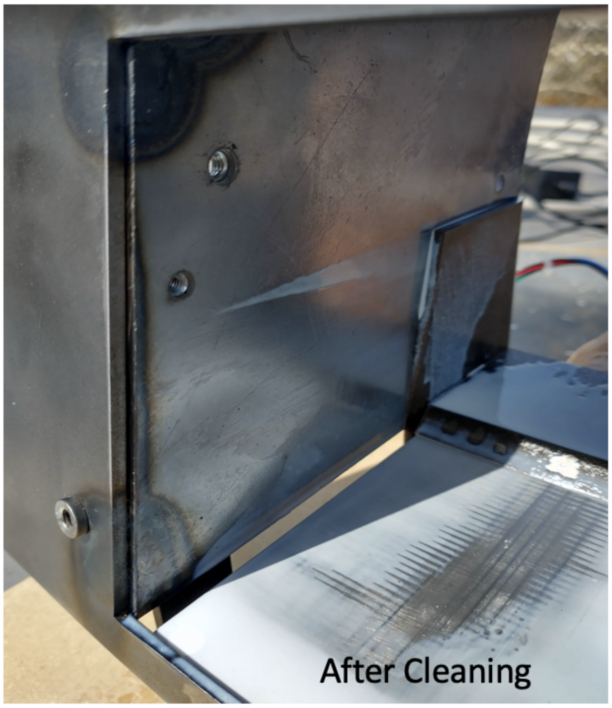


Figure 16: *Manifold after cleaning*

Dry Time:	1 min	5 min	10 min	30 min
Scrapes (Yes/No)	Yes	Yes	Partially (some binding)	No (motor binds)

Table 2: *Scraper effectiveness over dry time*

Conclusion

Based on our test results, if operated according to our recommendations running the scraper once every 5 minutes, and using a 3 second air spray every 20 minutes, our prototype should reduce machine downtime from around 20 minutes per 12 hour shift to a max of 6 minutes (accounting for time required to manually clean our device each shift).

Our team overcame significant challenges of remote work and limited access to resources to deliver a functioning prototype solution to our clients' needs. Our device functions in the way it was designed utilizing concepts from fluid mechanics, solid mechanics, and component design. The compressed air cleaner performs high level cleaning, removing coating from all sides of the coating nozzle tip, and the scraper removes coating build up from the manifold walls and pushes it into the disposal box.

Next steps for a future iteration would be testing our prototype at the Ball factory under real conditions. Our control system would need to be integrated with the machine in order to stop its operation while the compressed air is being sprayed. In further testing we could also experiment with different materials for the scraper plates to determine which type of material interfaces best with built-up coating and the steel manifold sides. We would test our scraper with a more powerful motor that would not bind when encountering dried coating. Finally, we would determine the fatigue life of our device but running it continuously for an extended period until one or more components failed. These tests would help Ball determine the potential life cycle cost savings of installing a cleaning device based on our prototype on each of their can coating machines.

Meet the Team

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