SourceAmerica Design Challenge
Delta Snap

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YouTube Link: **https://youtu.be/QEn1mRXkEdw**

Abstract

Weaver ProPak Industries, a company that primarily employs individuals with disabilities, required an engineered solution that optimizes the assembly of grinder caps (see Figure 1). Previously, Weaver ProPak had nearly lost their contract to assemble grinder caps because their former assembly process lacked efficiency, quickly fatigued employees, and required excessive quality checks. The entire process was prone to error and highly time-consuming.

Consequently, our engineering team solved the grinder cap assembly problem by designing and building a custom machine that met each of Weaver ProPak's needs. Using our machine, Delta Snap, the employee only needs to set the grinder caps correctly into a tray and press a button. Then, the machine uses pistons (see Figure 2) to simultaneously assemble six grinder caps before gently sliding them into a box. Furthermore, our machine not only pays close attention to the operator's safety but is also entirely food safe and easily cleanable between every production round.

On average, Delta Snap improved the efficiency of Weaver ProPak's assembly of grinder caps by 33.7% and increased the number of qualified workers by 300%, enabling all of Weaver's employees to accomplish the job. Most importantly, it also improved the accuracy of the process by 25% such that virtually every cap is assembled perfectly.

Figure 1

Figure 2

Problem Statement

Our team, the Copley Innovators, sought to create an assistive device for the company Weaver ProPak that would drastically reduce the manufacturing time by eliminating quality control issues and reduce the production cost per cap. Such a device should also enable all of the employees to complete the cap manufacturing process regardless of their disability. Additionally, this device had to be made of food safe materials because the caps are used in food shakers.

Before receiving our machine, each cap cost Weaver three cents and only twenty-five percent of the workers at Weaver ProPak could accomplish the tedious task. The manual assembly process prevented any employee lacking strong fingers, shoulder strength, and dexterity from performing the job. First, the employee had to snap the top and bottom pieces completely together by squeezing his or her pointer finger and thumb on their centers. Significant effort and precision is required to ensure that the top and bottom of the caps are securely snapped in place. Second, the caps had to be gently set in a box. If placed too roughly, the delicate caps easily unsnap. Finally, because of quality issues, a supervisor had to perform a manual quality control check on each cap, which made the process highly inefficient. Since every box holds 834 caps, the process quickly fatigued the employees and caused more defectively assembled caps.

Quality control checks became necessary after Weaver sent a package of incorrectly assembled caps to WeatherChem, the company that contracts Weaver to assemble the caps. WeatherChem requires every single cap to be assembled properly, since defective caps can damage the machines that continue the assembly process. Weaver nearly lost their contract with them following this incident. To ensure defective caps would never be sent to WeatherChem again, Weaver implemented quality control checks; however, this more than doubled the average manufacturing time, according to Weaver. This wasted time detracted from Weaver's main goals, as the time that supervisors spent on quality control checks could have been used to teach employees skills for future employment. Moreover, Weaver had to pay the supervisors for these quality control checks, which diminished the wages of their employees.

Background

Weaver Industries, founded in 1971, employs people with disabilities and trains them in preparation for future employment elsewhere. Located in Summit County, Ohio, Weaver has an overwhelmingly positive impact on those in the local community with disabilities. ProPak is the production branch of Weaver and contracts services for assembly, packaging, kitting, labeling, and fulfillment ("Production Services", n.d.). Weaver is dedicated to improving the lives of those with disabilities, and we aimed to help them continue achieving this goal through our project.

One product that Weaver ProPak manufactures is grinder caps for the company WeatherChem. Once the caps are sent to WeatherChem, they will ultimately become part of salt and pepper grinders (see Figure 3) that are sold across America. These caps come in two pieces, which must be firmly snapped together. This process was difficult for the majority of employees at Weaver; most lacked the strength and dexterity to do the job sufficiently, while the remaining few often assembled caps improperly and suffered bruises because of its difficulties. Currently, assistive technologies for people with disabilities exist to help with common problems that they encounter in the workplace, such as magnification devices for reading. Such assistive devices can vary widely in their complexity, from cardboard and felt communication boards to computers. They help to solve many problems that people with disabilities struggle with on a daily basis, such as speaking, seeing, hearing, learning, and walking ("What is AT?", n.d.). However, the job of producing grinder caps is very specific and there has not been any assistive device created for it. Our goal is to create such an assistive device that will solve all of the problems Weaver has been having with the grinder cap manufacturing process.

Figure 3

Rationale

Our team initiated this project to help persons with disabilities and the company that employs them while gaining real-world engineering experience. Our team consists of high school students who hope to become engineers and are passionate about giving back to their community. By creating an assistive technology for Weaver, we, the Copley Innovators, could improve the lives of people with disabilities by expanding their job opportunities and changing their lives for the better.

Weaver ProPak's mission is to employ those with disabilities and help them learn the skills they need to be more employable in the future. However, assembling grinder caps in such a costly and inefficient way hindered Weaver ProPak in achieving that goal. So, we sought to create an assistive technology that would help both the company and its employees by reducing the difficulty of the task. Our device is faster and more efficient at producing the caps than the former process since it automates the hardest parts of the job. The assistive machine increases the number of employees able to do the task by simplifying the process and eliminating the need for strength and dexterity. Opening up this job to all workers also helps Weaver fulfill its mission to boost the employment opportunities of those with disabilities.

Development

We, the Copley Innovators, first had the idea to use a large, heavy tube to roll over the caps and push them down. We designed the tube to roll freely while suspended at the height of a cap above the table. We constructed a prototype out of a large PVC pipe (Figure 4), but after testing it we found that it did not improve efficiency and only assembled half of the caps correctly, which would not have solved Weaver's main problem of quality issues with the caps.

Since the roller design failed due to inconsistency, we focused on creating a device that would be more reliable. We decided to use pistons to push the caps together, which are used in many industrial applications because of their strength and dependability. Relying on air pressure to force an arm to extend or contract, pneumatic pistons ensure that every cap is perfectly assembled by pushing the caps together with the same exact force every time. As a proof of concept, we clamped a piston above a cap and used an air compressor to push it down on the cap (Figure 5). Once we determined the optimal pressure and speed, the piston assembled the caps correctly every single time.

We created a prototype based on these tests, consisting of a wooden frame holding a piston and a lever that caused the piston to move down and assemble a cap (Figure 6). The worker's job involved placing the cap directly under the piston and pulling the lever. While more reliable, this design suffered two significant drawbacks. First, it was unsafe because no safety precaution existed to prevent the employee from placing his/her hand underneath the piston. Second, there was no mechanism to ensure that the employee centered the cap under the piston. When the cap was not centered, the piston often only partially assembled the cap. However, when the caps were centered below the piston, this design assembled every cap successfully.

Since the piston worked much better than the roller, we decided to further develop the idea to create the most reliable, efficient, and safe machine possible. Considering the first prototype's safety issues, we made safety a top priority of our new design and focused on creating a machine (Figure 7) that would work effectively by using pistons while keeping the users safely away from the force they exert. We also ensured the caps would be centered beneath the pistons by adding a precisely positioned tray. Finally, we wanted to make it user friendly by adding lights and displays to notify the user of important information and problems.

Figure 4

Figure 5

Figure 6

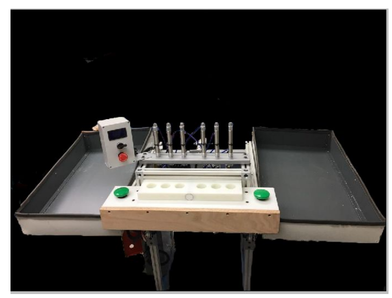

Figure 7

Final Design

The machine's final design uses pistons to accurately assemble six caps simultaneously. Caps are placed into a six-slotted tray that slides into the machine's operation area when buttons are pushed. In the operation area, six pistons assemble the caps before a trap door opens and the assembled caps slide down a ramp into a box, where they are slowed down enough that they do not break. The machine is mounted on a box-like structure with enough space beneath for a wheelchair to fit easily.

Our machine is made out of safe, strong materials to make it user friendly and robust. The frame of the machine is constructed out of T-Slotted aluminum, which is both light and strong. This material also facilitates the construction process since it could be easily adjusted if necessary. The tray is made of polyethylene, a food safe material that is commonly used in cutting boards, since the caps will be used to store food. Our machine uses pistons to move the sliding tray and trap door, as well as to push the caps together. These pistons are magnetic, so they allow a sensor to check if the piston is at a certain height. This allows the machine to tell if the cap is closed to the perfect height, or if it had been placed in the tray incorrectly and should be rejected. The machine is controlled by a CLICK PLC (programmable logic controller) from AutomationDirect, chosen because of its reliability. Although other, less expensive controllers could have been used, we decided on the CLICK PLC because we knew that it would work correctly all of the time and ensure the workers' safety. The PLC acts as the "brain" of our machine and directs the sequence of piston movements and lights according to the buttons pressed.

The machine has many safety features that make it almost impossible for an employee to get hurt. The fundamental design is based around safety, with a tray that slides the caps away from the employee to be assembled. An employee can never use the machine without a supervisor, since only the supervisor has the key to the switch that turns on the machine. The pistons that assemble the caps and the electronics are completely covered. Furthermore, our machine prevents employees' hands from getting stuck as the tray slides into the area of operation by ensuring their hands are on the buttons. If the buttons are not pressed down while the tray is moving underneath the pistons, the tray will come back, preventing any potential danger. The pistons in the machine are very forceful, but they are covered by plexiglass so an employee cannot get his/her hands stuck. In the event that something does go wrong, an emergency stop button will stop the machine from continuing its normal sequence of assembly and an emergency air release valve will stop the pistons from applying force.

The machine incorporates many features that make it simple and effective to use. The machine allows more employees to complete the job via a selector switch on the front of the machine. It has a setting that allows for an employee to operate the machine while pressing only one button if he/she is unable to use both hands. When the caps are assembled by the pistons, sensors detect if they have been assembled perfectly, and if they have not, the tray comes back out of the machine. Red lights mark caps that did not assemble properly so the employee can put the cap back in the tray correctly, and green lights mark correctly assembled caps. If it is difficult for an employee to get a cap back out of the slots, he/she can push up on bolts that are underneath the slots, which push the caps up out of the slots if needed. A counter locating on the front of the machine displays the total number of caps that have been assembled for this box, allowing the employee to check his/her progress. When this counter hits 834, this means that an entire box of caps has been assembled. At this point, the machine will stop assembling more caps and green LEDs will blink until a reset button is pressed.

Cost Analysis

All of the materials needed to build this machine cost a total of $1,300.18. Many of these materials were generously donated or discounted, so the amount of money actually spent on the machine was $503.64 (for the complete list of materials and donations, see the appendix). While this is a large amount of money, it allows for sophisticated safety features and the reliability that Weaver was looking for. In addition, since so much was donated, we added features that were helpful to the employee and would improve efficiency even more, such as the red and green lights that would prevent a worker from inspecting every cap to determine which one was incorrect. Our team spent a total of 925 man-hours working on every aspect of the machine, from the first formulation of the idea to delivering the machine to Weaver. All of the time, effort, and money spent on this machine was worth it as Weaver saw enormous cost benefits due to this machine. As the machine improves the efficiency of the process in caps per second by 33.7% or more, Weaver will likely see outputs and likewise profits increase by a similar amount. This means that for every $3 Weaver made on the caps before, Weaver can now expect to make $4 or more with the new process (for the data we used to come to these conclusions, see the appendix).

Testing Procedure and Results

To test how our machine improved the workplace at Weaver Propak, we collected data on the improvements in efficiency and accuracy with our machine. We had three employees assemble about one hundred caps, first using the old manual process and then using our machine. The employees varied wildly in both their accuracy and their rate of assembling caps, with defect rates for the caps ranging between 0.9% and 38.0%. Our machine had a failure rate of 0.0%, perfectly assembling every cap we tested and improving the accuracy of the process on average 25% (Figure 8). This is a massive improvement, and because the machine has an accuracy of 100.0%, quality control checks can be completely eliminated. This will significantly decrease the time the process takes, resulting in an overall efficiency improvement measured in caps produced per second of 33.7% on average (Figure 9). Additionally, for an average order of caps that Weaver makes, our machine saves 33 man-hours of time.

All of these improvements are based on data that was taken in the *best case scenario*. The workers we tested had not been doing the job for hours, so they were not experiencing the fatigue that would set in on a normal work day for the old process. This means that they were operating at their peak efficiency and accuracy. The machine, however, never slows down and thus the improvements in accuracy and efficiency are even greater than these numbers after hours of assembling caps.

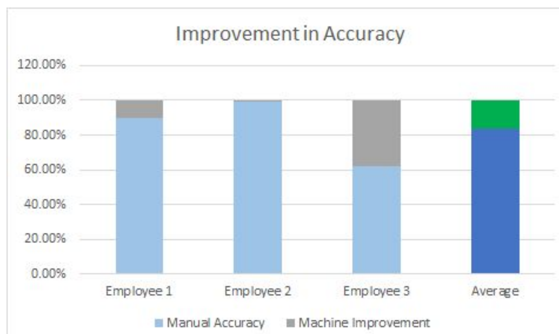

Figure 8

In addition, the caps that the workers used to collect our data had been clicked and unclicked numerous times during our testing, wearing them down and making it easier for the workers to assemble them more accurately and more quickly than they would with new caps. Meanwhile, our machine assembles the caps with the same accuracy and efficiency regardless of the caps' wear. The workers had also been completing the cap assembly process for years, whereas in our data collection it was the employee's first or second time using the machine. Their efficiencies using the machine would increase with practice over time, making the machine even more of an improvement over the old process.

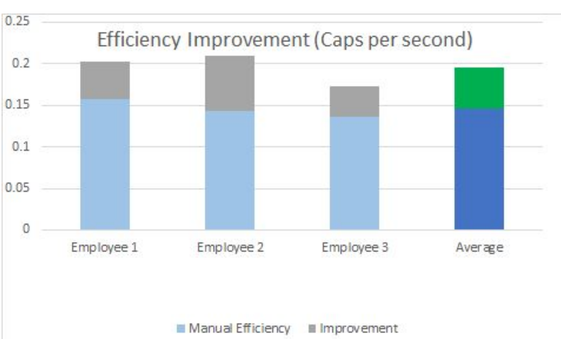

Figure 9

If we use data that Weaver collected toward the end of the day for our SME Michelle, and compare it to the data we collected using our machine, we find that there is an 83% increase in efficiency. Since this is based on Weaver's official data, it is most likely more representative of our machine's true efficiency improvement. So, in the long run, the efficiency improvement of our machine should match this number more accurately and even exceed it. Overall, our machine outperformed the old process in terms of production time per cap and accuracy rate even in the best conditions for the old process.

Community Impact

Our machine greatly impacts our community by helping both the facility at Weaver ProPak and its employees with disabilities. The facility will be able to produce more caps at a faster rate and will no longer have to inspect every single cap to ensure that it is assembled properly, as the machine executes the task correctly every time. Virtually all of the employees will be able to do the job, even if they only have the use of one hand, which is a major improvement over the 25% of employees that are currently able to do so. By simplifying the employee's job to setting up the caps and holding a button, the machine will also eliminate the more difficult aspects of the task, such as clicking the caps together, counting out the 834 required caps for each box, and setting the caps gently into the box. Furthermore, the machine will accomplish all of this while ensuring employee safety by only operating when employees' hands are holding buttons. The machine is able to drastically simplify the employee's job and improve production costs without eliminating the employee altogether. By making the task easier and more efficient, the company will be able to save money while at the same time hire more employees. The employees will also be happier working the job. When we showed the machine to our SME Michelle, she remarked that it was like playing a game and seemed to genuinely enjoy testing it. This is a stark contrast to when she demonstrated the old process and showed how the caps could pinch her fingers. The machine obviously aids the worker using it, but also the entire community benefits from this machine. More local people with disabilities will be able to find jobs, and the company that hires them will have additional time and money to continue making a positive impact.

Conclusion

Weaver ProPak required an improved method to assemble grinder caps for their contract with WeatherChem. Consequently, we, the Copley Innovators, sought to simplify and optimize their assembly procedure in a safe manner. Our primary approaches to optimizing ProPak's cost-effectiveness were to 1) improve quality of the assembly process so the necessity for double-checking is eliminated, 2) increase the rate of production without compromising ProPak's mission to employ persons with disabilities, 3) maintain a safe workplace environment with minimal risk of operation by employees, and 4) enable all employees to perform the job.

We met each of these aims while successfully building a custom machine to help Weaver ProPak with its grinder cap assembly problem. We followed a comprehensive engineering design process while creating our solution for Weaver ProPak. First, we researched Weaver ProPak's problem with assembling the grinder caps by closely examining their current process and asking supervisors about their biggest struggles with the process. Second, we brainstormed several potential designs to optimize their process. Third, we developed several prototypes before selecting our final design, in which pistons simultaneously assemble six grinder caps and the employee's effort is limited to setting up the caps and holding a button. Fourth, we built a prototype of the machine and then developed it into the final design.

We also ensured that our machine enacted the most rigorous safety standards to protect the employees. Primarily, we designed the machine such that it only operates when the worker's hands are holding buttons (be that one or two). With this approach, the workers stay safe while operating the machine because none of their body parts will be capable of obstructing the machine and being harmed. Furthermore, we guaranteed that all of the materials used in the machine follow food-safety standards, so the eventual customers are met with the same safe quality of product as before.

Altogether, our custom machine successfully met Weaver ProPak's needs. We met their most urgent need to eliminate quality double-checks, increased the efficiency by 33.7%, simplified the ease of assembly for workers, and enabled virtually all employees to perform the job.

Acknowledgements

We would like to give a special thanks to the following people and organizations:

- Our SME Michelle for allowing us to collect data on her assembly process of the grinder caps.
- John Moll, the Operations manager in charge of assembling packaging and quality control of the grinder caps, for his time, support, and advice.
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- Roger Cornell for helping us order the HDPE Plastics.
- Wissam EL Rassi for helping us with the part bins.

References

Production Services. (n.d.). Retrieved from http://www.weaverindustries.org/

What is AT? (n.d.). Retrieved from https://www.atia.org/at-resources/what-is-at/

Appendix

Cost Analysis

Bill of Materials

Qty	Description	Place	Total Cost	After Donation
2	Green pushbutton	Automation Direct	$41.00	$0.00
1	Selector switch	Automation Direct	$18.00	$0.00
1	Emergency stop button	Automation Direct	$18.00	$0.00
3	NITRA pneumatic valve	Automation Direct	$88.50	$0.00
6	NITRA pneumatic piston	Automation Direct	$183.00	$0.00
7	Magnetic pneumatic cylinder switch	Automation Direct	$80.50	$11.50
1	NITRA pneumatic fitting	Automation Direct	$8.25	$0.00
1	NITRA pneumatic piston	Automation Direct	$46.00	$0.00
1	CLICK PLC	Automation Direct	$109.00	$0.00
1	CLICK input module	Automation Direct	$49.00	$0.00
1	CLICK output module	Automation Direct	$35.00	$0.00
1	CLICK power supply	Automation Direct	$29.00	$0.00
1	NITRA pneumatic exhaust silencer	Automation Direct	$2.25	$0.00
1	NITRA pneumatic valve manifold	Automation Direct	$30.00	$0.00
1	NITRA banking plate	Automation Direct	$4.25	$0.00
1	NITRA mounting bracket	Automation Direct	$1.00	$0.00
1	NITRA pneumatic fitting	Automation Direct	$6.00	$0.00
1	NITRA pneumatic exhaust silencer	Automation Direct	$2.50	$0.00
1	NITRA pneumatic hex fitting	Automation Direct	$6.00	$0.00
1	Green wire	Automation Direct	$25.00	$25.00
1	Red wire	Automation Direct	$25.00	$25.00
1	White wire	Automation Direct	$25.00	$25.00
1	White crimps	Automation Direct	$5.50	$5.50
1	Red crimps	Automation Direct	$5.50	$5.50
1	1.5" plastic	Professional Plastics	$44.78	$44.78
1	.75" plastic	Professional Plastics	$43.98	$43.98

5	T-slotted profile	Ralph A. Hiller Comp	$212.25	$189.04
6	3 way corner connector	Ralph A. Hiller Comp	$54.06	$43.25
6	2 way corner connector	Ralph A. Hiller Comp	$54.06	$43.25
40	5/16-18x3/4 FHSCS	Ralph A. Hiller Comp	$20.00	$16.00
16	5/16-18x1/2" FBH	Ralph A. Hiller Comp	$8.00	$6.40
10	T-nut	Ralph A. Hiller Comp	$1.80	$1.44
1	Counter	Amazon	$12.00	$12.00
4	Ground wires	Automation Direct	$6.00	$6.00
		TOTAL COST:	$1,300.18	$503.64

Hours

In Class	In school	After School	Visiting Weaver	Total
160hrs	200hrs	300hrs	70hrs	925 hrs

Data Collection

With the Machine:

Employee	Caps Done	Caps Correct	Time
1	96	96	0:07:55
2	114	114	0:09:03
3	114	114	0:10:58

Without the Machine:

Employee	Caps Done	Caps Correct	Time	Quality Control time
1	115	103	0:07:21	0:04:48
2	116	115	0:08:38	0:04:50
3	137	85	0:11:00	0:05:43

Data Analysis:

WITHOUT MACHINE:

Employee	Accuracy	Failure Rate	Efficiency (caps/second)
1	89.57%	10.43%	0.1578672817
2	99.14%	0.86%	0.1436052342
3	62.04%	37.96%	0.1366215583
Average	83.58%	16.42%	0.146031358

MACHINE:

Employee	Accuracy	Failure Rate	Efficiency (caps/second)
1	100.00%	0.00%	0.2022074311
2	100.00%	0.00%	0.209832686
3	100.00%	0.00%	0.1733787565
Average	100.00%	0.00%	0.1951396246

IMPROVEMENT:

Employee	Accuracy	Failure Rate	Efficiency	Time savings for 1 order (~70,000 caps)
1	12%	10.43%	28.09%	27:00:31
2	1%	0.86%	46.12%	42:44:08
3	61%	37.96%	26.90%	30:10:24
Average	25%	16.42%	33.70%	33:18:21

Michelle’s Improvement using Weaver’s end-of-day data:

	Assembly per 6	Assembly 139 caps	Quality Control Check	Quality Control Check 139 caps	Total Time per 6 Caps	Total Time 139 caps	Total Time per Box (sec)
SME-Michelle	36	997	12	267	48	1264	6672

Caps per second: 0.10996835443