Ergonomic Nutritional Laboratory Container Opener

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Client: Robert Radwin

Advisor: John Puccinelli

Team Members: Scottland Adkins, Crysta Frank, Nick Haller, Hunter Higby, Katie Werth

Abstract

Laboratory procedures often necessitate extensive use of wrists and hands. The current procedure at a local lab requires each technician to open a large number of containers each day, invoking tremendous hand stress and strain. A device is required to significantly reduce the technicians' hand strain from continuously opening containers. While manual and automatic devices are currently on the market, there are benefits to fabricating a new device. A manual device will only marginally reduce hand strain relative to an automatic device. The majority of automatic devices are not created for industrial use and do not have the power to open containers fast enough for the technicians. A new device will be designed to specifically meet the technicians' needs; most importantly, the device will significantly reduce hand strain without interrupting workflow.

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Introduction

An ergonomic device for the opening of containers is necessary and useful for a wide variety of situations. According to American Academy of Orthopedic Surgeons, basal joint arthritis is a common problem that is the result of the wearing away of cartilage in the joint of the hand/wrist at the base of the thumb and leads to aching and sharp pain [1]. Anyone who repeatedly opens containers is at risk for developing this condition. Currently, there is not a device on the market that can sufficiently open a wide range of container sizes without disrupting workflow and producing strain in the hand, wrist and fingers. The lack of an adequate product is especially problematic for laboratories that are opening many containers in a continuous manner. It is crucial to develop an alternative that reduces discomfort for users that experience these factors.

Problem Statement

A large, commercial food-testing laboratory employs over 400 technicians that are required to repeatedly cap and uncap laboratory containers. Each technician follows a procedure, which involves the uncapping and capping of 50-100 containers per day. The repetitive counter-twisting motion that these technicians exhibit daily leads to significant strain on their hands, wrists and fingers. The goal is to reduce this discomfort by developing a container opener tool or stationary fixture that assists in the opening of variably sized containers.

Current Methods

Manual Opener

Manual openers are one of the products on the market designed to make containers easier to open. This type of design eliminates a large amount of the grip force required to open a container. Manual openers also use a larger moment arm in order to lower the force required to open said containers. However, this design still requires the user to exert a twisting force that when repeated can cause unnecessary hand strain.

Automatic Opener

Automatic openers are also used, but are sometimes not as efficient as manual openers. Automatically operated openers are beneficial in that they can take away almost any force needed by the user, however they often take longer to open containers than if done by hand or manual opener. Additionally, these styles of openers can be loud during use. Many automatic models do not remove lids completely as a means of not worrying about lid height increase while the lid is being removed [2]. Most automatic openers also require constant observation or for a user to hold some form of switch down, as they are not intelligent systems enough to know when a lid has been removed.

Background

Research

The need for a device to assist with container opening is necessary for the two major reasons. Repetitive hand motion has been found to wear the cartilage in the joints of the hand and the wrist; in the most extreme cases the wearing of the cartilage leads to basal joint arthritis [1]. The torque required to open many containers has also been found to be extremely difficult for most users [3]. Many devices have been fabricated to assist users with opening containers but none have been sufficient for the purposes of the client.

Client Information

The client, Dr. Radwin, is affiliated with the Industrial and Systems Engineering and Biomedical Engineering programs at the University of Wisconsin-Madison. He collaborates with a local lab that requests the development of a device or tool that is able to assist technicians in opening variably sized laboratory containers.

Design Specifications

The client desires a device that is able to repeatedly cap and uncap up to 5,000 laboratory containers each day while reducing the stress and strain of the laboratory technicians' hands. The device must be integrated into the technicians' current procedures without impacting the workflow. Technicians are expected to meet specific quotas, making it crucial for the device to be easily added into the current procedure without forcing the technicians' pace of work to decrease. In order to maintain the productivity of technicians while using the machine, it is essential that the device is both accessible and easy to use. The device must open a wide variety of container sizes, and, since the device will be used to open nutritional containers, be able to undergo a simple sterilization procedure. The client has not set a precise budget for the device, but design ideas will be comparable in cost to similar products on the market. Full Design Specifications are included in Appendix A.

Preliminary Designs

Manual Opener

The first design is a manual torque-increasing device that incorporates a variety of sizes of circular molds on one device in order to open a range of container sizes. The user selects the size on the device and slips the device around the cover of the container. The user then deforms the sides of the device to provide a clamping function. The device acts as a lever to increase the torque being applied to the lid while the user would hold the container. This design is easy to fabricate and would significantly increase the torque that the user comfortably and consistently applies. This design does, however, require manual input and may not reduce enough hand strain due to the vast number of containers the technicians uncap and cap each day.

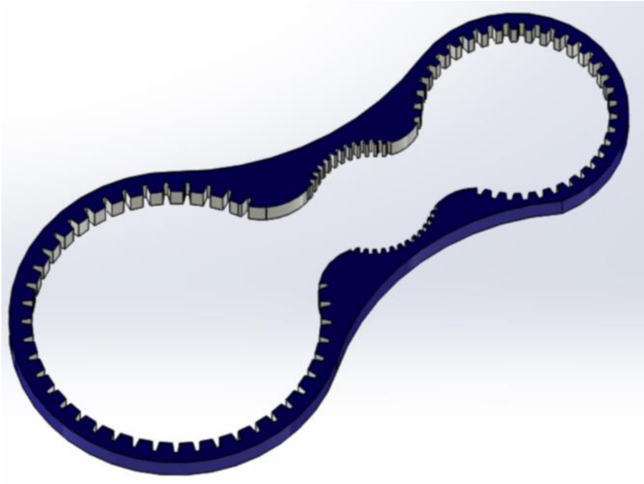

Figure 1: Manual Opener

Clamp Hold Opener

The Clamp Hold Opener consists of a base clamp that holds onto the container while a top clamp is lowered onto the lid and rotates to remove the lid. The top clamp operates by using a set of anti-parallel racks around a single pinion, which rotates to bring the two halves of the clamp together. Once the clamp halves obtain a secure hold on the lid, the pinion then provides the necessary torque to uncap the lid. This design is adaptable to many sizes of containers, both in height and diameter. However, it requires significant setup as each container must be centered precisely and the motor only starts to remove the lid once the pinion has rotated enough to completely close the clamp.

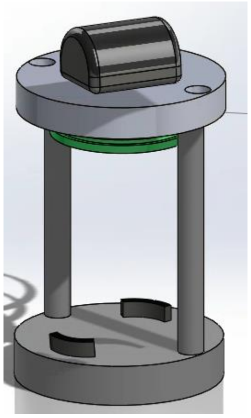

Figure 2: Clamp Hold Opener

Friction Hold Opener

The Friction Hold Opener design consists of an aluminum cone with a high friction interior coating mounted to a motor on a frame. The user pushes the lid into the cone, activating the motor, while holding the container to provide counter torque while the lid is removed. This design easily adapts to various container heights and lid diameters, has potential to improve workflow, and significantly reduces hand strain. On the other hand, it does not remove hand strain altogether, as the user is still required to grasp the bottom portion of the container.

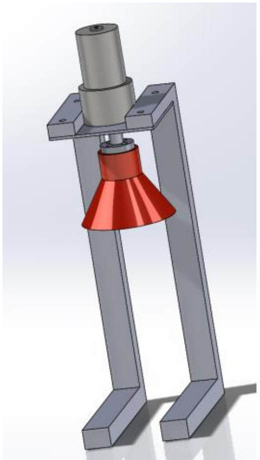

Figure 3: Friction Hold Opener

Pneumatic Opener

This design consists of a pneumatically operated clamp that grabs the sides of the container, along with a pneumatically operated clamp that lowers onto the lid and rotates to remove the it. This design is be capable of clamping quickly and generating a large amount of torque. However, it would require either a loud compressor, access to a compressed air supply, or pressurized air tanks which are not appealing to users and encompass dangerous component failure modes.

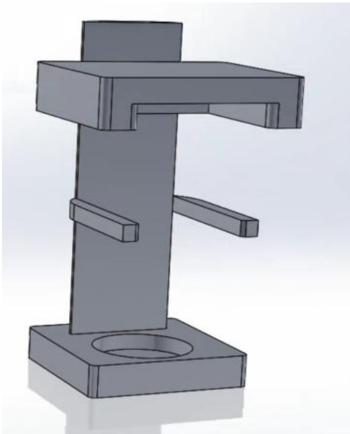

Figure 4: Pneumatic Opener

Preliminary Design Evaluation

	Manual Opener	Clamp Hold Opener	Friction Hold Opener	Pneumatic Opener
Hand Strain Relief (25)	(2/5) 10	**(4/5) 20**	(3/5) 15	**(4/5) 20**
Impact on Workflow (20)	**(4/5) 16**	(3/5) 12	**(4/5) 16**	(3/5) 12
Safety (10)	**(5/5) 10**	(4/5) 8	(4/5) 8	(3/5) 6
Sterility (10)	**(4/5) 8**	(3/5) 6	(3/5) 6	(3/5) 6
Durability (10)	(1/5) 2	**(4/5) 8**	(3/5) 6	**(4/5) 8**
Range of Container Sizes (10)	(3/5) 6	(3/5) 6	**(4/5) 8**	(3/5) 6
Cost (5)	**(4/5) 4**	(2/5) 2	(3/5) 3	(2/5) 2
Ease of Fabrication (5)	**(4/5) 4**	(2/5) 2	(3/5) 3	(2/5) 2
Ease of Use (5)	**(4/5) 4**	(3/5) 3	**(4/5) 4**	(3/5) 3
Total (100)	64/100	67/100	**69/100**	65/100

Figure 5: Design Matrix

Hand Strain Relief

Hand Strain Relief was a criterion that was stressed greatly by the client, making it the most important testing criteria. The main goal of the design is to significantly reduce the stress and strain on a technician's hands, wrists and fingers during the opening of containers. Therefore, the highest ranked designs in this category represent the devices that provide the greatest relief, which are the Clamp Hold Opener and Pneumatic Opener. Both designs include a clamping mechanism at the base of the device that stabilizes the container while the rotating mechanism twists the container cover. The Manual Opener requires a significant amount of counter-twisting by the user, and the Friction Hold Opener requires the user to hold the base of the container while the cone semi-automatically twists the cover off of the container.

Impact on Workflow

Impact on Workflow was an important criterion due to the quotas that technicians are required to meet in the laboratory. In order for employees to uncap and cap a high volume of containers each day, the device must not significantly interrupt their workflow. The highest ranked designs in this category are devices that most similarly relate to employees' workflow when manually opening containers. The Clamp Hold Opener and Pneumatic Opener both require the user to set the clamping mechanisms onto the base of the container being opened, which greatly slows down the user's procedure. Since the Manual Opener and Friction Hold Opener do not require the user to set clamping mechanisms on the base of the container prior to opening, they are considered to be more efficient devices, and are therefore ranked highest in this category.

Safety

Safety had a relatively high weight due to the consideration of the well being of the user. Since the device will experience high usage each day, it must be reliable and have minimal risk for hazardous situations. The Manual Opener was rated highest since it does not contain any moving parts or dangerous components. The Clamp Hold Opener and Friction Hold Opener contain compact AC gear motors, resulting in a lower safety rating in this case. The Pneumatic Opener would present significant risk to the user, as standard cylinder compressor pumps require about 70 PSI to function. For these reasons, the Manual Opener was ranked highest in this category.

Sterility

Sterility was one of the third most important criteria and a crucial consideration due to the environment in which the device will be operated. In a nutritional laboratory, sterilization of all samples is vital to the accuracy of test and evaluations. The top rated design in this category, the Manual Opener, is a device that can be sterilized easily and efficiently by any technician at any time. The remaining three designs are more complex in their components and assembly, making the sterilization of the structures more time consuming and intricate. For these reasons, the Manual Opener ranked the highest in this category, while the Clamp Hold Opener, Friction Hold Opener, and Pneumatic Opener were tied for the lowest ranking.

Durability

Durability was another one of the third most important criteria due to the high traffic that the device will endure. Since each employee uncaps and caps 50-100 containers each day, and the device may be used by multiple employees, it must be capable of functioning under consistent usage while also requiring minimal maintenance. The Clamp Hold Opener and Pneumatic Opener are composed exclusively of high strength materials, while the Manual Opener and Friction Hold Opener involve the use of weaker strength materials such as plastic and silicone, respectively. For this reason, the Clamp Hold Opener and Pneumatic Opener achieved the highest ranking in this category.

Range of Container Sizes

Range of Container Sizes had a relatively high weight in the evaluation of the four designs. The greater the range of container sizes that a design can uncap and cap, the more functional and valuable it is to the laboratory. The Friction Hold Opener is capable of opening a wide variety of sizes of containers due to the cone mechanism that contacts the container cover. The Manual Opener, Clamp Hold Opener, and Pneumatic Opener are capable of interacting with approximately the same range of container sizes. The Clamp Hold Opener and Pneumatic Opener contain similar clamping mechanisms to stabilize the base of the container, and the Manual Opener is restricted to the diameters of each ring. Hence, the Friction Hold Opener is ranked highest in this category.

Cost

Cost had a relatively low weight in the evaluation. The laboratory is interested in a device that significantly decreases the level of discomfort that technicians are experiencing, and has not placed a strict cost limit on the device. The Manual Opener requires only two materials (plastic and silicone), neither of which are particularly expensive. The Friction Hold Opener involves a motor along with an aluminum structure, hub, and cone with a silicone interior, and the Clamp Hold Opener requires a greater volume of the same materials. The Pneumatic Opener involves integration of a motor, cylinder, and valves in addition to an aluminum structure. For these reasons, the Manual Opener scored highest in this category.

Ease of Fabrication

Ease of Fabrication is a lowly weighted category. While it is important that the design is feasible, it is not crucial that the fabrication process is simple. The Manual Opener, again, requires the least components and does not include a motor of any kind. The Friction Hold Opener is more complex, but does not necessitate an unfeasible fabrication process. The Clamp Hold Opener and Pneumatic Opener would be the most difficult to fabricate due to the addition of the clamping mechanism at the base of the device. Hence, the Manual Opener was ranked highest in this category.

Discussion

Following fabrication, the container opener will be extensively tested to confirm that the device fulfills the client's specifications. First, the device will be tested and evaluated to ensure that workflow is not negatively impacted. To do so, 20 specifically sized containers will be opened manually and the time-required will be recorded. Then, the device will be used to open the same amount and size of containers. The time-required to open 20 specifically sized containers manually and using the device will be compared to understand the impact that the device has on the workflow of a technician.

Qualitative and quantitative tests will be conducted in order to confirm that the device reduces the manual force necessary to open variably sized containers. To obtain qualitative data, 20 containers will be opened and closed manually, followed by 20 containers being opened and closed using the device. An explanation of the method of opening and closing the user preferred, along with a detailed description of the hand strain the user experienced, will be obtained. A test will be developed to obtain quantitative data. Proceeding testing, the data will be analyzed to determine changes that must be made to ensure that the device fulfills the client's requirements.

Sources of Error

At this time, specific design errors cannot be quantified. However, there are some aspects of the testing processes that we anticipate opportunities for error. In the testing protocol that evaluates the impact on workflow, a team member is required to time the user, which introduces human error. To standardize this potential error, the same team member will monitor all trials.

Conclusions

The repetitive counter-twisting motions that the laboratory technicians perform daily to open containers produces significant strain on their hands, wrists and fingers. Currently, there is not a product on the market that can sufficiently reduce hand strain without disrupting workflow. The Friction Hold Opener design will reduce hand strain without disrupting workflow. The user will hold the container up to the cone, the motor will activate and the lid of the container will be removed with a significant reduction in the user’s hand strain. This design will not have a negative impact on workflow since the user simply holds the container, rather than securing it with clamps.

Future Work

The chosen design must undergo significant finalization measurements. This includes specifying dimensions, selecting materials, and conducting a precise cost evaluation. These steps must be approved by the client to ensure that the final device is adequate for the laboratory.

Additionally, there are several potential roadblocks that could hinder the implementation of the device. The laboratory’s Health and Safety Department will evaluate the device before it can be introduced to the laboratory space in which it will be used. It is important that any moving parts associated with the device meet the expectations that the Health and Safety Departments have established. Also, it will be imperative to implement as many the client’s requirements as possible, including the consideration of the device handling containers that are as cold as -70 degrees Celsius.

Acknowledgements

We would like to recognize and express gratitude to the individuals that have assisted our design thus far. The assistance and guidance that we have received from Dr. Radwin, Dr. Puccinelli, and Dr. Yen has been crucial to the success that we have experienced thus far in the design process. Additionally, we would like to express appreciation to the local nutritional laboratory, as they have provided us with ample information along with an explanatory tour of the laboratory area that will house the device.

References

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Appendix A

Preliminary Design Specifications

Function:

An ergonomic laboratory container opener is a device that is capable of opening variable sizes of laboratory containers with minimal effort exerted by lab technicians. Openers range from manually operated to entirely automatic. Manual openers are beneficial because they are able to open variable sizes of containers. However, they generally fail to require a low amount of force exertion from the user. Automatic openers are ideal in reducing user effort, but are often less lenient in the range of container sizes that they are capable of opening. A local commercial food testing laboratory that consists of over 400 employees, follows a protocol which requires multiple technicians to repeatedly cap and uncap up to 100 laboratory containers each day. The goal is to design a laboratory container opener that significantly relieves strain from lab technicians' hands and fingers.

Client Requirements:

The laboratory container opener must open containers with minimal manual intervention. It must be capable of opening laboratory containers in a variety of sizes; specific size range will be determined upon a tour of the laboratory. The container opener should operate in a timely manner and maintain function after excessive use. A budget has not yet been defined, but a reasonable cost for a product of this type would make it more attractive to relevant companies.

1. Physical and Operational Characteristics:
    a. Performance Requirements:
    The most important function of the opener is to open laboratory containers with minimal manual force. The jar opener must withstand excessive use (~5,000 containers per day) and function in a timely manner to accommodate the constant use of the device.

    b. Safety:
    The design of the opener must account for potential device failures, and any harmful device components must be properly contained so that the user is not harmed by the laboratory container opener.

    c. Accuracy and Reliability:
    The container opener must function in a reliable, consistent manner to avoid setbacks in the lab.

    d. Life in Service:

The laboratory container opener must maintain functionality while being used upwards of 5,000 times per day.

e. Shelf Life:
All materials used in fabrication of the opener must have abundant shelf lives to ensure that the container opener operates successfully over an extended period of time.

f. Operating Environment:
The container opener will be operated in a nutritional laboratory, meaning it must be sterile, resistant to potential spills, and able to withstand abundant use. The laboratory is room temperature.

g. Ergonomics:
The operation of the device must be straightforward and efficient for lab technicians to use.

h. Size:
At largest, the laboratory container opener should be small enough to be installed on a lab bench. The component of the opener which contacts the laboratory containers must be adjustable to account for variable container sizes.

i. Power Source:
The only potential device component that would require power is a motor, which would be powered through an outlet.

j. Weight:
The weight of the laboratory container is not entirely crucial, since it will be stationary. However, it must be light enough to be installed on the top of a lab bench without causing damage to the surface.

k. Materials:
Metals, polymers, and plastics are all materials that could be used to fabricate the device. Additionally, to accommodate a variety of container sizes, rubber to grip the container and gears to adjust the size of the opener could also be utilized. The materials used must be capable of simple cleaning and sterilization.

l. Aesthetics, Appearance, and Finish:
The opener must be functional and easy to handle. It should resemble a professional piece of laboratory equipment.

2. Product Characteristics:
   a. Target Product Cost:
      The target product cost of the device has not yet been specified, but will be within reason for the customer.

   b. Quantity:
      Ideally, a one-size-fits-all opener will be made to accommodate for various laboratory container sizes. Multiple openers will be made, if necessary, to cover all container sizes.

3. Miscellaneous:
   a. Standard and Specification:
      No additional approvals are necessary for this project.

   b. Patient-Related Concerns:
      The finished product must maintain sterility upon use, especially in areas that come into contact with laboratory containers.

   c. Competition:
      i. Manual Opener:
         Manual openers alleviate some strain from users when opening containers. However, since laboratory technicians must open an excessive amount of containers each day, this strain is still too great.

      ii. Automatic Opener:
          In general, automatic opener devices are operated by a single touch. They rotate around jars to open them, and are adjustable in size to open a variety of container sizes. However, these devices are quite small, require AA batteries, and therefore are not entirely powerful. Additionally, it is not likely that their ranges are wide enough to open the variety of container sizes requested by the client.

   d. Customer:
      The customer for this project is Covance, a globally known drug development and research company based in Madison, WI. The design will be made to open any style of container, research or household.