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WEGMANS PARBAKE ROUNDING

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ABSTRACT

The Wegmans bakery produces many baked goods that are sold in their stores. One of the products is an artisan loaf of bread that is produced on the parbake line. The current process of dough rounding used for the artisan loaves on the parbake line is very ergonomically challenging and has been rated as a high risk task by Wegmans' internal ergonomic evaluation. When the raw dough comes down a conveyor to the employee, he or she has to grab the dough, cup their hands around it, and move their hands and arms in a circular motion to achieve a smooth round ball of dough. By studying the current state and evaluating the different options for reducing the ergonomic risk it was determined that the best possible option would be to develop a first-of-its-kind prototype device that would round an artisan loaf of bread. This would achieve the goal of reducing the ergonomic risk while ensuring quality and efficiency goals are met. The prototype design involves a number of small conveyor belts positioned to pull the dough from outside of dough to the bottom center point. With long term implementation in mind, it is envisioned that the dough will drop into the device from the current conveyor, then be released by the opening of the bottom like a trap door and fall onto the proofing sheet so that the seams are tucked neatly at the bottom point. Ergonomic evaluations and suggestions were also performed and delivered to help reduce the ergonomic risks in the short term.

BACKGROUND

Wegmans Food Markets, Inc. is a family-owned U.S. grocery chain based in Rochester, New York. The 235,000 square-foot bakeshop produces Wegmans-brand baked goods that are distributed to all stores. A large variety of processes occur in the Wegmans bakeshop. One of the lines in the bakeshop known as the "parbake line" produces the artisan loaves of bread that are sold in Wegmans stores. Parbake means for the bread to be only partially baked at the bakeshop and then the baking is finished at the stores where the bread is sold. This is a common technique used by bakeries to help ensure the bread is fresh for the customer.

The manual process of parbake rounding has been determined to be an ergonomically challenging job. The process of rounding is used on the types of bread that are meant to be round loaves as opposed to square or baguette styles. When the raw dough comes down the conveyor to the employee, he or she has to grab the dough, cup their hands around it, and move their hands and arms in a circular motion to achieve a smooth round ball of dough that has all the seams neatly tucked underneath. This overly manual task has potential to be improved greatly by our RIT Senior Design team. The dough seams are only minor breaks in the raw dough but after proof and bake can make the dough appear blown apart and cause the piece to be scrapped. This is why during rounding the goal is to have a smooth outer surface with the seams on the bottom.

With the goal in mind to reduce ergonomic injuries that may occur at the Wegmans parbake line, improve quality of the final product and maintain production efficiency. We determined that the best solution would be a mechanical rounding device. This seemed to be the only solution that would end up reducing the operator task as a manual rounder and improving the consistency of quality long term. While many mechanical dough rounding devices exist on the market our approach was to design a custom dough rounder that would not cause the dough to become over worked and de-gassed. When raw dough is made natural air pockets are formed within it, these air pockets will become smaller if the dough is overworked and the final product will appear too flat. This will take away from the artisan style that Wegmans is trying to achieve.

DESIGN PROCESS

During the design phase of the project, a total of 10 customer needs were identified. Each of the needs was then ranked by importance to the customer. The most important needs are indicated by an importance level of 1 and can be seen listed in the customer needs table (Figure 1). Based on these customer needs and the results indicated from a root cause analysis, a functional decomposition was performed to help better understand and visualize the functions that would be necessary of a device that performed the task of rounding (Figure 2). The results indicated the most important functions were grab dough, apply vertical pressure, fold sides under, apply circular motion, apply horizontal pressure, and release dough. Initial concept tests were then performed to see what success different concepts might have. Using an air gate to form the dough, forming the dough to a mold, rolling the dough in a mold, and spinning dough with a pottery wheel helped to give a better idea of what was really needed when it came to rounding dough. Each concept was then analyzed for feasibility and compared to the other concepts in a detailed Pugh's analysis, the results of which helped give us a guiding direction.

Given the outputs from the Pugh's analysis and feasibility analysis different designs were pursued through an iterative process and evaluated against each other to make a decision on which design to pursue. The first design was a

Customer Need #	Importance	Description
CN1	1	Reduces Ergonomic Risk
CN2	1	Rounds Bread Correctly
CN3	2	Is Durable
CN4	2	Can be Cleaned/Sterilized
CN5	1	Can Maintain Production Rate
CN6	2	Can be Easily Repaired
CN7	1	Meets Food Safety Requirements
CN8	2	Meets Budget/ROI
CN9	1	Is Reliable
CN10	1	Safely Fits in Production Space

Figure 1: Customer Needs

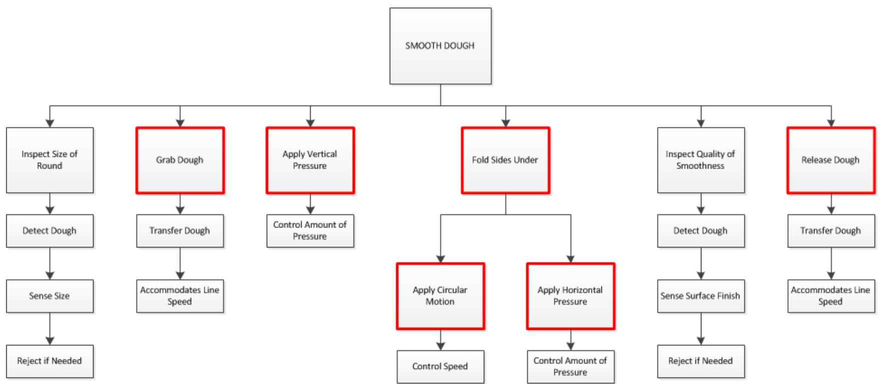

Figure 2: Functional Decomposition

Mold with Rollers

Plus	Minus
Gives rotational contact	Flush with the table top
Gives tucking motion	Hard to tuck under the dough
Operator interaction	Seams staying on the sides of the dough
Can utilize rotating arms	Different dough sizes means different contact points
	Only tucks from one half
	Dough sticking on conveyors

Ice Cream Scoop

Plus	Minus
Gives better tucking motion	Flush with the table top
Operator interaction	Hard to tuck under the dough
	Seams staying on the sides of the dough
	Different dough sizes means different contact points
	Contact point at two scrapers creates a twist
	Dough sticking on conveyors

Drop & Pinch

Plus	Minus
Gives better tucking motion	Contact point at two scrapers creates twisting
Operator interaction	Dropping into the device difficult to keep shape
Able to get all the way around the dough	Flipping out of device difficult to keep shape
Tucks to a point	Dough rolls on itself while flipping out
Contact at all points since it drops in	Dough sticking on conveyors

Twister

Plus	Minus
Gives tucking motion	How to get dough into the device
Operator interaction	Dough sticking on conveyors
Able to get all the way around the dough	
Tucks to a point	
Contact at all points since it drops in	
No flipping out of the device	

Figure 3: Compared Designs

mold with rollers which was determined would not work because it would not be able to tuck the sides under the bread and achieve a true smooth outer surface for baking. The second design was an ice cream scoop which was determined could result in a smoother surface but could still not tuck the sides under past the table surface. The third design was a drop and pinch type design however this would lead to many complications with line integration due to flipping dough in and then flipping it out as well. The last design was a twister and tucker which would use belts on an angle under dough to pull towards center, tuck the sides under, and encourage a round shape. Then it would twist to make sure all parts of dough ended up getting on the tucking belts. Each of these design ideas were evaluated for advantages and disadvantages. These are displayed in figure 3.

Measurements were taken of the current conveyor work areas where the employees perform the dough rounding. These measurements were to be used to evaluate line ergonomics and space constraints. The plan for the ergonomic study is to provide current and ideal reach envelopes of employees while performing the dough rounding, the optimal conveyor heights, and trunk flexion.

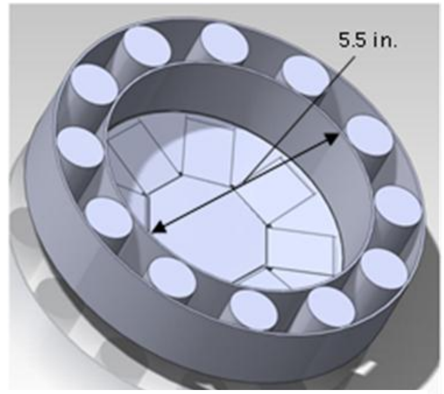

Figure 4: Twister Concept

PRELIMINARY DESIGN

The twister and tucker then went from paper to computer drawing to get a better understanding of the concept. This can be seen in figure 4. A risk assessment was performed to evaluate the risks that might occur throughout the project (Figure 5). The importance was determined based on likelihood and severity. This allowed the team to focus on and create a plan to mitigate those risks that were most important.

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk
	Describe the risk briefly	*What is the effect on any or all of the project deliverables if the cause actually happens?*	*What are the possible cause(s) of this risk?*	*1-3*	*1-3*	*L*S*	*What action(s) will you take (and by when) to prevent, reduce the impact of, or transfer the risk of this occurring?*
30	Delays in fabrication	No or limited time to test the concept or complete the full design fabrication	Complexity of the design and limited fabrication support	3	3	9	Get Wegmans fabrication support early. Find ways to incorporate off the shelf parts.
21	No artisan look on the finished bread	Wegmans loses brand recognition for artisan bread	Too much handling causing degassing, unforeseen changes down the line	3	3	9	Run test loaves through the entire Parbake line
9	Wrong product ordered	Delay in completion/unable to complete	Other people ordering for us, inexperience in part specs	3	3	9	Very specific with product numbers and manufacturers' standards. Double check our orders
29	Delays in getting full scale testing time on the production line	Delays in getting the appropriate data to confirm the results of the device	Breakdowns on the line that screw up the production schedule	3	3	9	Scheduling buffer to allow for multiple weeks to get in production line testing
15	Not enough time to finish project	Unable to deliver final project	Problems along the process, poor time management	2	3	6	Buffer time at end of Project Plan and have a plan B
7	Operators not supporting the changes	End project without meeting goals	Not using operators in design process	2	3	6	Keep operators informed in product testing and inform them of the benefits

Figure 5: Risk Analysis

With support from the Wegmans team, the twister and tucker proved to be the best design and it moved forward on to the next stage. Progress was then made in developing a bill of materials, testing plans, and fabrication steps. The bill of materials wouldn't necessarily be expensive, it was estimated that based on the initial bill of materials the entire expense to build and implement wouldn't be more than $5,000. The actual cost of used parts is around $650 with the cost of purchased parts a couple hundred on top of that.

The initial bill of materials was added on-to throughout the fabrication process as design specifications became clearer. New motors were purchased as the specifications for speed and torque were better understood. Also, the Wegmans' fabrication shop was relied on to supplement this bill of materials with a few stainless steel assemblies that were beyond the machining capabilities of the RIT machine shop.

ENGINEERING MODEL

The fabrication of our device proved to be the hardest and most time consuming aspect of the project. It was underestimated the amount of custom fabrication that would be required and the time it would take to make the parts that we required. Of the bill of materials only a few items could be purchased and used exactly the way they were obtained, the rest of it required some sort of converting to transform the part into what we would need it to do. The gears required turning down to make axles. Blocks of aluminum had to be milled and drilled to make the frames that would be used for the conveyors. Stainless steel fabrication was not precise due to the limitation of the Wegmans' shop and the difficult design features. There was testing that needed to be done with different conveyor material as well as how it would be applied to the timing belts.

A failure modes and effects analysis was performed to bring-to-light any failure points of the design. The failure modes that were identified to have the greatest risk are cycle time fluctuation due to quality out of the current belts, too much pressure causing degassing, and dough getting caught at bottom point.

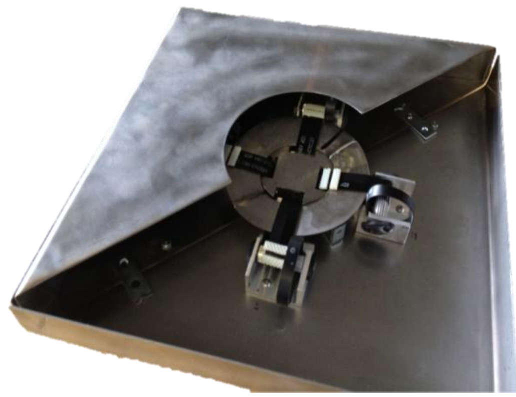

Figure 6: Prototype (without motors and wiring)

The design was a brand new prototype. It was not as simple as building from a known drawing. There were many components such as the hinging, electronic programming, and implementation that could not be completed. This was due to the time limitations and team staffing limitations such as delayed fabrication support and no electrical engineering support. All in all, the design concept was based on the conveyors being able to tuck the seams of the dough so that is where the focus was shifted. The project was now a concept test of the conveyor system instead of an implementation of an all-encompassing rounding device. The conveyor assemblies were finished and hooked up to electric motors so that dough could be tested on them.

The design of the hinging release system was started but then it was decided that it would be more important to focus on the conveyors because if time was running out we needed at least the conveyors to be done. This process started with figuring out the lengths of the ½ and ¼ inch rollers and determining how they would be driven.   With the original motors found, we couldn't direct drive the rollers due to the space and motor size. A deign decision was made at this point to drive the ½ inch roller with a timing belt instead of a direct drive system. This decision played a large role in the length & design of the roller system and housing for all the components. The roller system was developed to meet the need for a way to attach the rollers and bearings. An aluminum block was designed and fabricated to meet this need. After having the roller system developed, we started attaching the conveyor material to the timing belts for pulling the dough towards the center. However, we found the conveyor material and timing belts couldn't be attached all the way around because the conveyor became too stiff to go around the ¼ inch roller. The plan then was altered to: placing four little strips of belt material on our timing belts which allowed for the right flexibility to get around the ¼ inch roller but still have a friction surface to pull the dough.

Figure 7: Finished Device

Originally DC motors were ordered based on torque however this became clear that it was a poor decision because the revolutions per minute (rpm) weren't considered. A second round of motors were ordered for a better rpm while keeping the torque in mind however it was a model motor and the rpms were now too high. Plus, we also didn't understand how to hook up that type of motor and control it. On the third attempt, finally the correct motors were specified correctly for torque, speed, and voltage.

EXPERIMENTAL SETUP AND PROCEDURE

The device being designed was a prototype for the purpose of proof-of-concept. In order to prove a concept, statistical significance is highly important and it is even more important as an analysis before line integration. Some statistical tests were performed early on in the project to help develop a better understanding of the defect rates and efficiencies. These were intended to be used as a means for comparing the results of our device to the results of the current operation. Throughout the project it became clearer that the prototype design we were making would not be implemented during this project. Due to this change of scope our testing procedure changed as well. It became a question of does the dough rounding device achieve the goal of pulling the dough from the sides and bottom to the center and prove that this concept could work with more testing. This was tested by running four pieces of dough through the device and then evaluated by Wegmans' for quality. The conveyor belts were able to pull the dough in the intended fashion however more engineering work will need to be done before it will be ready for implementation. Some of the findings that came out of this testing include: motors not strong enough, dough getting sucked in at center roller and rollers not parallel causing belts to get off track. The team suggests better tolerance drawings for fabrication, larger rollers for avoiding dough getting stuck, smoother belt conveyor material, properly fastened assembly, and direct driving the rollers.

DATA ANALYSIS

One of the most important aspects of this project is to make sure that the final product will be able to maintain line efficiencies and be able to integrate smoothly into the space available. The line speeds were already determined to be about 3 seconds per piece. The next step was to determine what the current defect rates were. This would help us to better compare the results of our dough rounder with the quality rates of the current rounding process. It was found that Wegmans did not take very accurate counts of the defects and that when they did; the type of defect wasn't recorded.

Data collection occurred during a few different stages of the project. One of the more important stages was collecting data of the workspace attributes and evaluating the ergonomic conditions. From measurements of the conveyor height and through comparison to general ergonomic guidelines, it was determined that the current conveyor height, set at 38 inches, is optimal for performing a light assembly task such as dough rounding. When it comes to trunk flexion, the optimal position is standing straight up[2]. Currently, the employees' trunk flexion while dough rounding fluctuates between 0 and 22 degrees during their work. Figure 8 shows the difference between current state and future state reach envelopes if the electrical boxes surrounding the conveyor line could be relocated and the dough can be 2 inches closer to the operators.

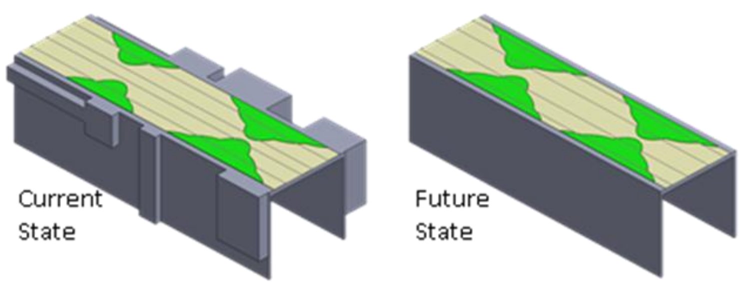

Figure 8: Ergonomic Reach Envelope

RESULTS AND DISCUSSION

From the data, the reject rate was found to be significantly different between bread types. The Tuscan bread had a higher defect rate than the seasonal breads. This cause was hypothesized to be from the number of loaves on a tray since Tuscan used 6 versus the 4 for seasonal. Tests were run to determine how the reject rate differed between running through the current rounding belts one time without operator and with operator. It was determined that there is statistical significance between the two and that the operator involve indeed gives a smaller reject rate. Our next step was to compare a situation of running two times through these current rounding belts without operator. This test however requires and extensive amount of time and could not be conducted due to time and scheduling.

The ergonomic recommendations started with the height of the conveyor. At the current 38 inches which is deemed optimal, it is actually optimal for workers within the height range of 5'4" and 5'9".[3] So it is recommended that operators above or below this range be limited on this station and better yet assigned to other operations on the line. Since this is a repetitive motion operation, a couple of recommendations were made to mitigate repetitive motion injuries. This includes, pre-work stretching and stretching breaks, job rotation, and proper standard work techniques[1]. Finally, to mitigate the back and shoulder strain it is recommended that Wegmans purchase anti-fatigue mats, sit/stand stools, and a foot rest. All of these will give the flexibility for the operator to find their particular comfort throughout their shift. The electrical boxes on the line should also be removed (as shown in the figure 8) to allow for a better reach envelopes and to eliminate the trunk flexion of the operators. This will allow them to stand right up to the conveyor and not have to lean in.

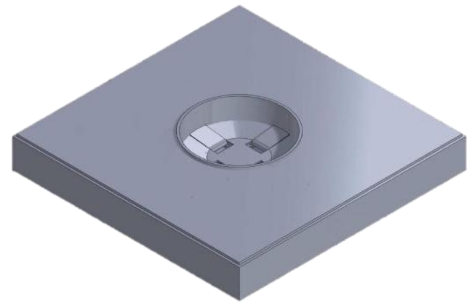

Figure 9: Detailed CAD Assembly

Modeling was done for the current fabricated parts so that they can be reproduced or redesigned during future engineering work. The team recognized that one device would not be able to keep up with the production rate and that two to four would probably need to be manufactured. Therefore, it was necessary to make models so that our work could be duplicated. Figure 9 shows a final CAD assembly of the fabricated twister device.

Originally success was to create a device that could be integrated onto the production line that would reduce the ergonomic concerns of the current rounding operation. However this proved to be more than what the team could handle with their time and resources. So when the project scope was reduced so was how it would be evaluated for success. If the concept would work for rounding the dough to a quality equal to or better than the operators it would be seen as a success.

CONCLUSIONS AND RECOMMENDATIONS AND NEXT STEPS

The overall project we view as a success. As a team, we were able to evaluate the ergonomic needs of the parbake line. Then we made suggestions for how to improve the line for the current operators. We learned and documented the current state of the dough without operator involvement to better understand what a device would need to be able to do. The current belt rounder that is used on the line was tested and it was found that it will not suffice without the operators. Finally, we began the first stage of an engineered rounding device that can integrate onto the production line.

Spec. #	Function	Specification (metric)	Unit of Measure	Marginal Value	Ideal Value
	Cost effective				
S1		Budget	dollars ($)		
S2		Fits corporate ROI	years	<2 yrs	<1 yr
	Good Quality				
S3		Hand Made Look	go/no go	Go	Go
S4		Minimum Degassing	go/no go	Go	Go
S5		Low defect rate	percentage	<5%	0%
	Meeting demand				
S6		Improve Employee pacing	ratio (s/s)	<1	<0.5
S7		Production rate - Apple, RWB, CranOrange, Cinna, 3 varieties of Round Rye	loaves/min	44	>44
S8		Production rate - Round PDC	loaves/min	34	>34
S9		Production rate - Tuscan	loaves/min	38	>38
	Safety and Ergonomics				
S10		Effort Level	1-4	2	1
S11		Time per Effort	1-4	1	1
S12		Efforts per Minute	1-4	4	3
S13		Task Duration	1-4	3	2
S14		Number of Employees	1-4	2	2
S15		Recordable Strain/Sprain Injuries	1-4	3	1
	Improving Productivity				
S16		Quick Changeovers	minutes	<30	<15
S17		Effective Utilization of Space	Sq*m	<16.25	<2
S18		Minimize Handling of Products	seconds	<3	<1
S19		Reduce Downtime	minutes	<15	<5
S20		High Reliability	percentage	>95%	100%
S21		Operator Feedback Test	1-5	>3	5
	Food Safety				
S22		Material Grade for Production	material grade	Food Grade	Food Grade
S23		Materials touching Food	qty	Minimum	Minimum
S24		Exposed Material Type	unit	SS, PVC, UHMW	SS, PVC, UHMW
S25		Water Resistant	unit	Yes	Yes

Figure 10: Specification Table

Figure 10 is the specifications table that was used to evaluate where the team did well and where the team came up short. The red is what we could not meet, most of which has to do with production and we were never able to get the device to that point. Yellow is what we assume that the device will be able to meet. The green were specifications that the team was able to meet such as production grade materials touching the dough and we assume the ergonomic score will be reduced with the erogonomic recommendations and future implementation of the device. This gives a visual representation of what the expectations were of the team during the first couple weeks and what we were actually able to deliver on twenty weeks later; the plan versus actual.

As far our failures, we needed to be better staffed with electrical support. This could have been prevented by better understanding team strengths and weaknesses so that assistance could be sought out in areas of weakness. This caused the issues with ordering the correct electric motors to drive the conveyors and that no work was done on electrical timing or automation. Also, the restructuring of the scope during week 5 of MSD II since the original schedule could not be met should have been prevented. More critique during the detailed design phase from mechanical or fabrication support would have prevented the over ambitious goals since they could offer up their knowledge and criticism of the design.

Our twister design recommendations are to accommodate more off the shelf components where capable. This will reduce the fabrication time and make it much easier to maintain. The enclosure should be made out of a lighter metal or plastic to make the separation hinging system easier to design in. There should be tighter tolerances on the ring and cone which could have been seen had sufficient CAD modeling been done prior to fabrication. These tolerances will make a tight fit which will eliminate places where flour can get to the motors. Finally, design changes to shrink the overall footprint of the device will prove to be beneficial in order to better integrate onto the line.

The next steps for this project would be to pass the work we completed on to another Senior Design Team. They would be able to work on a hinging system, automating the device, and integrating it onto the line. Also, the Wegmans' team can start to implement the current recommendations to make the parbake line better ergonomically for the operators.

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