# Automated Bread Maker: Implementing Techniques of Product Design Process

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## Abstract

Bangladesh is one of the fastest developing countries in the world. To save valuable time, we need to do our necessary work as fast as possible. In crowded restaurants, people wait a long time to have their ordered bread for the lengthy flour bread-making process. The automatic flour bread maker machine has helped people make flour bread in a very easy way and quickly. We have proposed and improved the design for the automatic flour bread maker machine and additional features such as 'hand wheel' for portability for emergency usage, and a safety box is used for safety. In this study, results from customer surveys are used as Voice of Customer (VOC) and expert opinion as design requirements to propose a House of Quality (HOQ), part of Quality Function Deployment (QFD). Finally, to quickly understand the machine's functionality, Functional Decomposition has been performed to learn in detail how the automatic flour bread maker machine works. We have designed all the parts of our product in the 'Solid Works 2014' software, and the outcomes of the stress analysis are implemented for design improvisation, which results in reduced material and space consumption.

## Keywords
Product Development Process (PDP), VOC, HOQ, QFD, Functional Decomposition.

## 1. Introduction
"Product Design" of a physical object or a service can be summarized as the concept generation, concept development, testing, and/or manufacturing and implementation of that object or service (Aurich et al., 2006). Developing a design concept for a product or service is the initial part of design engineering. Before developing a design concept, the fundamental question that arises is- "What to produce" or "What to design"(Amano, 2019).

Automatic Flour Bread Maker machine is an efficient and cost-effective, and time consumable mechanism installed at restaurants where flour bread has a huge demand of customers. A large number of pieces of bread can be produced automatically in a short time. In crowded restaurants, people wait a long time to have their ordered bread for the lengthy flour bread-making process. It is also difficult to give a proper size to the bread. The automated flour bread maker machine has helped people to make flour bread in a very easy way. Flour pest is given on the rollers, and the rollers pressed the flour pest to make the flour sheet. A cutter is used to automatically cut the flour sheet as a proper size and shape of the bread. Then the bread is separated from the flour sheet and dropped on the conveyor. The conveyor takes the bread to the tray. Meanwhile, a motor is turning the rollers to pressed the flour pest. The benefits of automatic flour bread maker machine can be listed as follows: A large amount of bread can be produced in a short time, Proper design of Roller and cutter to give the perfect bread size, increases customer convenience, Boosts the comfort level of employees, customers and visitors, Reduce the cost of the machine than the machine which are in the market now.

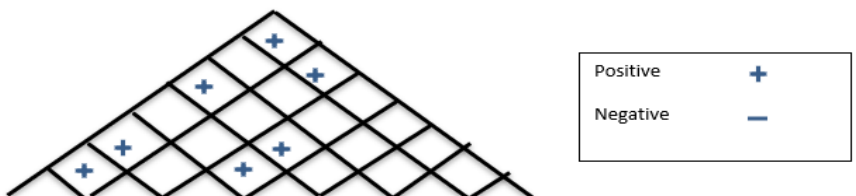
This study aims to apply PDP to introduce an automated bread machine design that can increase bread-making efficiency, reduce cost and time, reduce the bread-making effort, employing better quality of bread's shape and size, and fabricating a simple model to depict the system. The machine is designed to part by part so that the parts can be interchanged or replaced easily. Customer survey initiates with HOQ, a phase of QFD which describes the relationships between design requirement and customer survey in section 2. The functional decomposition of the product has been performed in section 3 to gain a better understanding of the product. Finally, the outputs of all product design processes have been applied to the design section, described in section 4.

## 2. Implementation of Quality Function Deployment on Automated Bread Maker

Quality function deployment is an extremely useful methodology to facilitate communication, planning, and decision making within a product development team. It is not a paperwork exercise or additional documentation that must be completed to proceed to the next development milestone. It brings the new product closer to the intended target and reduces development cycle time and cost in the process. Quality Function Deployment (QFD) is a customer-oriented product innovation process (Costa et al., 2000). QFD provides a means for organizations to "delight" customers by including their voice into the product design process (Lockamy & Khurana, 1995). Quality Function Deployment (QFD) is a quality tool that helps to translate the Voice of the Customer (VOC) into new products that truly satisfy their needs (Jaiswal, 2012). House of Quality (HOQ) is the primary metric for QFD and a conceptual map that provides the means for inter-functional planning and communications (Shrivastava, 2013).

### 2.1 House of Quality

HOQ is conducted in the machine to diagnose the relationship metrics between the voice of customers (VOC) and technical requirements. VOC can be determined in numerous ways. In this study, VOC is conducted by a qualitative analysis. Experts' recommendations identified targeted customers. After that, the (VOC) was captured by a customer survey with a relevant questionnaire. A tree diagram is used to resolve the design requirements. Figure 1 represents the desired HOQ, where the Voice of Customer and the technical requirements are incorporated.




■ – Strong (9)
□ – Moderate (4)
♦ - Weak (1)

| | 220V 1HP DC Motor | Conveyer | Roller | Cutter | Durability | Weight & height | Color & Shape | Importance | We Today | Target In Future | Improvement Ration | Sales Point | Scores | Percentage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bread Amount | ■ | | | ♦ | | | | 8 | 7 | 8 | 1.14 | 1.2 | 10.94 | 10.37 |
| Low Energy Consumption | ■ | □ | | | | | | 7 | 6 | 7 | 1.16 | 1.4 | 11.37 | 10.77 |
| Quite | ■ | □ | ♦ | ♦ | | | | 6 | 4 | 6 | 1.50 | 1.1 | 9.9 | 9.38 |
| Safety | | □ | ■ | ■ | | | | 9 | 8 | 9 | 1.13 | 1.1 | 11.19 | 10.60 |
| Easy To Operate | | □ | ♦ | ♦ | | | | 8 | 7 | 8 | 1.14 | 1.3 | 11.86 | 11.24 |
| Space Contraction | ♦ | ♦ | ■ | ♦ | | ■ | | 5 | 4 | 5 | 1.25 | 1.1 | 6.88 | 6.52 |
| Hygienic Food | | □ | ■ | ■ | | | | 9 | 8 | 9 | 1.12 | 1.3 | 13.10 | 12.41 |
| Reliability | ♦ | | ■ | ■ | ■ | □ | ♦ | 7 | 6 | 7 | 1.67 | 1.2 | 14.03 | 13.30 |
| Low Cost | □ | □ | ■ | ♦ | | | ■ | 9 | 7 | 9 | 1.29 | 1.4 | 16.25 | 15.40 |
| Score (Sum∑=1993.7) | 369.36 | 95.88 | 606.55 | 538.43 | 119.7 | 71.98 | 191.8 | | | | Sum 105.52 | | | |
| Percent Score (100) | 18.53 | 4.80 | 30.42 | 27.01 | 6.00 | 3.61 | 9.62 | | | | | | | |

Figure 1: House of Quality for Automated Bread Maker.

The importance of the customer viewpoint and technological perspective is shown with a bar chart.

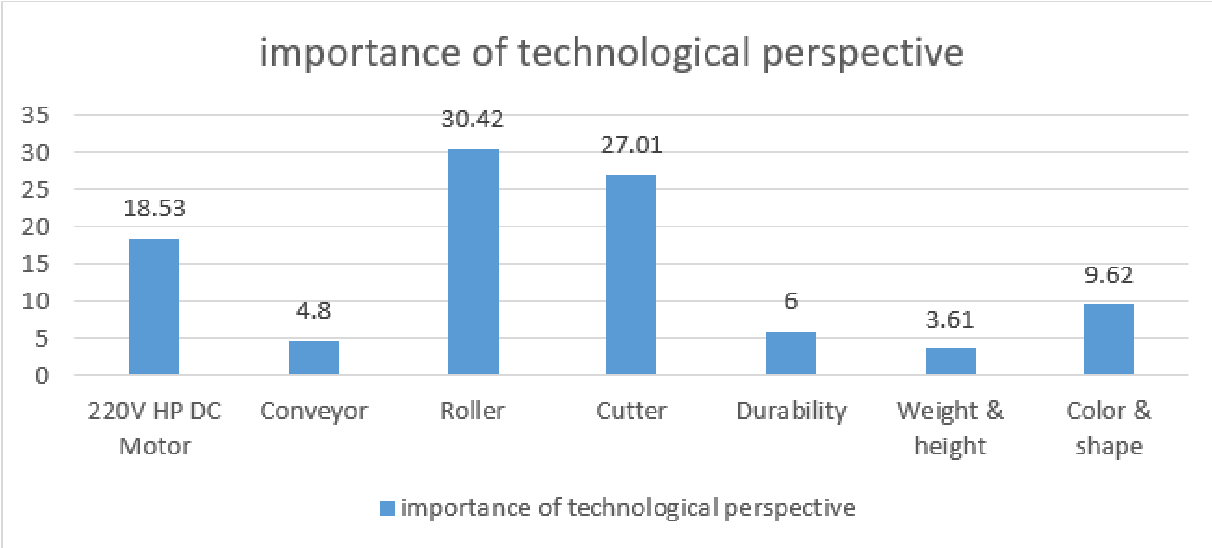



Figure 2: Bar Chart of Technological Perspective

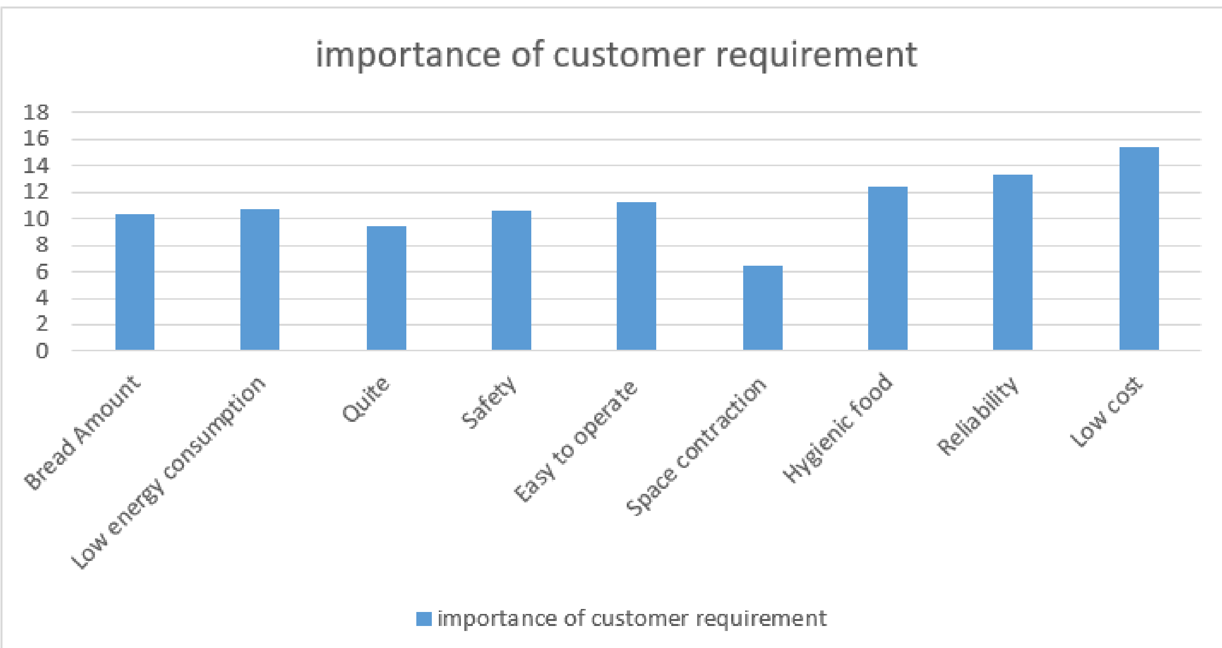



Figure 3: Bar Chart of Customer Requirement.

## 3. Implementation of Functional Decomposition on the Machine

Functional Decomposition makes it easier to understand a complicated system, its components, interactions, and interfaces and is a useful tool for providing requirements insights for both analysis and design (Sasao, 1993). Specifying each function's precise requirements and features becomes easier because the functions and processes are broken into smaller units. The partitioning and independence of the functions of localize errors and minimizes system faults. It allows the customer to view and discuss the organization in a form that can be dealt with, i.e., as a collection of functions, rather than as a continuous process.

As the machine is more complex, it has become important not only to break the design process separately into an organized task (Ullman & Bentler, 2003) and break down the design problem into more easily manageable subproblems (Pailhès et al., 2011). Functional modeling is defined as a process of decomposing the global function into sub-functions, and these authors propose a standard vocabulary known as the functional base (Pailhès et al., 2011). Functional decomposition is a term that engineers use to describe a set of steps in which they break down the overall function of a device, system, or process into its smaller parts (Hirtz et al., 2002). This is usually accomplished through thoughtful analysis and team discussions of project information, and the result is a chart that describes the problem and or solutions in increasing detail (Alam & Humayra, n.d.).

### 3.1 Black Box Model of Automated Bread Maker

Black Box Model is a robust and complete method for modeling a product's functionality (Koh & Liang, 2017). It is called the "black-box" because its internal form is deemed unknown. It allows us to focus on the greatest and the overall need for a product. The Black Box initiated a technical understanding of our product based on its inputs and outputs, known as material, energy, and information. A black box model depicts all factors and responses for the design task's primary, high-level function.

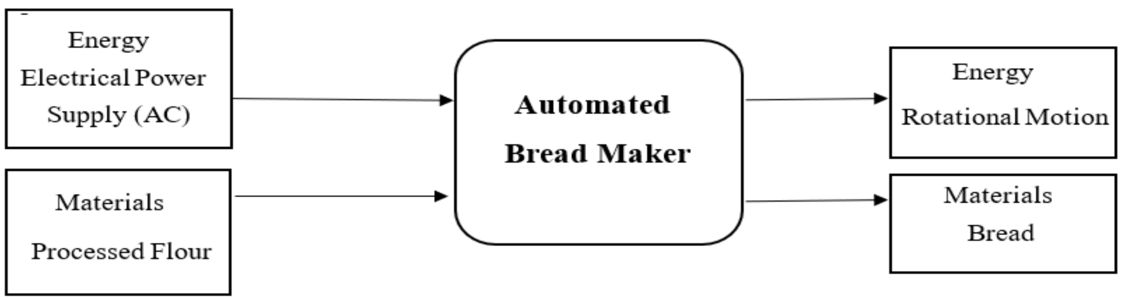



Figure 4: Black box model of Automated bread maker.

### 3.2 Component Hierarchy of Automated Bread Maker

Component Hierarchy describes the relationship between a product's content components in terms of structure and function (Alam & Humayra, n.d.). It divides the components into various major groups and subgroups and grounds the basis of a product's design perspective. The individual elements and their hierarchical relationship to each other are commonly displayed in a diagram called a functional decomposition diagram. The component hierarchy is a tree of components shown in Figure 5.

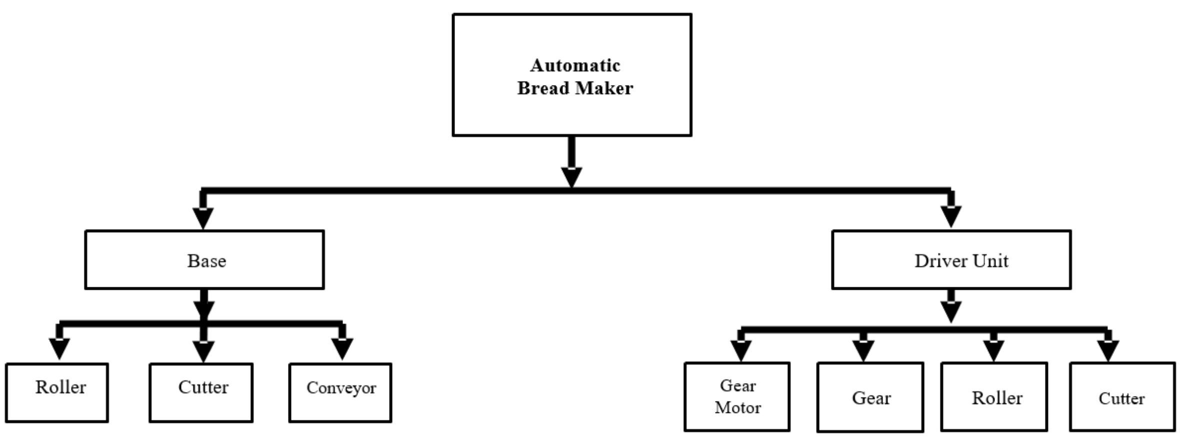



Figure 5: Component hierarchy of Automated bread maker.

### 3.3 Cluster Function Structure

The cluster function structure represents the overall mechanisms of a product and shows the relationship among them. Figure 6 has shown the cluster function structure of the machine.

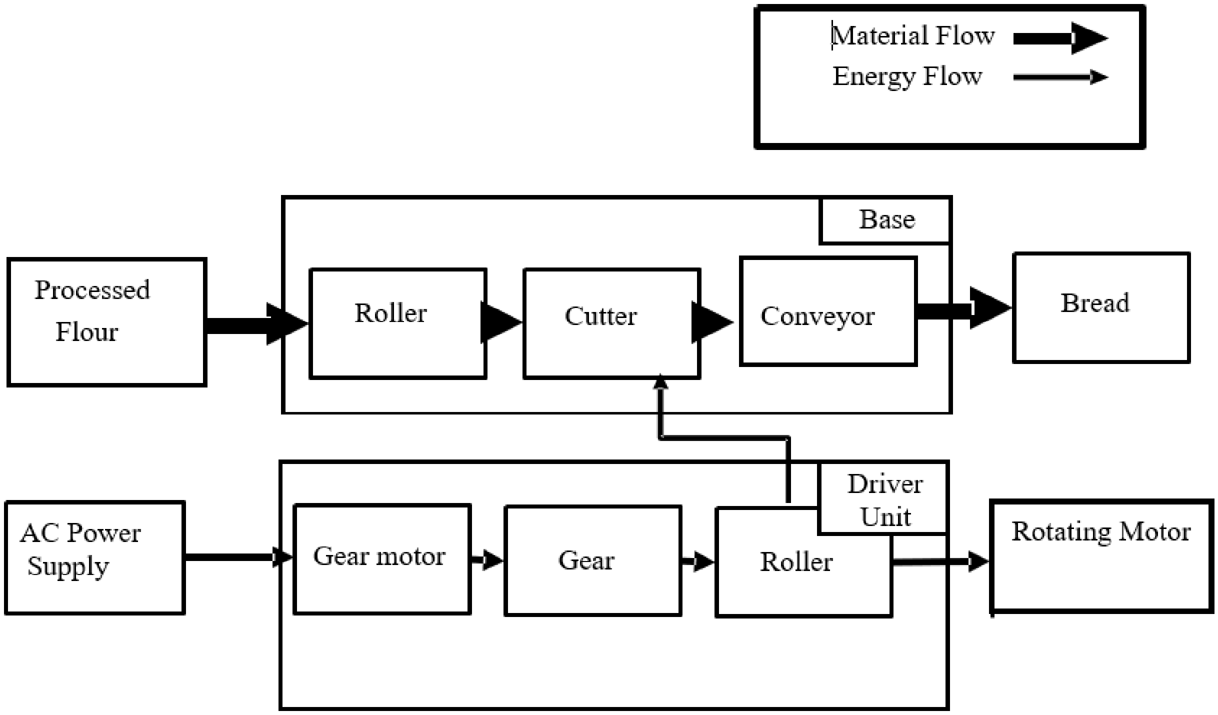



Figure 6: Cluster function structure for Automated bread maker.

## 4. Design Analysis of Automated Bread Maker

"The complexity of the design changes is multiplied when the product design involves multiple engineering disciplines. A simple change may propagate to its neighboring parts; therefore, it affects the entire product assembly. Both parts and assembly must be regenerated for a physically valid product model; simultaneously, the regenerated product model must meet the designer's expectations. When a product is being developed in a Concurrent Design and Manufacturing (CDM) environment, the design changes are usually implemented first by altering the geometry of the product represented in computer-aided design (CAD) solid models. If the solid product model is not parameterized properly, geometry changes often lead to invalid parts or assembly. The changes may yield a solid model with invalid geometric features at the part level if it is not properly parameterized. In this case, the entire product assembly is in vain. Even when individual parts of the product are regenerated correctly, parts may still penetrate to their neighboring parts or leave excessive gaps among them, if the solid model is not properly parameterized at the assembly level" (Silva & Chang, 2002).

Design Analysis is a tool for establishing an intelligent support system for designing a product through managing variety. The interpretive approach is applied to visualize the hierarchy of component interactions within a product. This process expresses the design priority and related design dimensions to provide variants of design solutions in a product. Engineers can use a design analysis to predict the physical behavior of just about any part or assembly under loading conditions (Madenci & Guven, 2015).

The automatic flour bread maker has 5 essential parts: motor, Gears, Base & body frame, Rollers, and cutter. A small conveyor is used to take the bread to the tray after cutting. Figures 7, 8, 9, 10, and 11 represent the automated bread maker's significant parts, and Figure 12 represents the machine's final state. A high-power main Motor and two low power secondary motors are used in this product. The rpm of the main motor is 180 rpm. The rpm of the secondary motor is 140 rpm. These motors are coupled with a sprocket and chain transmission system. Mechanical gears to alter the speed/torque of the motor to operate the machine. This will be assembled on the bottom side of the rollers. It will mainly use to operate the rollers.

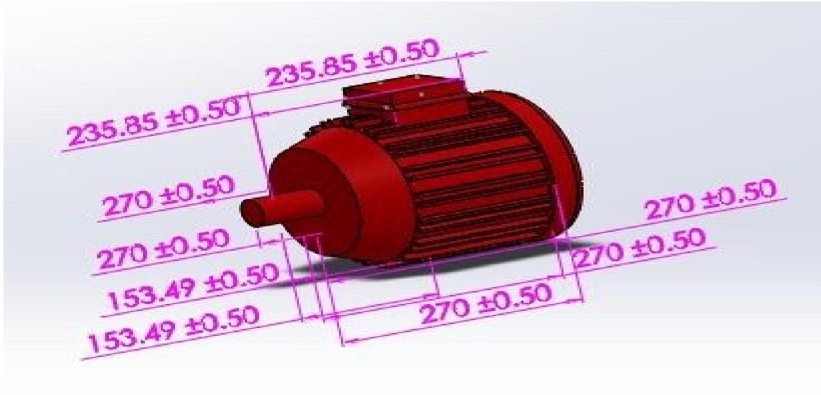



Figure 7: Gear motor.

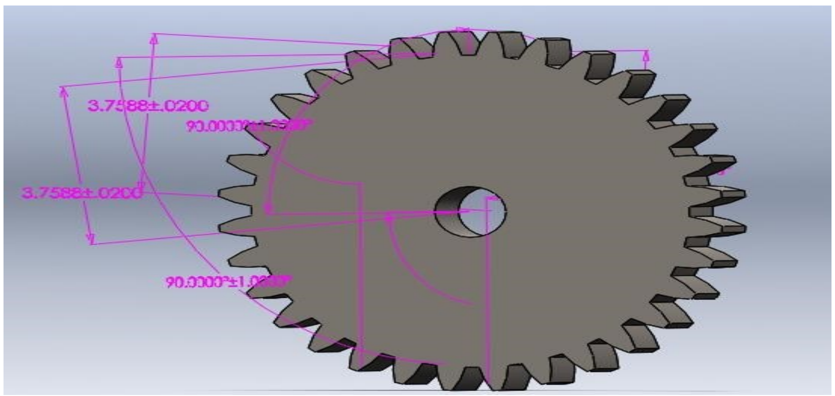



Figure 8: Gear.

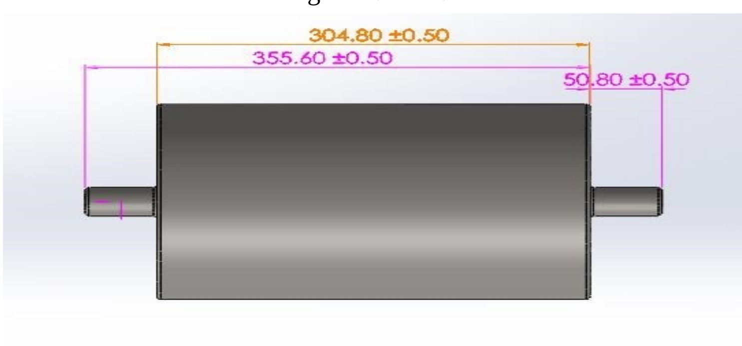



Figure 9: Roller.

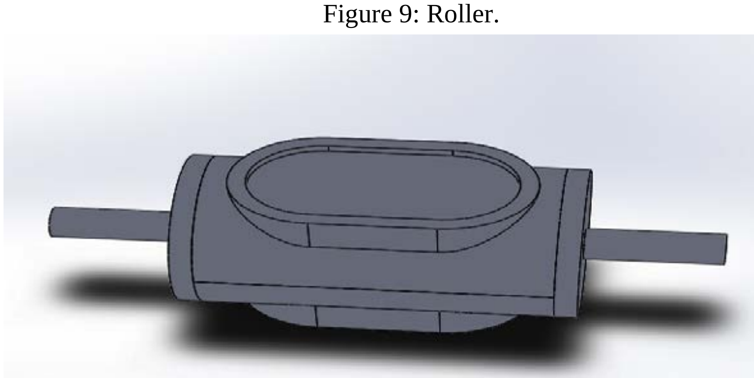


Figure 10: Cutter.

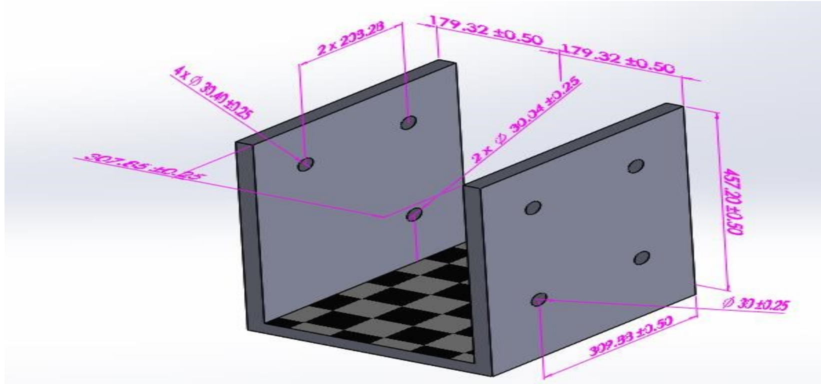



Figure 11: Base.

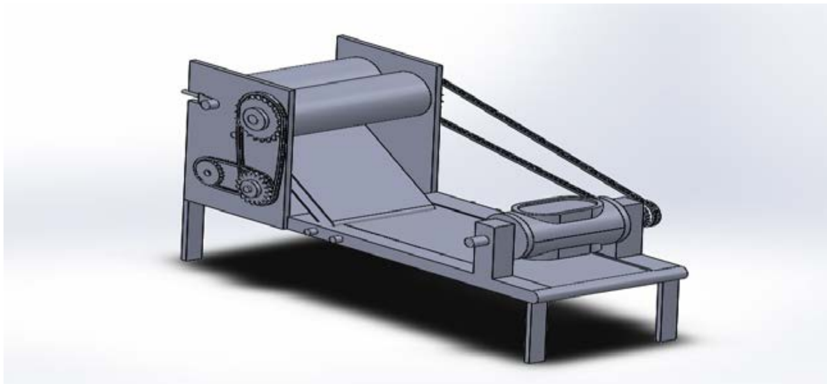


Figure 12: Final assembly of Automated Bread Maker.

### 4.1 Stress Analysis of Roller

Stress analysis is often a tool rather than a goal in itself; the goal is to design structures and artifacts that can withstand a specified load, using the minimum amount of material or that satisfies some other optimality criterion (Papalambros & Shea, 2009). The Stress analysis of the roller of this machine is shown as follows. It is clearly shown that the stress of the most portion of the roller is 3.638*10^1 N/m^2. Breaking Range: 7.696*10^4 N/m^2 to 5.773*10^4 N/m^2. Moderate Range: 5.623*10^4 N/m^2 to 2.00*10^4 N/m^2. Safe Range: 1.927*10^4 N/m^2 to 3.638*10^1 N/m^2.

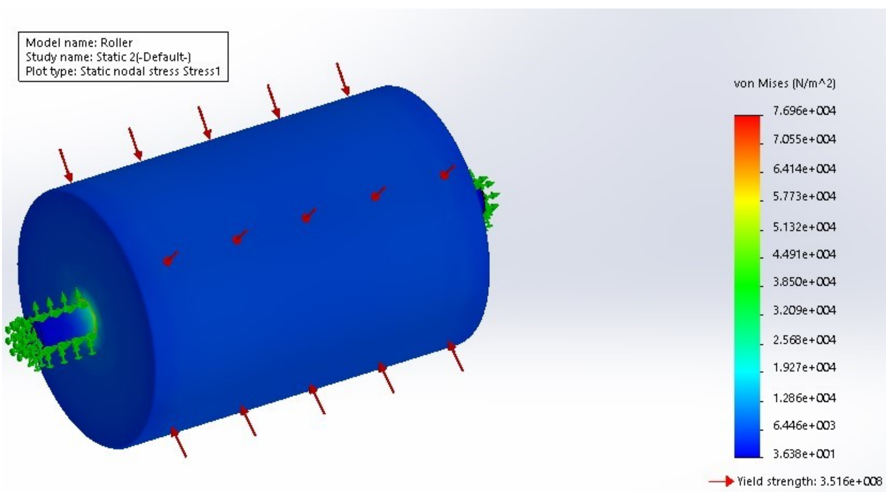



Figure 13: Stress Analysis of Roller

### 4.1 Stress Analysis of Cutter

The stress analysis of the cutter was done with the help of the Solidworks 2018 simulation. It is clearly shown that the middle part of the cutter's stress is 2.096*10^1 N/m^2. Maximum stress is generated in the welding joints between a hollow roller shape & plates of the cutter, and the amount is 3.825*10^1 N/m^2. Breaking Range: 3.134*10^1 N/m^2 to 4.171*10^1 N/m^2. Moderate Range: 1.404*10^1 N/m^2 to 3.134*10^1 N/m^2. Safe Range: 1.98*10^1 N/m^2 to 1.404*10^1 N/m^2.

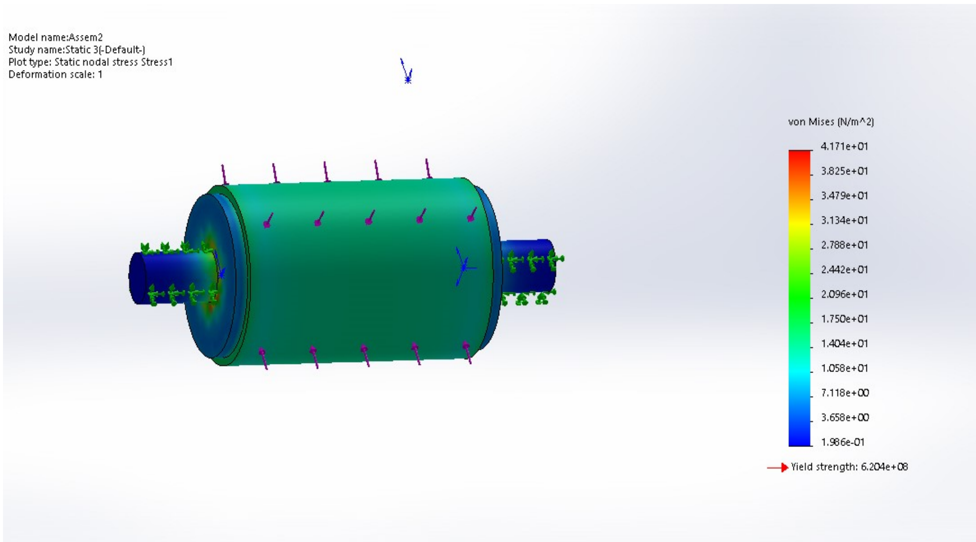



Figure 14: Stress Analysis of Cutter.

### 4.1 Stress Analysis of Base

The base's stress analysis was shown clearly that most of the cutter's stress is 2.452*10^4 N/m^2. Maximum stress is generated in the base's welding joints, and the amount is 2.234*10^5 N/m^2.

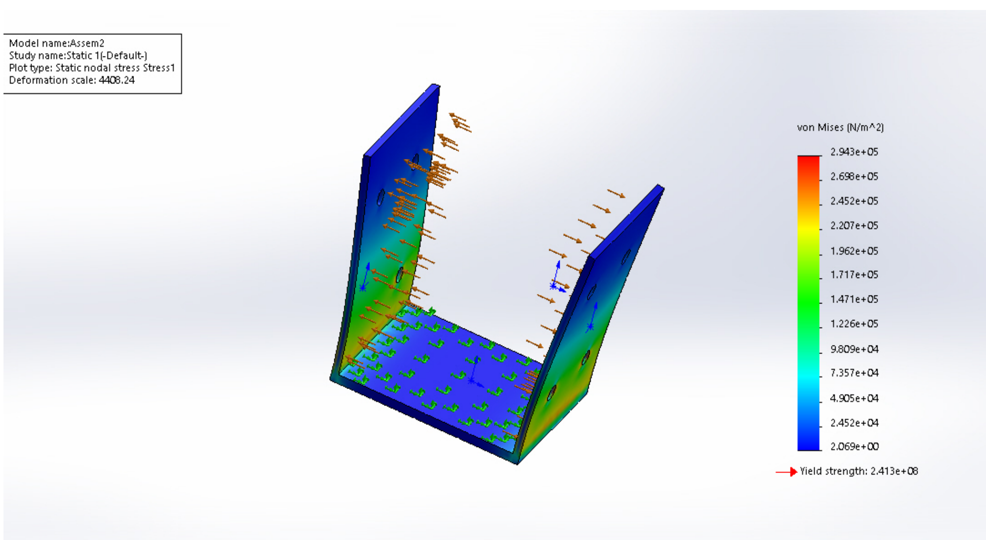



Figure 15: Stress Analysis of Base.

## 6. Conclusion and Recommendation

Emphasis must be provided towards an automated design that is more flexible and efficient in operations. Automated product design and development must be fabricated according to the voice of customers. This study aims to reflect both customers' desires while developing an automated product. The design factors were identified, which makes the automated machine more acceptable for the customers. This design can be modified, considering ergonomic analysis and adding more features for its flexibility and functionality.

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