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RESEARCH ARTICLE

DESIGN AND MANUFACTURE OF AN INDUSTRIAL AUTOMATIC ROTI (SOUTH ASIAN FLAT-BREAD) MAKER

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ABSTRACT

As a part of research, this product was consigned to design with the development with an engineering concept. At the preliminary stage, the industrial automatic flour bread maker machine was chosen the group, and accordingly, it was approved by the respected faculty. Bangladesh is not only a densely populated country but also a fastest developing country in the world. For saving precious time and capturing large market of this sub-continent, it is important to finish research on product development and market analysis accurately. Restaurants in busy area, people wait in a queue to have their ordered Roti (a south Asian bread with round and flat shape) for the lengthy process of Roti making as they are made by human hand. Industrial automatic Roti maker will help people a lot to make Roti in a very simple way within a short time. This machine can rapidly use in restaurants, canteens, and hostels to serve bread to the customers timely. It reduces the working effort of the chef as well. In this project, it was offered with progressed design for the automatic Roti maker machine along with supplementary features like a 'hand controlled wheel' to operate without power source for emergency purpose, safety box was used for safeties. The innovative design reduces the cost of the machine more than before. This project aims to learn with close observation about the industrial automatic Roti maker machine and its working functions. It was also tested the efficiency of Roti making process considering cost and time factors. The main purpose was to reduce the bread-making effort along with maintaining a better shape and size of Roti to illustrate a simple system model. All parts of this machine are structured by 'Solid Works-2015' software.

KEYWORDS

Cost function; Manufacturing; Solid works; House of quality; market analysis

1. INTRODUCTION

The industrial Roti Maker machine is an effective system which has economically balanced mechanism. The setup consumes less time where restaurant has high level of demand from customers. Huge amount of Roti can be produced in a short time automatically. A restaurant can easily serve customers who wait in a queue for a long time. It was noticed that the queue of customers is made because of the process of Roti making is so long. On the other hand people refuse to take Roti if it is not in proper rounded shape. Automatic Roti maker machine is so beneficial to produce Roti with proper shape in a very easy way. It is only need to produce flour dough and put it in specific place of the machine. The rest process of Roti making are done by Roti maker. First of all the rollers pressed the dough and produce a dough sheet. A cutter automatically cut dough sheet roundly for the proper Shape and size of Roti. Then a pinch notch helps the cut dough to separate from the dough sheet and the Roti is dropped slowly on the conveyor which take away the final product to finish the Roti making process. A motor is used to rotate rollers and cutter to continue the process repeatedly.

1.1 Benefits Of The Product

- Consume less time to produce huge pieces of Roti than the manual process.
- Proper Shape and size are maintained.
- Increases the convenience of Roti manufacturer.
- Increases satisfaction of customers and employee.
- To ensure work environment safe, machine parts are covered by safety box.
- Manufacturing cost of this product is less than the products which are available in market.

1.2 Major components of this product

The major components of the industrial automatic flour bread maker machine are as follows:

- DC motor
- Base & body frame
- Rollers
- Cutter
- Gears
- Conveyor

This machine has come in various sizes. and roughly weighs about (25-30)

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kg. Normally 220V 1HP DC motor provides the electricity supply for the motor.

1.3 Industrial automatic flour bread machine manufacturer in Bangladesh

In Bangladesh, there are very few automatic Roti maker machine production factories. Some remarkable local shops at 'Dholai Khal' near 'Shadar Ghat' produces automatic flour bread machine costing around 95.24 USD with an installation fee of 95.24 USD ~ 142.86 USD. Although it is cheaper than the imported one, it includes heavy weight and vast use of corrosion resistant materials and no safety which eventually makes the product purchase in vain. The use of mild steel and cast iron for the whole machine is very common in Bangladesh which is eventually non-long lasting. If this design can be developed, the demand for automatic flour bread maker machines will undoubtedly increase. High manufacturing cost is also a reason which is hindering its popularity. These factors have led us to analyze this product and develop a better design to increase its availability and acceptability to the general people.

2. Market Analysis

2.1 Customer survey areas

The automatic Roti maker is a product which is related to the food content. As primary research, a survey was carried out in several restaurants where huge amount of Roti are produced. They are situated in areas like Mirpur(1, 2, 10), Shaymoli, Agargaon, and Farmgate, Sahabag and so on. Our interaction with the retailers enabled us to get raw data for the survey. The customers of the end product such as hotel manager, owner of a restaurant, large family where produce large amount of flour bread in a day. About Roti making facilities were questioned to understand their attitude towards the particular product (Taherdoost, 2016). The questionnaire was mainly based on the following categories:-

- Problems of making flour bread with hand.
- Disadvantage of the machine if they use this machine before.
- Time duration.
- Accuracy of the bread.
- Safety.

In total, 78 people were communicated to get sufficient data for the survey (Roopa and Rani, 2012).

2.2 Summary of Customer Survey Chart

From this survey, it can be seen that most demandable feathers are 'Easy to operate', safety issue and obviously hygienic food quality. Most demandable feathers are considered at the time of product designing.

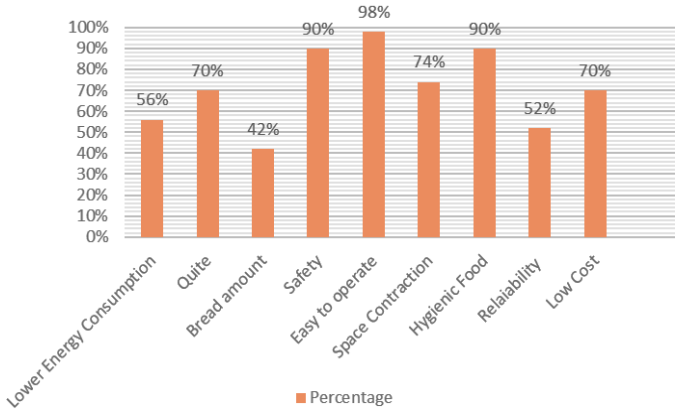


Figure 1: Summary of Customer Survey Chart of automatic flour bread maker

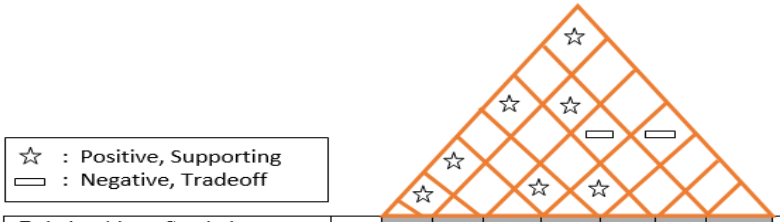
2.3 Quality Function Deployment

2.3.1 House of Quality

House of Quality is a set of matrices which contains the requirements and the detailed information to achieve those requirements (how's, how much). It is a table that connects the dots between the Voice of the Engineers and the Voice of the Customers. These Customer's requirements can be converts to the technical requirements (Park and Kim, 1998; Vairaktarakis, 1999).

The following table consists of the House of Quality dome of automatic flour bread maker. The legends for the House of Quality are as follows:

Table 1: Automatic Roti maker's House of Quality



Major sales point: 1.4
Minor sales point: 1.1

Relationship	Symbol	score
Strong	+	9
Moderate	*	4
Weak	^	1
No-relationship	Blank	0

Customers' Requirements	Product Requirements	1HP DC Motor (220V)	Conveyor	Roller	Cutter	Durability	Weight & Height	Fixed & Operating Cost	Importance(10)	We Today (10)	Target in Future (10)	Company A (10)	Company B (10)	Improvement Factor	Sales Point	Importance Rating	Percent Score (100)
Amount of Roti production		+			*				8	8	9	9	8	1.13	1.3	11.75	11.10
Safety			^	+	+				9	8	9	9	9	1.13	1.1	11.19	10.60
Quite		+	^	*	*				8	7	8	7	8	1.14	1.1	10.03	09.50
Energy Consumption		+	^						7	7	8	8	7	1.14	1.4	11.17	10.50
Easy to operate			^	*	*				8	8	9	9	8	1.13	1.3	11.75	11.10
Hygienic Food			^	+	+				9	9	9	9	9	1.00	1.3	11.70	11.00
Low Cost		*	^	+	*			+	9	7	9	9	8	1.29	1.4	16.25	15.40
Space Contraction		*	*	+	*		+		6	5	6	7	8	1.20	1.1	07.92	07.50
Reliability		*		+	+	+	^	*	7	6	7	8	7	1.67	1.2	14.03	13.30
																Sum= 105.79	Sum= 100
Score (Sum= 2050.20)		424.70	98.10	602.60	532.50	119.70	80.80	191.80									
Percent Score (100)		20.72	4.78	29.39	25.97	5.84	3.94	9.36									

2.4 Function

A predictable and balanced link between the available input and the intended output of a manufacturing process is called a function. The product function is planned and expected functional representation of the product (Eckert et al., 2012).

2.4.1 Sub-function

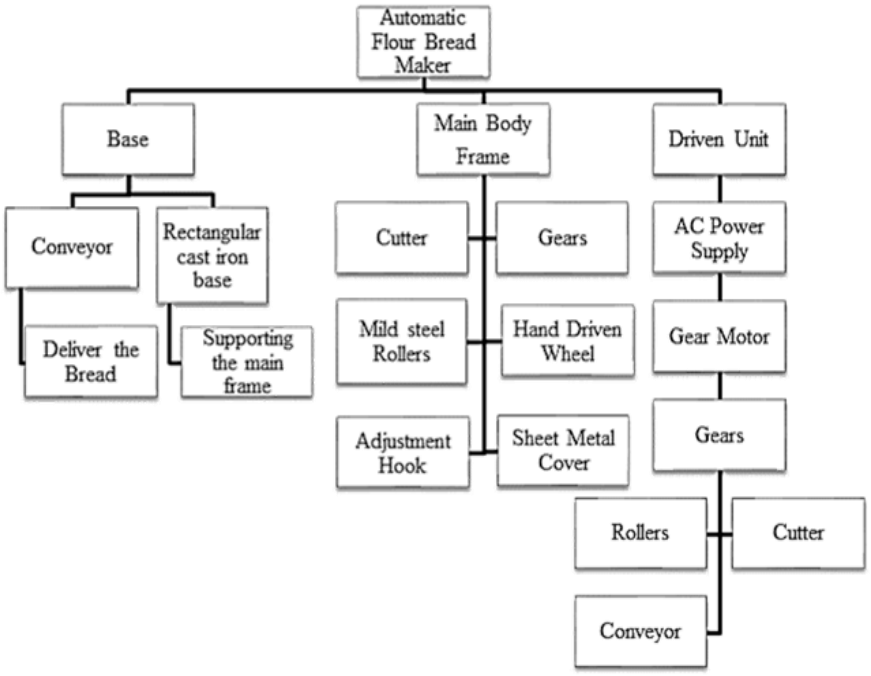


Figure 2: Functional decomposition of Automatic Roti Maker

Components which are used for functional deployment of product are called sub-function (Eckert et al., 2012). A complete function must be segmented into distinct sub-functions. Typically, the input-output relationship or a constraint guides the overall function. To develop a functional description of a product, a fundamental strategy is to systematically decompose the overall function into sub-functions. The overall product function is accomplished when all requirements are satisfied. 'Functional trees' can be structured for better representation of product function.

2.4.2 Black Box

The model is known as "black-box" because the internal structure is supposed to unknown. This Model constructs overall methodology of product's functionality with its robust behavior. It helps to identify the technical mechanisms of a product considering the input and output system (Karlsson et al., 1998). Actually the model is the combinational representation of three entities (energy, information and material) of the product.

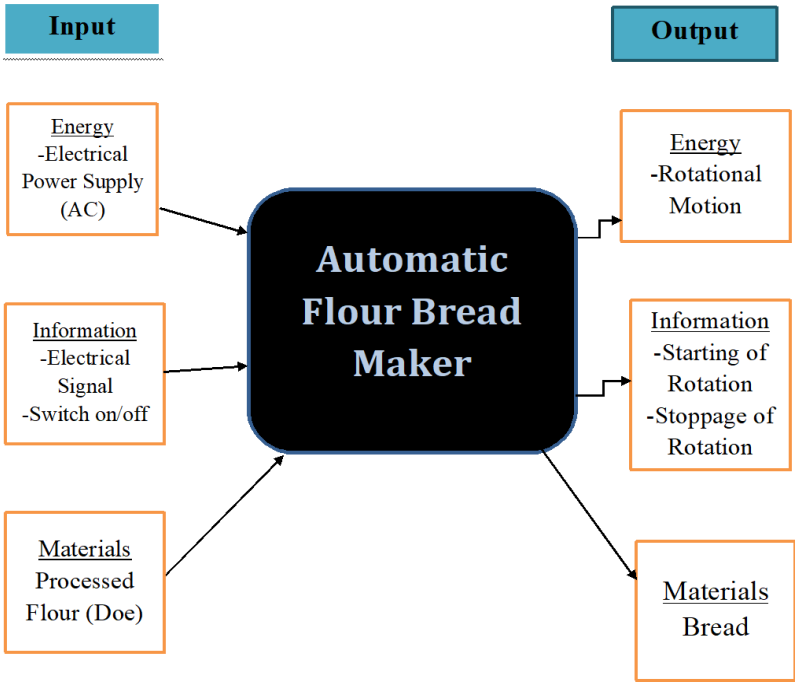


Figure 3: Black box model of automatic Roti maker

3. Specification and Design Analysis

3.1 Specifications

Automatic Roti maker is manufactured with 5 basic components. Gears, Motor, structural frame with base, Rollers and bread cutter. A short length conveyor attached to main structure to convey final product after cutting operation. Finally Roti are accumulated in tray or something like that which can be placed at the end of the conveyor.

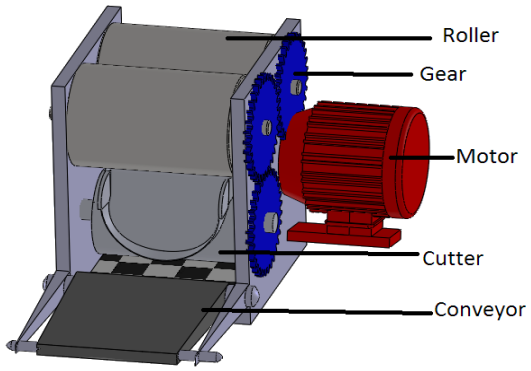


Figure 4: Automatic Roti maker

3.1.1 Motor

A 1HP 'DC Gear Motor' was used. It can be an AC or DC motor coupled with a gearbox. Mechanical gears are attached together to transmit the torque/speed from the motor to the main functional structure (Roller and Cutter). Motor parts are assembled in the bottom of the right side roller's gear to transmit rotating power.

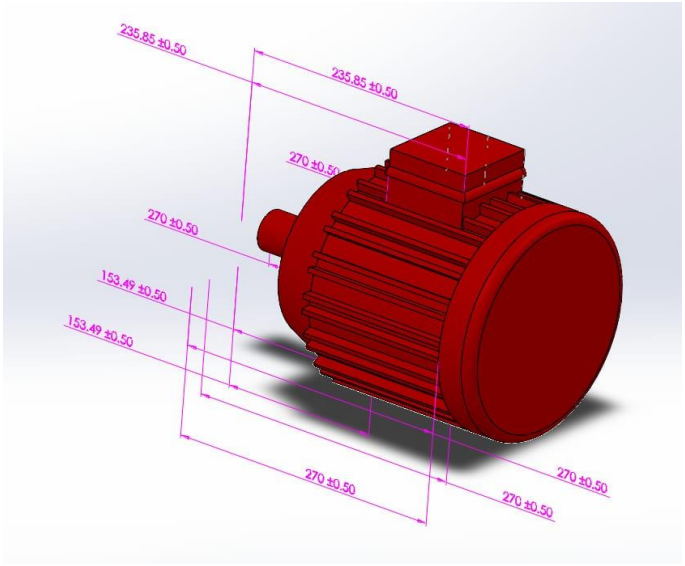
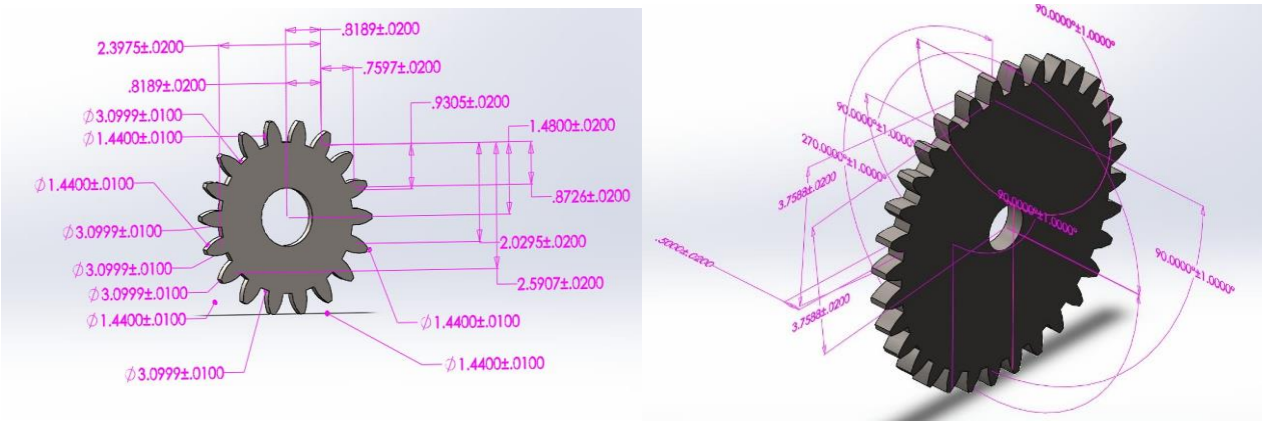


Figure 5: Gear motor

3.1.2 Gear



(a) (b)

Figure 6: Gear (a) Front view (b) side view

Two different sizes of gears will be used,

Larger gear (3 pieces) number of teeth : 32
Pressure angle : 20°
Diametral pitch : 4mm

Smaller gear (1 pieces) number of teeth : 18
Pressure angle : 20°
Diametral pitch : 6

For both gears width of face is '0.5 inch'. These 4 gears will be used to transmit electric power from motor to the roller.

3.1.3 Roller

Two mild steel rollers will be used in this machine to resize the flour pest for making bread. This Rollers make the flour pest a thin sheet of flour.

The dimensions of roller will be,

Length : 304.80 mm

Diameter : 203.20 mm

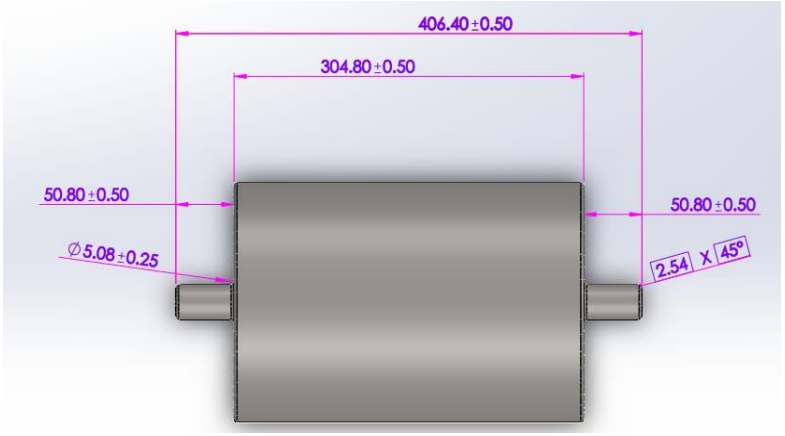


Figure 7: Roller

3.1.4 Cutter

A Mild steel cutter will be used to cut the thin flour sheet to give the actual size of bread. This cutter will be installed just below the rollers. All dimensions are in inch scale.

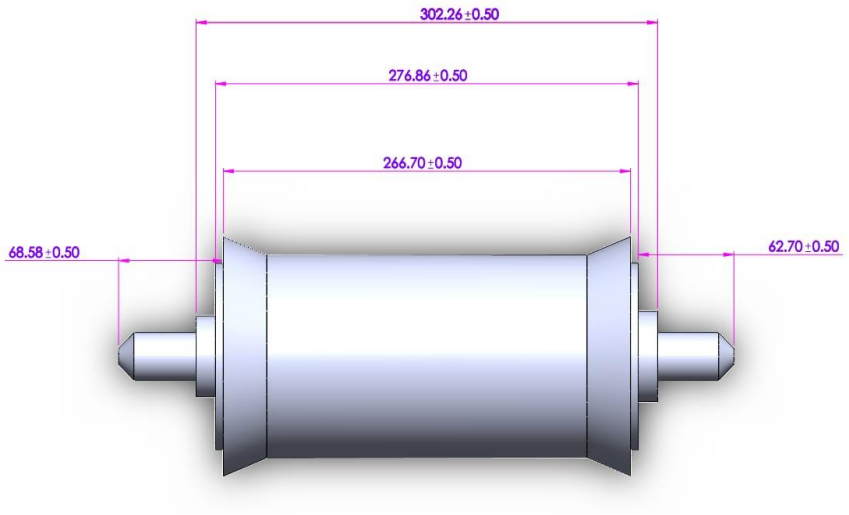


Figure 8: Cutter

3.1.5 Base

A Mild Steel base is used to support the main parts of the machine. It has 2 boundaries which support rollers & motor. The base has 7 holes to install the roller, cutter, gear & motor parts. All dimensions are in mm scale.

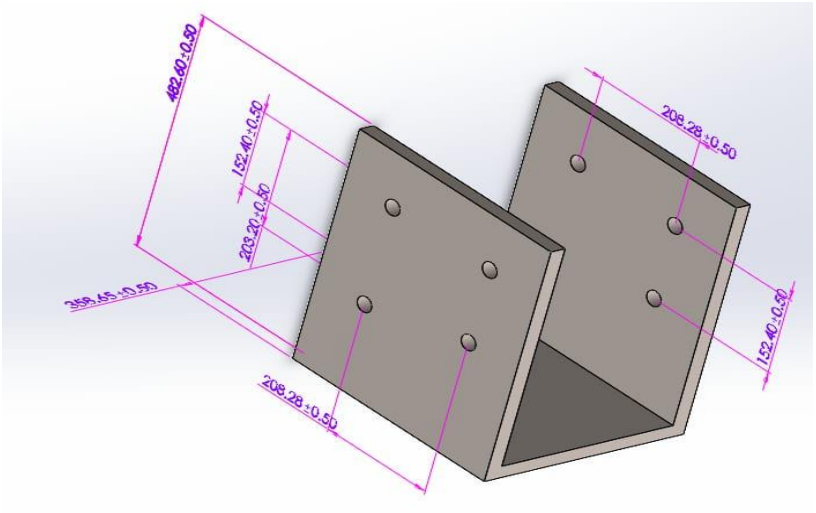


Figure 9: Base

3.2 Design Analysis

Design analysis upgrades the quality of a product design and makes manufacturing process easy. Design analysis point out product limitations and help the user to solve those limitations make a better product which overcome the limitations (Tovey, 1997). It also minimizes the product manufacturing cost (Twerski and Henderson, 1998).

3.2.1 Designs for Manufacturability (DFM) & Designs for Assembly (DFA)

Proactively producing products maximize all manufacturing processes including assembly, fabrication, procurement, testing, delivery, shipping, service and repair as well as to assure the greatest cost, quality, dependability, regulatory compliance, safety, time-to-market, and customer satisfaction (Bathaia et al., 2018; Boothroyd, 1987). The product is made of such a material which can be machined easily. The product is made following the least cost so that the customers can afford the product easily. Steps of assembling are given below:

3.2.2 Larger parts first assembled

For assembling largest part of the machine is selected. 'The base' is the largest part of this machine. So according to guideline, it should be set first. This is exactly what happened. The welding and drilling of the base was completed first.

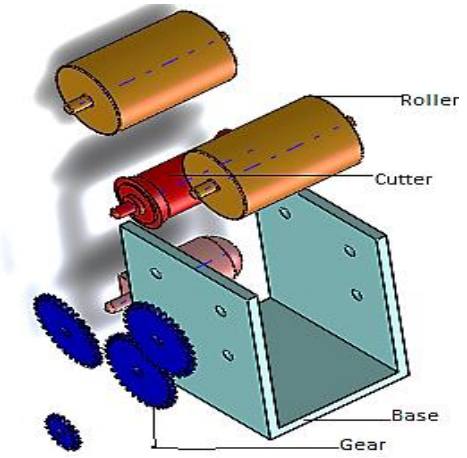


Figure 10: Assemble from top

3.2.3 Minimized Parts Counts

Minimum Parts were used in the Product. There Could Be More Screws with Threads To Complete The System. But the screws were reduced in such a way that now by only performing welding will be enough to execute the operation of the machine.

3.2.4 Design for cost (DFC)

Design for cost is a vital part of design analysis. One of the main goals of this guidelines are followed, it is very easy to reduce cost and make a more effective product design is reducing cost. DFC guides the designer to design in a way to reduce the cost. Increased cost means less sale and further break-even point of the product (Geiger and Dilts, 1996).

3.2.1.1 Use of Low-Cost Material

Only Mild Steel plate will be used to make the machine's base. Mild Steel also will be used in making the Rollers & Cutter. It is a comparatively low-cost material than stainless steel. But its characteristics are good enough to meet the product requirements (Manshadi et al., 2007). This step took a large part in cost reduction.

3.2.1.2 Base was given minimum thickness

Thicker base means more cost. So, it was given a minimum thickness which is compulsory for the load. Only 20 mm thick Mild Steel Plate was used to fabricate the walls.

3.2.1.3 Design for reliability (DFR)

Reliability represents the probability that will perform specified function of a product (Lima and Kubota, 2022) -

a) At specified working condition: The basic working conditions involves the following requirements:

- Roller should be used at the speed adjustable to the motor.
- Roller & Cutter must be cleaned after every time use.
- Motor should be operated at specified voltage & current.

b) Specified function: the main purpose and function of this machine is to make bread at desirable thickness.

c) Economic survival time: the economic survival time of the product is estimated to be 3-4 years.

3.2.1.4 Green designing for the product

- Reuse: If the bread won't get out perfectly shaped then the bread can be used again as dough.
- Repair: Separate parts of this whole system are repairable and replaceable.
- Reconditioning: This product can be reconditioned without facing too many difficulties.
- Recycle: Parts of this product can be recycled.

3.2.1.5 Design for safety (DFS)

Design for Safety offers a set of tools and approaches for incorporating safety into the design of complex systems (Coulibaly et al., 2008). It describes how to design for optimal safety while minimizing the likelihood of accidents (Shariff and Leong, 2009). A cover will be used on the gear meshing side of the machine for increasing the safety.

3.3 Stress Analysis

In this section stress analysis will be performed on the critical parts to ensure the safety of the design. Stress, Deformation, Strain and Factor of Safety was determined for every critical part (Rubinstein and Shapiro, 1990; Murray et al., 2012). This section is completed with the help of SolidWorks 2015. All the results are shown graphically.

3.3.1 Roller

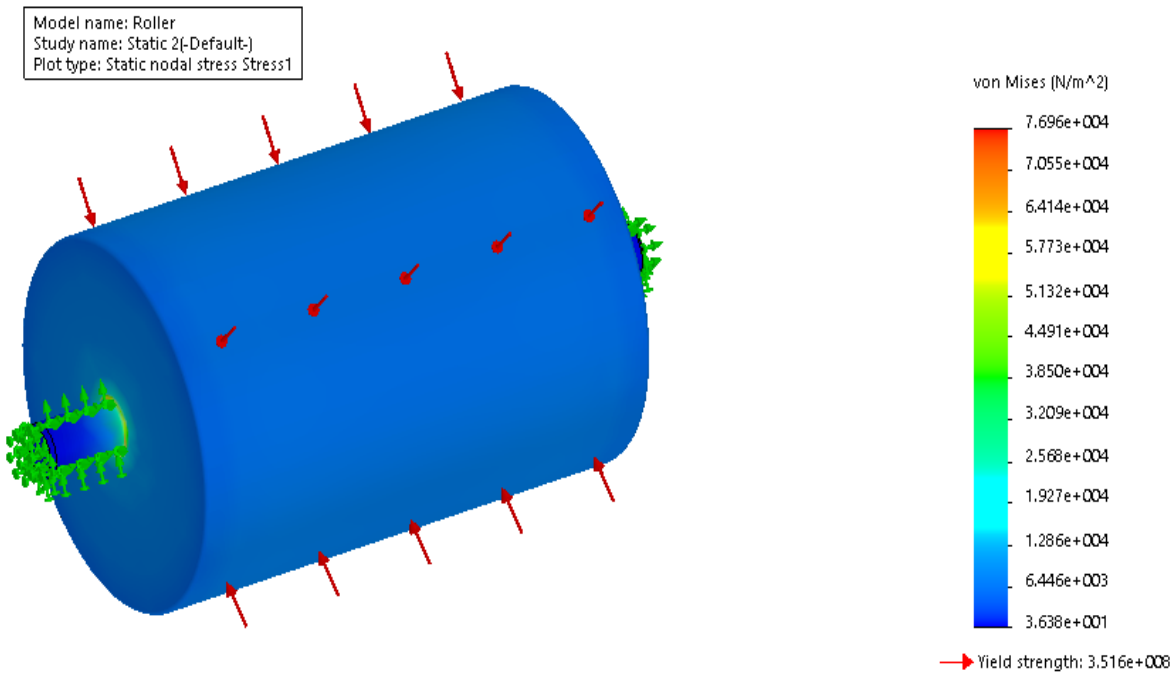


Figure 11: Stress analysis of Roller

Breaking range : 7.696×104Nm-2 to 5.773×104Nm-2

Moderate range : 5.623×104Nm-2 to 2.00×104Nm-2

Safe range : 1.927×104Nm-2 to 3.638×104Nm-2

Roller's stresses are analyzed which is clearly shown in figure-11 that most portion of roller can contain 3.638×101 Nm-2 stress.

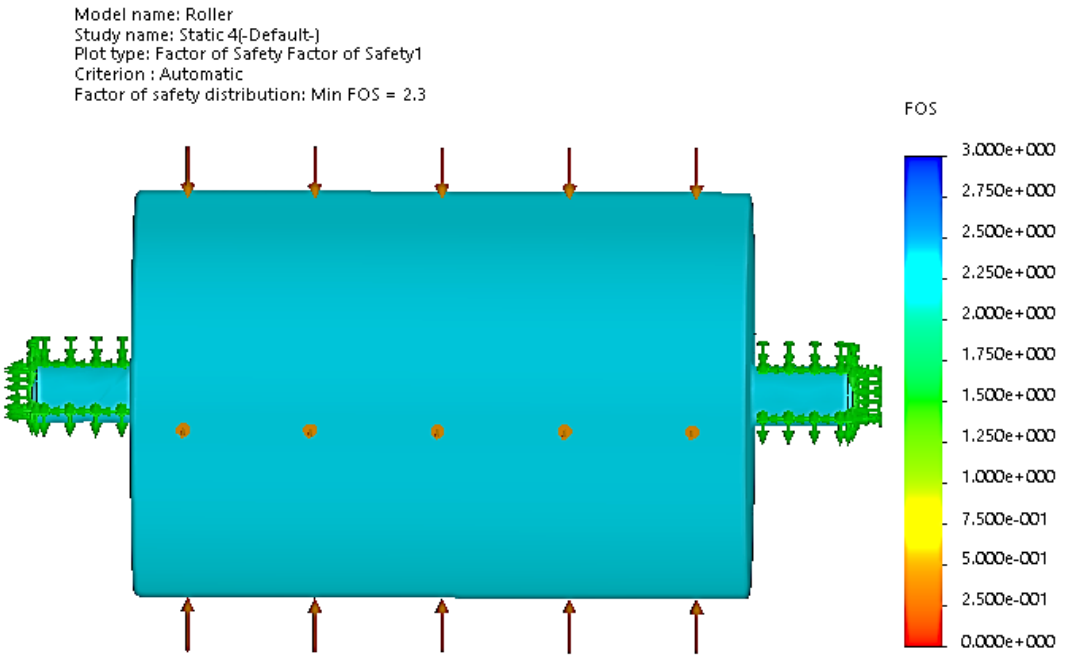


Figure 12: Factor of Safety of Roller

Breaking Range : 0.00 to 0.65

Moderate Range : 0.66 to 2

Safe range : 2.25 to 3

Factor of safety is a crucial part. A factor of safety (FoS), sometimes known as a safety factor (SF), is a term used in engineering to describe how much stronger a system is than the necessity for the specified load. Numerous analyses in-depth are frequently used to calculate safety factors (Wu et al., 2012). Very low (FS~1) Factor of Safety gives a warning that the part will fail in extreme conditions. For this part, the factor of safety is calculated 2.3. This is the minimum factor of safety for this part which indicates that the design is risk free.

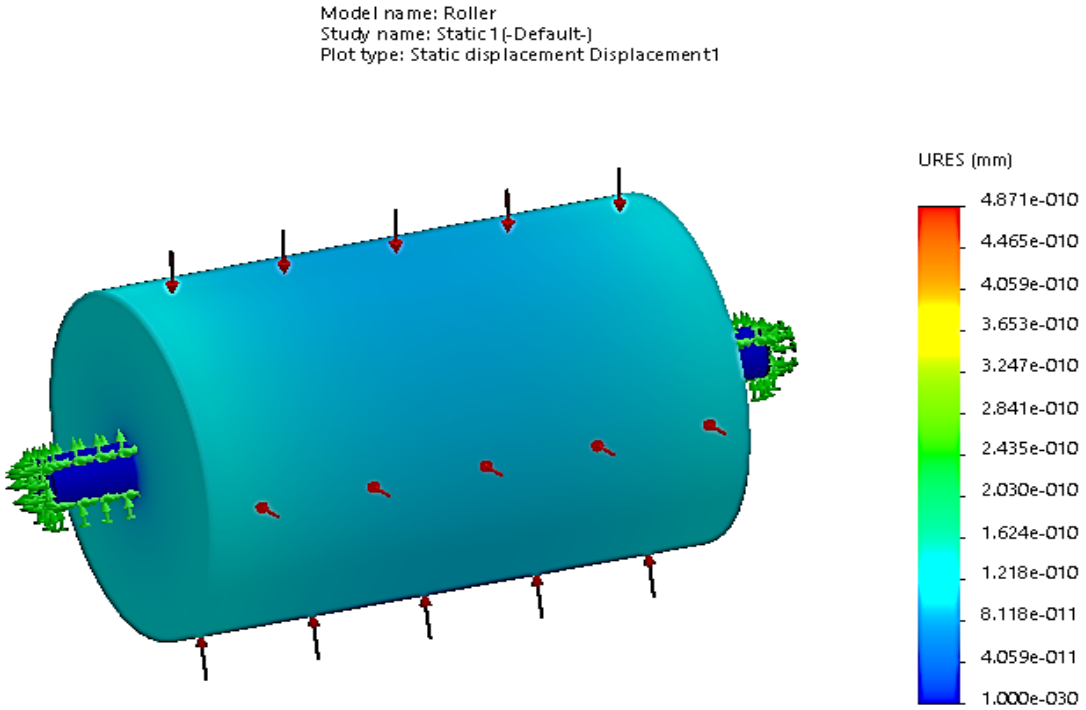


Figure 13: Maximum Displacement of Roller

Breaking Range : 4.871×10-10mm to 4.00××10-10mm

Moderate Range : 3.99×10-10mm to 1.624××10-10mm

Safe range : 1.623×10-10mm to 1.0××10-30mm

Solidworks simulation gives precise values of deforming bodies. The red zone is the part where maximum deformation will occur. The calculation says that the safe jone of deformation amount is 1.218×10^-10 mm.

3.3.2 Cutter

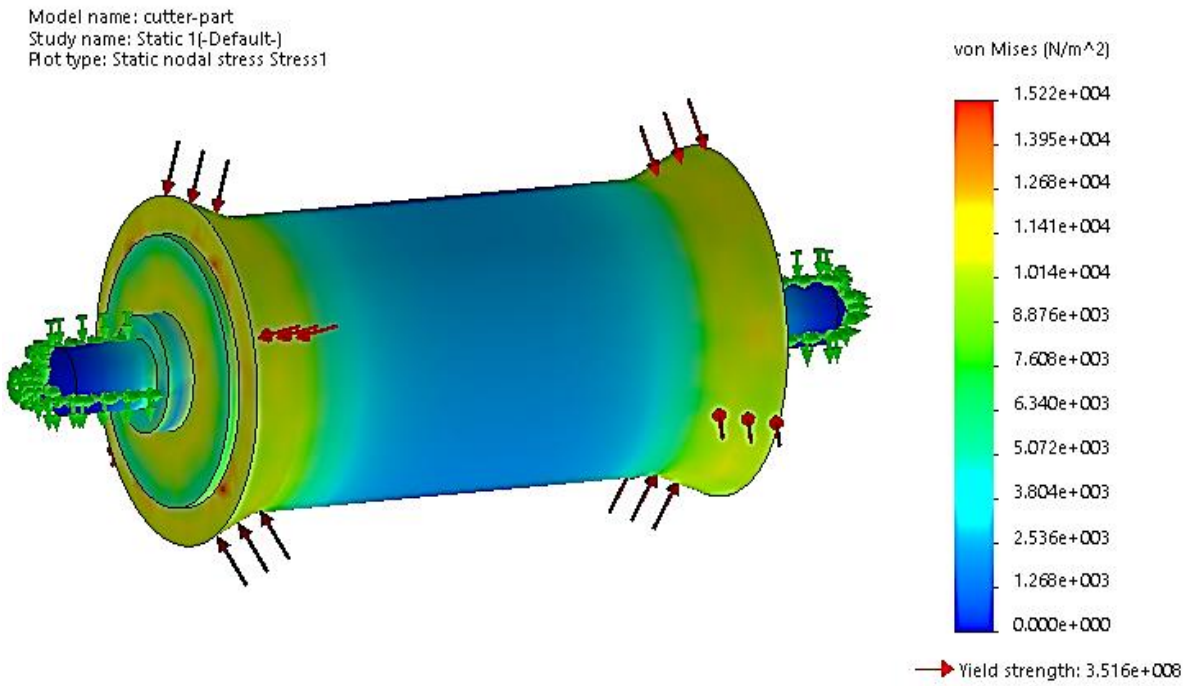


Figure 14: Stress of Cutter

Breaking Range : 1.141×104 Nm-2 to 1.522×104 Nm-2

Moderate Range : 5.072×103 Nm-2 to 1.140×104 Nm-2

Safe range : 0.00 Nm-2 to 5.071×103 Nm-2

The design of cutter is considered for stress analysis which was done with SolidWorks 2015 'simulation' system. It is shown clearly in figure-14 that middle portion of cutter can contain 2.536×103 Nm-2. Maximum stresses are generated in the cutting edge of the cutter and the amount is 1.268×104 Nm-2.

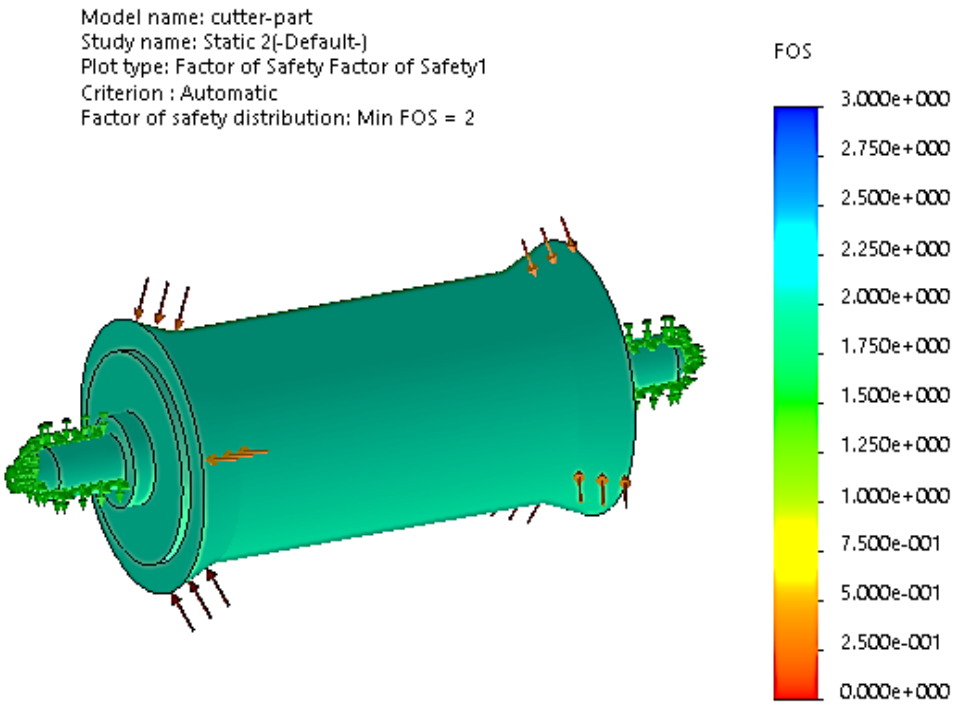


Figure 15: Factor of safety of Cutter

Breaking Range : 0.00 to 0.75

Moderate Range : 0.76 to 2.00

Safe range : 2.1 to 3.0

Figure 15 shows the Factor of Safety for cutter. It is a crucial term for a product. Very low (FS~1) Factor of Safety gives a warning that the part will fail in extreme conditions (Leong and Shariff, 2008; Kirezieva et al., 2013). For this part, the Factor of Safety is calculated 2.3. This is the minimum factor of safety for this part which indicates that the design is risk free.

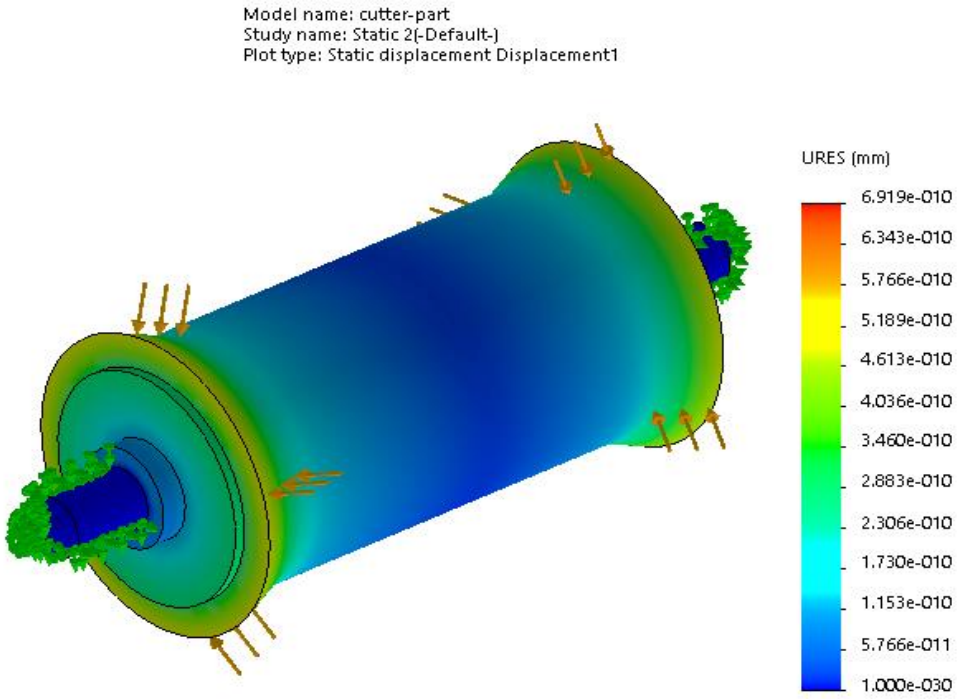


Figure 16: Maximum Deformation of Cutter

Breaking Range : 6.919×10-10 mm to 5.235×10-10 mm

Moderate Range : 5.234×10-10 mm to 2.282×10-10 mm

Safe range : 2.281×10-10 mm to 1×10-30 mm

In this part, the maximum deformation of the cutter is calculated and shown graphically. Solidworks simulation gives precise values of deforming bodies. The calculation says that in the middle part of cutter the deformation amount is 5.766×10-11 mm. And at the cutting edge, the deformation amount is 5.866×10-10mm. It is a pretty decent amount of deformation which will not compromise its functionality.

3.3.3 Base

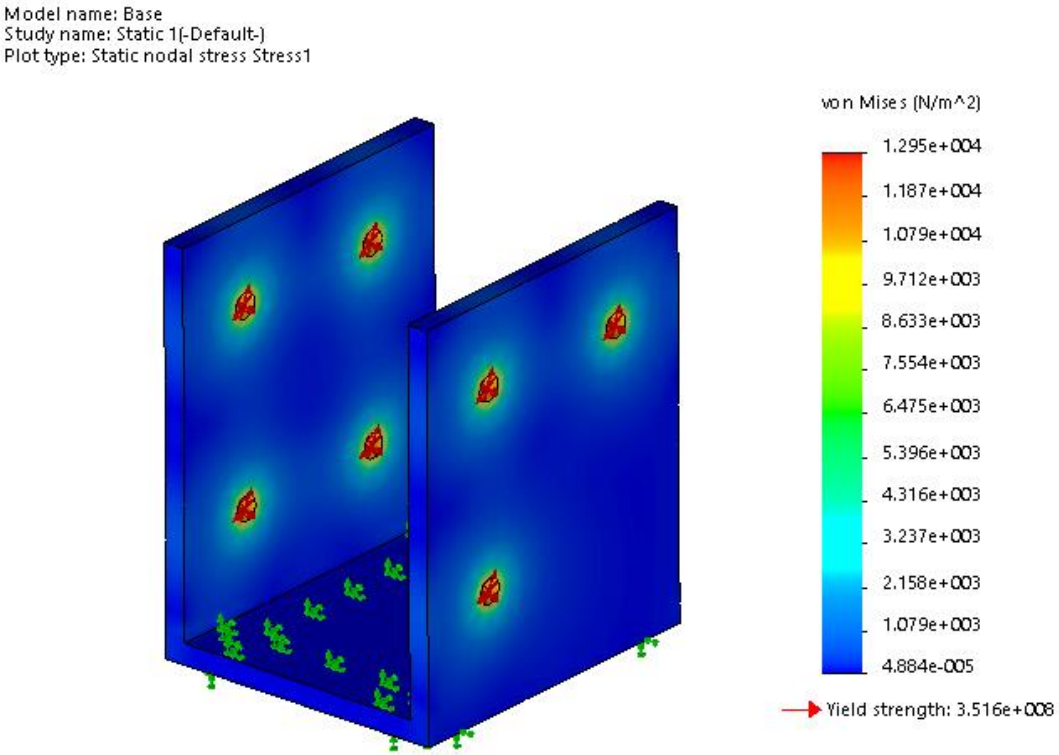


Figure 17: Stress of The Base

The design of base is considered for stress analysis which was done with SolidWorks 2015 'simulation' system. It is shown clearly in figure-14 that middle portion of base can contain 4.884×10-5 Nm-2. The holes which are created in base body to hold the total system are under maximum stress and that is about 9.912×103 Nm-2.

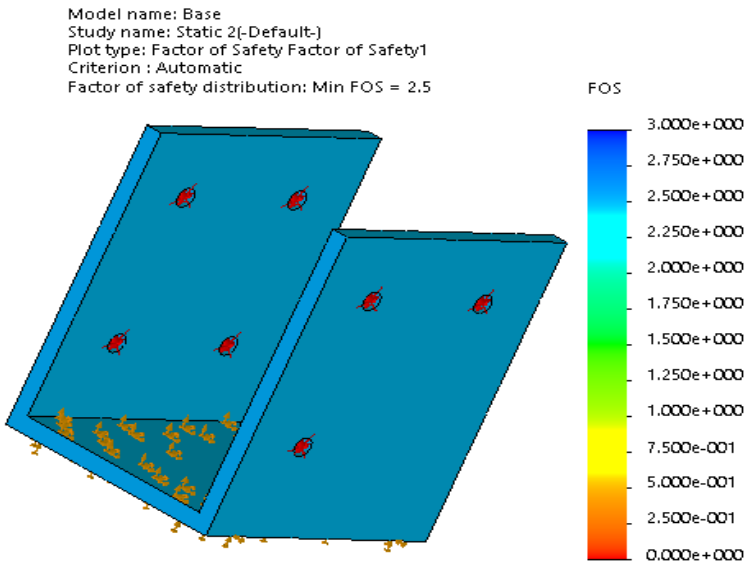


Figure 18: Factor of safety of base

Breaking Range : 0.00 to 0.75

Moderate Range : 0.76 to 2.00

Safe range : 2.00 to 3.00

Figure 18 shows the Factor of Safety for base. It is a crucial term for a product. Very low (FS~1) Factor of Safety gives a warning that the part will fail in extreme conditions. For this part, the Factor of Safety is calculated 2.4. This is the minimum factor of safety for this part which indicates that the design is risk free (Burdekin, 2007).

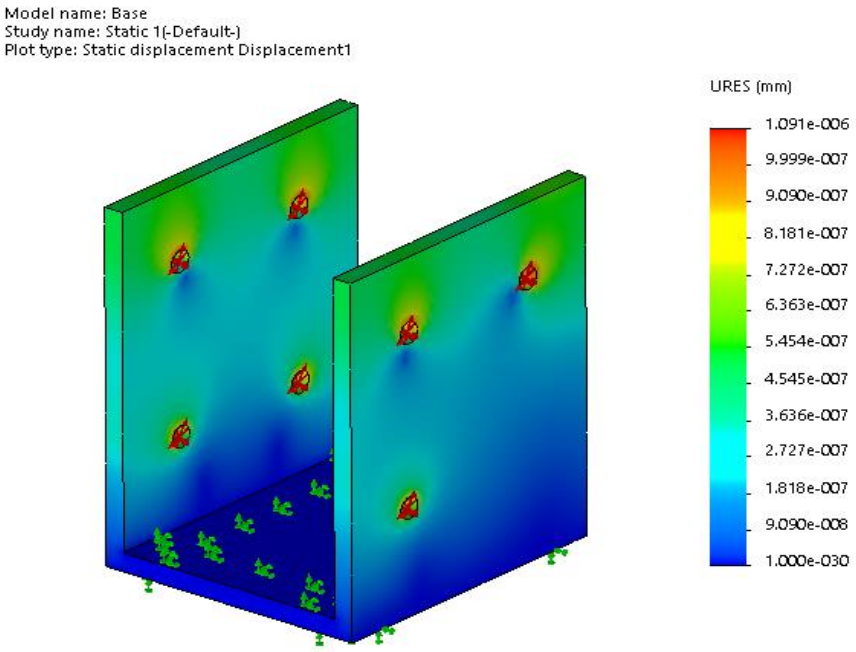


Figure 19: Maximum Deformation of Base

Breaking Range : 1.091×10-6 mm to 9.010×10-7 mm

Moderate Range : 9.009×10-7 mm to 3.636×10-7 mm

Safe range : 3.635×10-7 mm to 1×10-30 mm

Solidworks simulation gives precise values of deforming bodies (Thavai et al., 2015). The calculation says that the maximum deformation occures at the bottom part of the base & the deformation amount is 9.09×10-8 mm. At the top part deformation amount is 6.636×10-7 mm. It is a pretty decent amount of deformation which will not compromise it's functionality.

4. Materials and Manufacturing Processes

4.1 Materials selection: Qualitative analysis

A form of securities analysis known as qualitative analysis employs individual judgment based on intangible data like management experience, cycles of industry, research as well as development quality and relations of labor (Chenail, 2012).

4.1.1 Material selection process

Material selection plays an important role in the procedure for creating any physical object. The primary objective of material selection is cost minimization to satisfy the goals of product performance (Jahan et al., 2012). Making of flour bread is made by this machine easily. Maximum 25 pieces breads per minute can be produced by this machine. R.P.M. controller is used to control the production rate per minute if it is wanted. Two rollers and cutter is used to give breads perfect round shape. Rollers and cutter are set on the base and power is supplied to the parts by gear mechanism (Elmaraghy et al., 2012). So 3 main parts are need to make this product perfectly:

- Base
- Roller
- Cutter

Now we need to select material for these 3 parts.

4.2 Qualitative analysis of various parts: Base, Roller, Cutter

Table 2: Qualitative Analysis for Different Parts

Parts of Product	Criteria of Selection	Available Material	Selected Material
Base	-Strength -Hardness -Cost -Stiffness	-Cast Iron Plate -Mild Steel Plate -Stainless Steel Plate	Cast Iron Plate
Roller	-Hardness - Strength -Machinability -Chemical inertness -Stiffness -Cost	-Cast Iron -Mild Steel -Stainless Steel	Stainless Steel
Cutter	-Cutting Ability -Strength -Corrosion Resistance -Cost	-Aluminum -Stainless Steel -Mild Steel -Brass	Mild Steel

4.2.1 Quantitative Analysis for Base

Table 3: Digital Logic Method for Base

Properties	Decision Number						Positive Decisions	Weighting Factor
	1	2	3	4	5	6		
Strength	0			1	1		2	0.33
Hardness	1	0	0				1	0.17
Cost		1		0		1	2	0.33
Stiffness			1		0	0	1	0.17
Total Number of Decisions							6	∑α = 1.0

Table 4: Properties of Material for Base

Materials	Properties			
	Hardness (BHN)	Yield Strength (MPa)	Stiffness	Cost (per Kg) BDT
Cast Iron Plate	200	275	4	100
Mild Steel Plate	120	330	2	130
Stainless Steel Plate	190	365	1	400

For stiffness: 4 = Very high, 1= Low

All values are collected from the book 'Fundamentals of Mechanical Component Design' by 'KENNETH S. EDWARDS'

Table 5: Weighted Property Index Chart for Material Selection (Base)

Materials	Properties				Performance Index
	Hardness (0.17)	Strength (0.33)	Stiffness (0.17)	Cost (0.33)	
Cast Iron Plate	100	76	25	100	80
MS Plate	60	91	50	77	74.14
SS Plate	95	100	100	25	74.40

Even though "Cast iron Plate" has the highest performance index value, this material is selected to make base portion.

4.2.2 Quantitative Analysis for Roller

Table 6: Digital Logic Method for Roller

Properties	Decision Number															Positive Decisions	Weighting Factor
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Strength	1					1	0	1	1							4	0.27
Hardness	0	0	1	0	1											2	0.13
Chemical inertness		1				0				0	0	0				1	0.07
Machinability			0				1			1			1	1		4	0.27
Stiffness				1				0			1		0		0	2	0.13
Cost					0				0			1		0	1	2	0.13
Total Number of Decisions																15	∑α = 1.0

Table 7: Properties of Material for Roller

Materials	Properties					
	Hardness (BHN)	Yield Strength (MPa)	Chemical inertness	Machinability	Stiffness	Cost (per Kg) BDT
Cast Iron	200	275	2	2	4	100
Mild Steel	120	330	4	3	2	130
Stainless Steel	190	365	5	4	1	400

Chemical inertness, 5 = very high, 2 = Poor

For Machinability, 2 = very high, 5 = Poor

All values are collected from the book 'Fundamentals of Mechanical Component Design' by 'KENNETH S. EDWARDS'

Table 8: Weighted Property Index Chart for Material Selection (Roller)

Materials	Properties						Performance Index
	Hardness (0.13)	Strength (0.27)	Chemical inertness (0.07)	Machinability (0.27)	Cost (0.13)	Stiffness (0.13)	
Cast Iron	100	76	40	50	100	25	66.07
Mild Steel	60	91	80	75	77	50	74.73
Stainless Steel	95	100	100	100	25	100	89.60

'Mild Steel' was chosen. Because 'Mild Steel' is better than 'Cast iron' and cheap material than 'Stainless Steel'. The fund was not enough to choose 'Stainless steel'.

4.2.2 Quantitative Analysis for Cutter

Table 9: Digital Logic Method for Cutter

Properties	Decision Number						Positive Decisions	Weighting Factor
	1	2	3	4	5	6		
Strength	0	0	1				1	0.17
Cutting ability	1			1	1		3	0.50
Corrosion Resistance		1		0		0	1	0.17
Cost			0		0	1	1	0.16
Total amount of decisions							6	$\sum\alpha = 1.0$

Table 10: Properties of Material for Cutter

Materials	Properties			
	Cutting ability	Yield Strength (MPa)	Corrosion Resistance	Cost (Per Kg) BDT
Aluminum	2	300	3	350
Mild Steel	4	330	2	130
Stainless Steel	5	365	5	400
Brass	3	380	4	490

For Corrosion resistance, Cutting ability: 5= Best, 2=Poor

All values are collected from the book 'Fundamentals of Mechanical Component Design' by 'KENNETH S. EDWARDS'

Table 11: Weighted Property Index Chart for Material Selection (Cutter)

Materials	Properties				Performance Index
	Strength (0.17)	Cutting ability (0.50)	Corrosion Resistance (0.17)	Cost (0.16)	
Aluminum	40	96	79	37.14	74.17
Mild Steel	80	100	87	100	94.39
Stainless Steel	100	60	96	32.5	68.52
Brass	60	54	100	26.5	58.44

We choose 'Mild Steel'. Because 'Mild Steel' has highest performance value and cutting ability is enough for flour's sheet.

4.3 Selection of Manufacturing Process

The selection of manufacturing process is the strategic decision to select production process of manufacturing plant. The way of a factory organizes material flow utilizing one or more process technologies such as the assembly line, continuous flows, job shop and batch shop is referred to as the process flow in an organization. The process selection is determined by the product's level of customization and the market's volume requirements.

The manufacturing process is chosen with a balance of economic resources including product design, materials, labor, equipment, tools, plant space and numerous many more elements that affect manufacturing cost and adjustable to the customer from a functional, financial, and aesthetic perspective.

Here, the engineering methods for choosing the manufacturing process

are described:

- The objectives of processes are needed to establish
- All facts related to the problems must be collected
- Course of action must be developed
- Follow up to confirm activity and assess outcomes
- Alternative processes must be planned
- Alternative processes must be evaluated

The product is 'Automatic Roti maker'. It's a machine to produce perfect shape of south Asian flat bread automatically. There are 3 main parts of this product:

- Base
- Roller
- Cutter

For each part three types of manufacturing processes were considered:

- Process of Joining
- Process of Machining
- Process of Production

For those parts, a manufacturing procedure is selected.

Table 12: Manufacturing process analysis for different parts

Name of Processes	Parts	Properties for Selection	Available process of manufacturing	Process selection
Cutting Operation	-Base	-Operation time -Low cost -Safety -Good quality	-Flame cutting (Oxy acetylene flame) -Plasma Beam machining -Disk cutter machining -LASER Beam machining	Disk cutter machining
Production	-Roller -Cutter's roller -Cutting plate	-Low cost -Operation time -Sharp edge of cutting plate -Safety -Good quality -Eco friendly	-Lathe machining -Milling machining -Casting	Lathe machining
Holes making operation	-Base	-Low cost -Operation time -Good finish -Safety -Quality	-Drilling machining -Lathe machining -EBM machining	Drilling machining
Joining & assembly operation	-Base -Roller -Cutter	-Low cost -Operation time -Safety -Good quality	-MIG Welding -Electric Arc Welding -TIG Welding	TIG Welding
Finishing operation	-Base -Roller -Cutter	-Low cost -Operation time -Good finish -Safety -Quality	-Lathe machining -Milling machining -Grinding machining	Grinding machining

4.3.1 Manufacturing Process Selection for Cutting Base metal

Table 13: Weighting Factor and Digital Logic Method Calculation for Base Metal Cutting

Properties	Decision Number						Positive Decisions	Weighting Factor %
	1	2	3	4	5	6		
Low cost	0	0	0				0	0
Minimum Operation time	1			0	1		1	0.33
Quality			1		0	0	1	0.17
Safety		1		1		1	3	0.50
Total amount of decisions							6	$\sum\alpha = 1.0$

Table 14: Properties of Alternative Cutting Processes for base

Process of Manufacturing	Properties			
	Low Cost	Time of operation	Safety	Quality
Flame cutting (Oxy acetylene flame)	3	3	2	2
Plasma Beam machining	4	2.5	3	3
Disk cutter machining	2	4	2	2.5
LASER Beam machining	5	2	4	4

For cost: 5 = expensive, 1 = cheap

For all properties: 5 = highest, 1 = lowest

Table 15: Performance Index and Scaled Value of Properties					
Process of Manufacturing	Scaled Properties				Performance Index
	Low Cost (0)	Operation time (0.33)	Safety (0.50)	Quality (0.17)	
LASER Beam machining	40	50	100	100	83.5
Flame cutting (Oxy acetylene flame)	68	75	50	50	58.25
Plasma Beam machining	50	62.5	75	75	71
Disk cutter machining	100	100	50	62.5	69

It can be seen from the performance index that the optimum cutting method is LBM. But LBM and PBM both are expensive. To maintain low budget, third process 'Disk cutter machining' is selected for product manufacturing.

4.3.2 Selection of Manufacturing Process to produce different parts

Table 16: Weighting Factor and Digital Logic Method calculation to produce different parts																	
Properties	Decision Number															Positive Decisions	Weighting Factor %
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Low cost	0	1	0	0	0											1	0.07
Operation time	1					0	0	0	1							2	0.13
Sharp edge of cutting plate		0				1				1	0	1				3	0.20
Safety			1				1			0			1	1		4	0.26
Quality				1				1			1		0		1	4	0.27
Eco friendly					1				0			0		0	0	1	0.07
Total amount of decisions																15	∑α = 1.0

Table 17: Properties of Alternative Production Processes considering different parts						
Process of Manufacturing	Properties					
	Low Cost	Time of operation	Sharp edge of cutting plate	Safety	Quality	Eco friendly
Casting	2	4	2.5	2.5	3	2
Milling machining	4	3	3	3	3.5	2.5
Lathe machining	5	2	4	3	4	2.5

For cost: 5=expensive, 1=cheap

For all properties: 5= highest, 1=lowest

Table 18: Performance Index and Scaled Value of Properties							
Process of Manufacturing	Scaled Properties						Performance Index
	Low Cost (0.07)	Operation time (0.13)	Sharp edge of cutting plate (0.20)	Safety (0.26)	Quality (0.27)	Eco friendly (0.07)	
Lathe machining	40	50	100	100	100	100	89.30
Milling machining	50	75	75	100	75	87.5	81.0
Casting	100	100	62.5	84	62.5	75	69

As 'lathe machining' has the greatest value in the performance index, it is chosen for all production processes for this product.

4.3.3 Selection of Manufacturing Process for holes making operation

Table 19: Weighting Factor and Digital Logic Method calculation for holes making operation												
Properties	Decision Number										Positive Decisions	Weighting Factor %
	1	2	3	4	5	6	7	8	9	10		
Low cost	1	0	0	0							1	0.1
Operation time	0				1	0	0				1	0.1
Good finish		1			0			1	0		2	0.2
Quality				1			1		1	0	3	0.3
Safety			1			1		0		1	3	0.3
Total amount of decisions											10	∑α = 1.0

Table 20: Properties of Alternative Production Processes for holes making operation					
Process of Manufacturing	Properties				
	Time of operation	Low Cost	Good finish	Safety	Quality
Lathe machining	4	4	3	3.5	3
Drilling machining	4	3.5	3.5	3.5	3.5
EBM machining	3	5	4	4	4

For cost: 5=expensive, 1=cheap

For all properties: 5= highest, 1=lowest

Table 21: Performance Index and Scaled Value of Properties							
Process of Manufacturing	Scaled Properties						Performance Index
	Low Cost (0.1)	Operation time (0.1)	Good finish (0.2)	Safety (0.3)	Quality (0.3)	Low Cost (0.1)	
Lathe machining	87.5	100	75	87.5	75	82.5	89.30
Drilling machining	100	100	87.5	87.5	87.5	90	81.0
EBM machining	70	75	100	100	100	94.5	69

It can be seen from performance index that 'EBM machining' is the best process. But EBM is expensive process. To maintain low budget, the second process 'Drilling machining' was selected for holes making operation.

4.3.4 Selection of Manufacturing Process for assembly and joining operation

Table 22: Weighting Factor and Digital Logic Method calculation for joining different part								
Properties	Decision Number						Positive Decisions	Weighting Factor %
	1	2	3	4	5	6		
Low cost	1	0	0				1	0.17
Operation time	0			0	1		1	0.16
Quality			1		0	0	1	0.17
Safety		1		1		1	3	0.50
Total amount of decisions							6	∑α = 1.0

Table 23: Properties of Assembly Processes and Alternative Joining				
Process of Manufacturing	Properties			
	Time of operation	Low cost	Quality	Safety
TIG welding	4	5	4	4
Electric Arc welding	3	3	2	2
MIG welding	3	4	3	3

For cost: 5 = Expensive, 1 =cheap

For all properties: 5 = best, 1 = Poor

Table 24: Performance Index and Scaled Value of Properties					
Process of Manufacturing	Scaled Properties				Performance Index
	Low Cost (0.17)	Time of operation (0.16)	Safety (0.50)	Quality (0.17)	
Electric Arc welding	100	75	50	50	62.5
MIG welding	75	75	75	75	75
TIG welding	60	100	100	100	93.2

As 'TIG welding' has the greatest value in the performance index, it has been selected for all joining processes for this product.

4.3.5 Manufacturing Process Selection for finishing operation

Table 25: Weighting Factor and Digital Logic Method calculation for finishing operation												
Properties	Decision Number										Positive Decisions	Weighting Factor %
	1	2	3	4	5	6	7	8	9	10		
Low cost	1	0	0	0							1	0.1
Operation time	0				1	0	0				1	0.1
Good finish		1			0			1	0		2	0.2
Quality				1			1		1	0	3	0.3
Safety			1			1		0		1	3	0.3
Total amount of decisions											10	∑α = 1.0

Table 26: Properties of Alternative Production Processes for finishing operation					
Manufacturing Process	Properties				
	Low Cost	Time of operation	Good finish	Quality	Safety
Lathe machining	3.5	4	3.5	3.5	3.5
Grinding machining	4	3	4	4	4
Milling machining	3	4	3	3	3.5

For cost: 5= Expensive, 1=cheap

For all properties: 5= best, 1=Poor

Table 27: Performance Index and Scaled Value of Properties						
Manufacturing Process	Scaled Properties					Performance Index
	Low Cost (0.1)	Operation time (0.1)	Good finish (0.2)	Safety (0.3)	Quality (0.3)	
Grinding machining	70	75	100	100	100	94.5
Lathe machining	100	100	87.5	87.5	87.5	90
Milling machining	87.5	100	75	87.5	75	82.5

According to the performance index, "Grinding machining" has the highest value. Therefore, "Grinding Machining" procedure is selected for the finishing operation.

5. Cost Analysis

Cost analysis describes the process of gathering cost information from various business components, assessing it, determining the amount of additional and overall resources required to support existing and future business plans (Chen et al., 1994).

5.1 Types of Cost

It is typically simpler to think of costs as a component of particular categories. These many classifications are quite significant, especially when figuring out profits and taxes. Direct costs and indirect costs are the two different sorts of costs (Selvaraj et al., 2009).

5.1.1 Direct cost

Direct expenses are related to the quantity of units produced. Direct costs often depend on the volume of goods produced. In the other cases, they are maximum when a plant is running at its full capacity (Selvaraj et al., 2009).

5.1.2 Indirect cost

Indirect costs, commonly known as overhead, both are fixed and variable expenses incurred for the overall functioning of the organization and not specific to any one product (Selvaraj et al., 2009).

5.2 Cost calculation

5.2.1 Fixed cost

Factory rent Cost = 95.24 USD/month

Factory Cost = (95.24 USD × 12) USD/year
= 1142.86 USD/year

Machine Rent = 142.86 USD/month

Machine rent Per Year = (142.86 USD × 12)
= 1714.29 USD/year

Maintenance Cost = 438.10 USD/year

Office Rent = 285.71 USD/year

Total fixed cost = (1142.86+ 1714.29+ 438.10+ 285.71) USD/year

= 3580.95 USD/year

5.2.2 Quantity

Around 3.5 days is requered to make one complete product .

No. of product produced = (365/3.5) unit/year

= 104.28 unit/year

≈ 100 unit/year

5.2.3 Assembly cost

Assembly Parts = 5.71 USD

Welding = 8.57 USD
Total Assembly Cost = (5.71+ 8.57) USD

= 14.29 USD/unit

Assembly Cost = (14.29× 100) USD/year

= 1429.0 USD/year

Table 28: Materials & equipments cost	
Item	Cost (USD)
Base	7.62
Roller (2 pieces)	15.24
Cutter	3.81
Gear motor	28.57
Gears	7.62
Ball bearing	0.95
Electric wire	0.95
Conveyor	1.90

Total materials & equipment Cost = 66.67 USD/unit

Materials & equipment Cost = (66.67× 100) USD/year

= 6667.0 USD/year

5.2.4 Direct material Cost

Fixed cost +Assembly cost + Material cost = (3580.95 + 1429.0 + 6667.0) USD/year
= 11676.95 USD/year

5.2.5 Direct Labor cost

Worker = 114.29 USD/month
Labor Cost = (114.29 × 12) USD/year

= 1371.48 USD/year

5.2.6 Manufacturing overhead

Transportation Cost per unit = 1.90 USD
Total Manufacturing Overhead = 1.90 USD/unit
Manufacturing Overhead = (1.90 × 100) USD/year

= 190.0 USD/year

5.2.7 Total Cost of Goods Sold

Direct Material Cost + Direct Labour Cost + Manufacturing Overhead

= (11676.95 + 1371.48 + 190.0) USD/year

= 13238.43 USD/year

5.2.8 Total Advertisement Cost

Advertising Cost = 28.47 USD

Rent Cost for store in shop = 0.95 USD/unit

Total Rent Cost = (0.95 × 100) USD/year

= 95.0 USD/year

Total advertisement cost = (28.47 + 95.0) USD

= 123.47 USD

5.2.9 Total Cost

Total Cost of Goods Sold + Selling & Admin Cost

= (13238.43 + 123.47) USD/year

= 13361.90 USD/year

Margin of Safety = 2004.29 USD (15% of total cost)

5.2.10 Total Revenue

Total Cost + Margin of Safety = (13361.90 + 2004.29) USD

= 15366.19 USD

Quantity (Q) = 100 unit

Revenue per unit = (15366.19/100) USD

= 153.66 USD/unit

≈ 152.38 USD/unit

Total revenue per year = (152.38 × 100) USD

= 15238.0 USD

5.3 Profit

Profit = (Total revenue – Total cost)

= (15238.0– 13361.90) USD

= 1876.10 USD/year

5.4 Breakeven Analysis

When a company will be able to cover all of its costs and start to make a profit is evaluated using the breakeven analysis (Berryman and Nobe, 1999). It is important to comprehend the initial costs since they will influence the sales volume required to cover ongoing business expenses (Sintha, 2020).

At break-even point,

Total cost = Total Revenue

So, Total cost = (VC × Q) + Fixed Cost

Here, VC = (Total cost – fixed cost)

= (13361.90– 3580.95) USD/year

= 9780.95 USD/year

'VC' Per unit = (9780.95/0.95) USD/unit

= 97.81 USD/unit

Sales Income per unit, R = 152.38 USD

Now, (R × Q) = (VC × Q) + Fixed Cost

or, Q = Fixed Cost / (R –VC)

$$Q = \frac{\text{Fixed Cost}}{(\text{R} - \text{VC})}$$

$$Q = \frac{3580.95}{(152.38 - 97.81)}$$

= 65.61 unit

≈ 66 unit

5.4.1 Break-even point

According to economics, the break-even point is the point at which revenues and expenses are equal (Gutierraz and Dalsted, 1990). The break-even point in investment is the moment where gains and losses are equal (Kampf et al., 2016).

Table 29: Data for break-even analysis

Fixed cost (USD)	Sales income (USD)	Total cost (USD)	Variable cost (USD)	Quantity	Price (USD)	Profit (USD)
3580.95	0.00	3580.95	0.00	0	152.38	-3580.95
3580.95	761.90	4070.00	489.05	5	152.38	-3308.10
3580.95	1523.81	4559.05	978.10	10	152.38	-3035.24
3580.95	2285.71	5048.10	1467.14	15	152.38	-2762.38
3580.95	3047.62	5537.14	1956.19	20	152.38	-2489.52
3580.95	3809.52	6026.19	2445.24	25	152.38	-2216.67
3580.95	4571.43	6515.24	2934.29	30	152.38	-1943.81
3580.95	5333.33	7004.29	3423.33	35	152.38	-1670.95
3580.95	6095.24	7493.33	3912.38	40	152.38	-1398.10
3580.95	6857.14	7982.38	4401.43	45	152.38	-1125.24
3580.95	7619.05	8471.43	4890.48	50	152.38	-852.38
3580.95	8380.95	8960.48	5379.52	55	152.38	-579.52
3580.95	9142.86	9449.52	5868.57	60	152.38	-306.67
3580.95	9904.76	9938.57	6357.62	65	152.38	-33.81
3580.95	10666.67	10427.62	6846.67	70	152.38	239.05
3580.95	11428.57	10916.67	7335.71	75	152.38	511.90
3580.95	12190.48	11405.71	7824.76	80	152.38	784.76
3580.95	12952.38	11894.76	8313.81	85	152.38	1057.62
3580.95	13714.29	12383.81	8802.86	90	152.38	1330.48
3580.95	14476.19	12872.86	9291.90	95	152.38	1603.33
3580.95	15238.10	13361.90	9780.95	100	152.38	1876.19

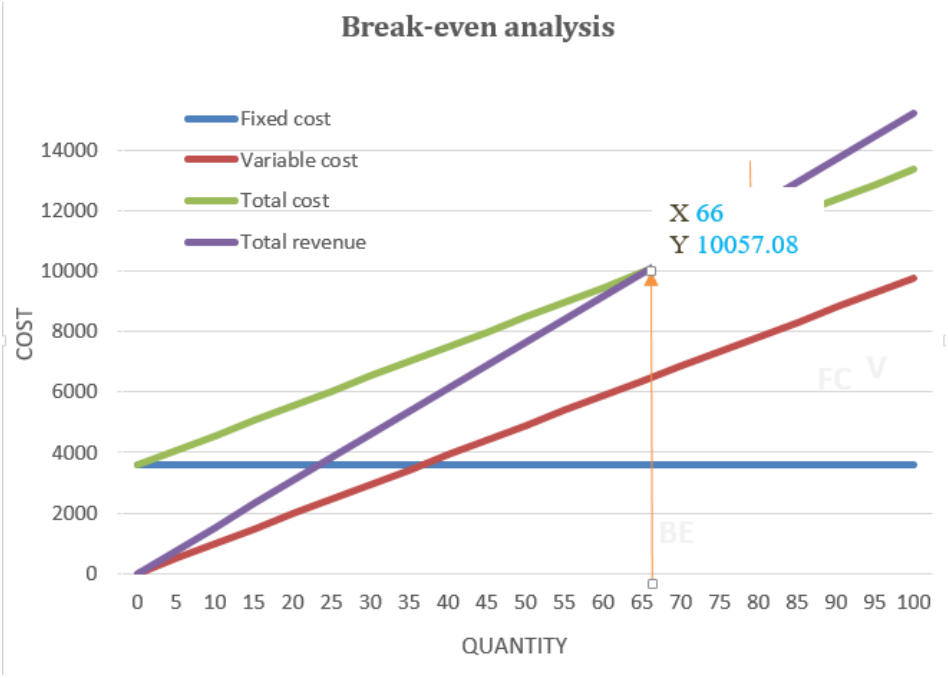


Figure 20: Break-even point

5.5 Payback Period

The time frame required to recoup the cost of an investment is known as the payback period (Weingarner, 1969). The payback time is a method often used by investors, financial professionals, and organizations to calculate investment returns. It aids in determining how long it takes to recover an investment's initial expenditures (Boardman et al., 1982). This statistic is useful before making any judgments, especially when an investor needs to make a quick decision regarding an investment initiative (Bhandari, 1985).

Initial investment = 5714.29 USD

Variable Cost = 97.81 USD/unit

Sales price = 152.38 USD/unit

Profit = 54.57 USD/unit

Table 30: Payback period

Month	Profit (USD)	Number of products	Payback (USD)
1	381.90	7	381.90
2	327.43	6	709.33
3	491.14	9	1200.48
4	545.71	10	1746.19
5	436.57	8	2182.76
6	381.90	7	2564.67
7	491.14	9	3055.81
8	327.43	6	3383.24
9	491.14	9	3874.38
10	327.43	6	4201.81
11	381.90	7	4583.71
12	545.71	10	5129.43
13	327.43	6	5456.86
14	272.86	5	5729.71

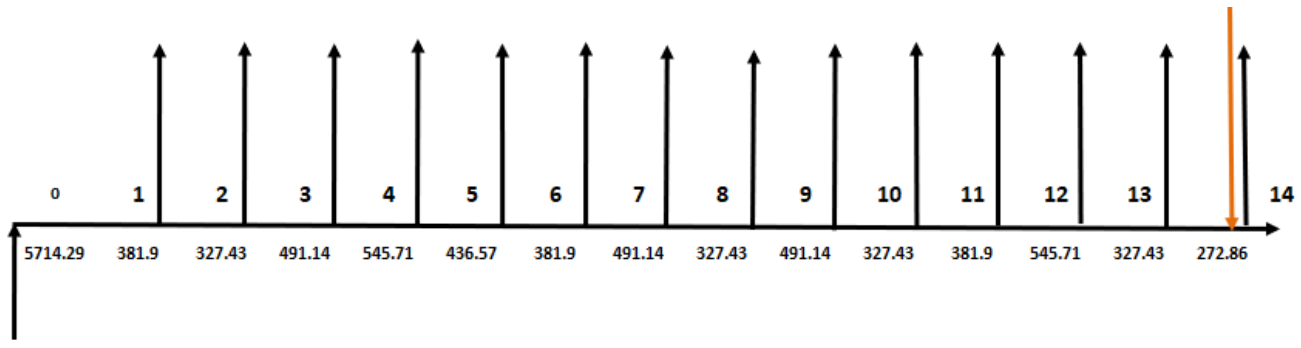


Figure 21: Cash Flow Diagram

So, the payback will be within 13 to 14 months.

Now, Payback period = 13 + (5714.29 - 5456.86)/272.86

= 13.94 month

= 13 month 28 days

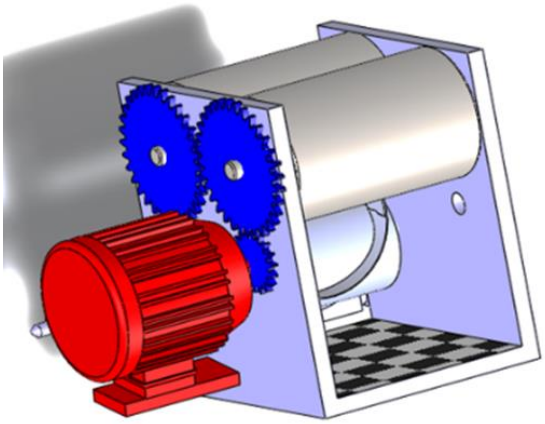


Figure 22: RPM reduction Mechanism

Here,

Motor gears diameter = 5 in

Roller's gear diameter = 10 in

Velocity ratio $= \frac{Distance\ Moved\ by\ Driver\ Pulley}{Distance\ Moved\ By\ Driven\ Pulley}$

$= \frac{10\ inch}{5\ inch}$

= 2 or 1: 2

So, the rollers rpm $= \frac{RPM\ of\ Driver\ Pulley}{2}$

$= \frac{60\ rpm}{2}$

= 30 rpm

By the mechanism the rpm of the roller was reduced to make sure the proper output of the bread. Otherwise, the production speed of breads would be too much that not to be controlled.

5.6 Final Product

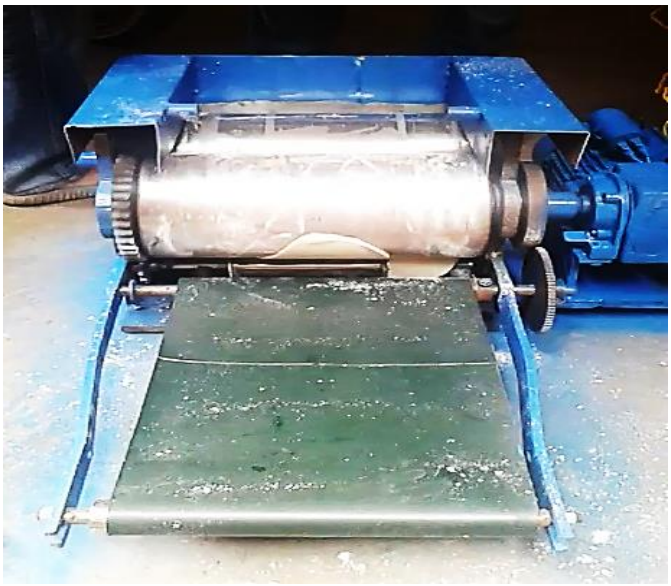


Figure 23: Final product (Industrial automatic Roti maker)

6. Conclusion

The industrial automatic Roti maker machine is developed by meeting the customer demand as well as the by fulfilling course requirements. It is manufactured by following and maintaining customer survey and user feedback. This machine is designed to perform according to the direction of the user so that he or she can get the best output from this machine. This machine has gears, rollers, cutters, motor, conveyor, and belt to make perfect bread at the reasonable cost and time. This machine can also be used for big restaurants as well as in industry dining to produce more breads at a time.

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