Development of a Small to Medium Size Dough Kneading Machine

ME 420: Mechanical Engineering Individual Research Project

Submitted By

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EXECUTIVE SUMMARY

This project focuses on the development of a compact, user-friendly dough kneading machine designed for household and small-scale commercial applications. The primary objective was to reduce manual effort in dough preparation while ensuring consistent mixing quality. A horizontal mixing configuration with a plate-embedded agitator was selected based on performance comparisons using ANSYS Fluent simulations. The prototype integrates a DC motor, timing belt transmission, and a modular frame, fabricated through a combination of traditional and additive manufacturing techniques.

Key features include speed control via PWM, compact design for countertop placement, and the ability to knead multiple flour types. Experimental evaluations showed that the developed machine reduces kneading time by over 4 minutes compared to manual methods, while requiring minimal user effort. Although challenges were encountered during fabrication and testing, the prototype met its core objectives. Future improvements have been proposed to enhance design, material durability, automation, and scalability. Overall, this project serves as proof of concept for a practical and affordable dough kneading solution.

ACKNOWLEDGMENTS

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Special thanks to the workshop engineer, technical officer and technicians for their assistance during fabrication process. I also acknowledge the valuable input received from evaluators and peers during project reviews, which helped refine the final system. Finally, I extend my appreciation to my family and friends for their patience and support during the intensive phases of this project.

DISCLAIMER

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ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
CAD	Computer-Aided Design
CFD	Computational Fluid Dynamics
DC	Direct Current
PWM	Pulse Width Modulation
RPM	Revolutions Per Minute
SS304	Stainless Steel Grade 304
TKE	Turbulent Kinetic Energy
VFD	Variable Frequency Drive

1. INTRODUCTION

Dough kneading is an essential process in the preparation of a wide range of flour based food products, such as bread, roti, naan, and buns. This process involves the even distribution of ingredients, gluten development, and helps introduce air into the dough structure. They are critical for achieving the desired texture and quality in the final product. Kneading is still performed manually in both domestic and small scale bakery settings. Manual kneading is not only physically demanding and time consuming but also results in inconsistent mixing quality due to variations in user technique and fatigue. As a result, the lack of affordable dough kneading machines presents a significant barrier to productivity, product consistency, and business scalability for many small-scale entrepreneurs and home bakers.

Most existing kneading machines are designed for industrial scale operations. They are too large, expensive, and complex for home use. Simplistic handheld mixers lack of torque and design features necessary for kneading tougher doughs. Furthermore, many of the available machines are imported and not suitable for local market needs, in size, cost, maintenance, and availability of replacement parts. These limitations create a need for a compact, medium-capacity kneading machine that is both affordable and efficient.

The primary goal of this project is to develop a medium capacity dough kneading machine that bridges the gap between bulky industrial mixers and low performance domestic appliances. The beneficiaries of this project are home bakers, small-scale bakery entrepreneurs, and manufacturers of compact food processing equipment.

The scope of the project includes mechanical design, simulation-based analysis, fabrication, and performance evaluation. A horizontal mixing configuration was selected as the base design due to its compactness, mixing uniformity, and suitability for a variety of dough types. The project involved the use of CAD modeling, computational fluid dynamics (CFD) simulations using ANSYS Fluent, and both conventional and additive manufacturing methods.

Key assumptions of the project include the use of wheat flour dough rheological properties for design calculations, and the consideration of shear forces as the primary load acting on the agitator. Other flour types and force interactions were accounted from the application of higher safety factors during design.

The expected outcomes of this project include a functional dough kneading machine prototype that meets the stated user requirements, efficient kneading with minimal user involvement, compact form suitable for kitchen countertops, compatibility with household power supply, and adaptability for different flour types. Additionally, the project aims to provide a cost effective design that can be further refined and scaled.

2. BACKGROUND

In the increasing demand for semi-automated food processing solutions, small-scale and household-level bakeries in developing countries face challenges due to the unavailability of affordable, compact, and efficient dough kneading machines. Manual kneading is still widely used there. It is labor intensive, time consuming, and often inconsistent, which negatively affects dough quality and overall productivity.

With the rise of home-based food businesses and the growth of the small bakery sector, especially in South Asian countries. There is a growing need for machines that bridge the gap between household appliances and large-scale industrial equipment. Most commercially available dough kneading machines are either designed for industrial capacities or for very light domestic use.

2.1 The Identified Problem

The core problem is the lack of a cost-effective, medium capacity kneading machine capable of handling tough doughs with minimal manual involvement. It should be operable using a single-phase household power supply. Existing manual methods result in inconsistent texture, poor mixing quality, and high physical strain for users. Moreover, they limit production scalability.

2.2 Likely Stakeholders

Stakeholders who would benefit from this solution are,

1. Small-scale and home-based bakery owners
2. Food startup entrepreneurs in rural and urban areas
3. Manufacturers of affordable food processing equipment
4. NGOs and development programs promoting cottage industries

2.3 Theory Behind Kneading

The rheological behavior of wheat dough affects the mixing performance its viscoelastic and shear thinning properties have major affect for that. Proper kneading requires controlled deformation of the dough to activate gluten development while minimizing overmixing and heat generation. Torque requirements vary with hydration, flour type and gluten development. Therefore, it requires a mechanical system with sufficient power transmission.

2.4 Tools and Methods Used in This Project

1. Mechanical design modeling with SolidWorks software
2. Simulation of kneading dynamics using ANSYS
3. Torque transmission analysis through gear and belt mechanisms
4. Material selection based on strength, cost and food compatibility
5. performance testing based on typical dough characteristics

3. SPECIFICATION & DESIGN

3.1 Overall Design Concept

3.1.1 Design Objectives and Constraints

The dough kneading machine is designed to meet several important user needs. Within the development of the prototype below requirements were focused.

1. The machine should reduce the physical effort required for kneading, making it easier for users who may find hand kneading or handheld machines difficult to use.
2. The machine should be easy to use and operate with low power, suitable for household electricity.
3. It should be able to handle small batches of less than 2kg of flour per batch, making it ideal for home or small business use.
4. The machine should be capable of kneading different types of flour, such as wheat flour, rice flour, millet flour etc.
5. The machine should have a compact design so it can fit on a kitchen countertop.
6. It should run quietly and smoothly without causing much noise or vibration.
7. The machine should allow speed and torque adjustments to handle different dough textures.

These features help make the machine simple, useful, and affordable for everyday use.

3.1.2 Selection Dough Kneading Configuration

In developing a dough kneading machine suitable for small to medium-scale applications, different mixing mechanisms were studied to identify the most effective, user-friendly, and scalable option. From the literature review, four key parameters were identified as essential for producing quality dough [1],[2],[3].

1. Kneading Time – Affects gluten network formation and gas release. It must be adjustable to control food texture.

2. Dough Temperature – Must be kept lower to avoid protein denaturation due to excessive mixing heat.

3. Mixing Speed – Improves gluten formation and consistency but should be optimized to prevent over-shearing.

4. Dough Aeration – Necessary for oxidation and gluten development; both over and under-aeration reduce dough quality.

Based on these parameters, the following four common types of mixers were compared

- Vertical Spindle Mixers
- Planetary Mixers
- Double Arm Mixers
- High-Speed Horizontal Mixers

A detailed assessment of their suitability for small to medium-sized applications is shown table 3.1.

Table 3.1 Advantages and Disadvantages of Different Kneading Method in Small to Medium Size Kneading

Type	**Advantages**	**Disadvantages**
Vertical Spindle	• Generates little heat • Good for fermented doughs	• Difficult to discharge dough • Hard to clean spindles
Planetary Mixer	• Can mix a variety of dough types	• Bulky • High cost • Not space-saving
Double Arm Mixer	• Low heat transfer • Adjustable arms	• Bulky • Low productivity • Scaling down is difficult
High-Speed Horizontal	• Even mixing • Compact and efficient	• Tends to raise dough temperature if not controlled

Among the reviewed methods, horizontal mixers showed the best performance balance for household and small business use. This type of mixer enables even dough distribution, efficient mixing across varying flour types (wheat, rice, finger millet), and easy cleaning due to accessible and detachable parts.

In addition, horizontal mixers

- Kneading happens automatically with little need for the user to assist
- Are more compact and mobile than vertical or double-arm designs
- Use less energy compared to industrial-scale mixers
- Are easier to fabricate in a scaled-down form

- Can be equipped with safe and user-friendly controls suitable for all ages

Although this method may slightly increase dough temperature due to friction, careful control of speed and mixing time helps maintain optimal conditions[4].

Considering these benefits, a scaled down horizontal mixer was selected as the most suitable configuration for the proposed dough kneading machine design

3.2 Agitator Design and Selection

3.2.1 Agitator Types

In the design process, two different types of agitators were compared to identify the most suitable one for the dough kneading machine. An agitator is the rotating component responsible for stirring, folding, and mixing the dough uniformly within the kneading vessel. The two main designs considered were:

1. Simple rod-type agitator
2. Plate-embedded agitator

These designs were selected based on inspiration from the blade configurations used in planetary mixers and machines are at development stage [2][4]. In addition, feedback from project evaluators and the supervisor highlighted the need for improved turbulence and coverage during mixing, which guided the selection and refinement of these agitator concepts. Simulations were conducted using Ansys Fluent to analyze how each design affected the movement and mixing of dough particles.

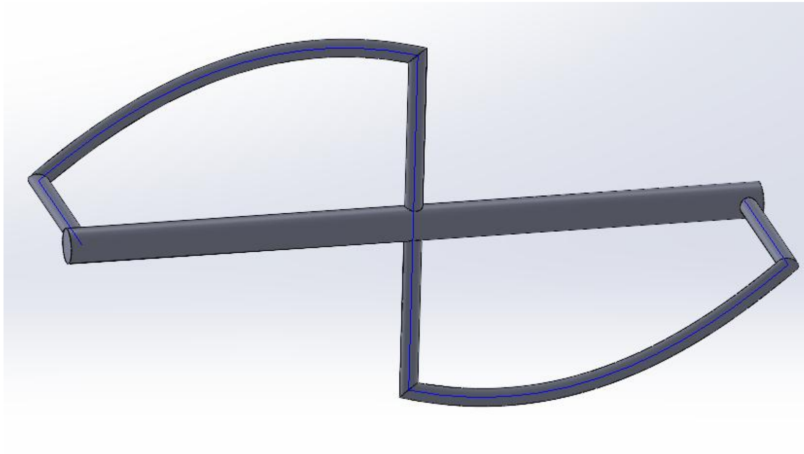


Figure 3.1 Rod Agitator

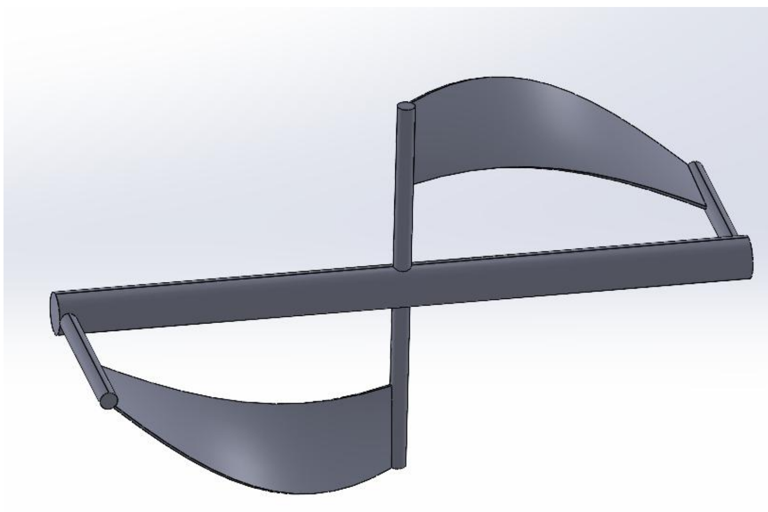


Figure 3.2 Plate agitator

3.2.2 Simulation Analysis using ANSYS Fluent

To evaluate the performance of each agitator type, computational fluid dynamics (CFD) simulations were conducted using ANSYS Fluent. The objective was to compare the mixing effectiveness of the two agitator designs under identical flow conditions. The simulation setup and boundary conditions were kept consistent across both models to have a fair comparison.

Simulation Setup

- Turbulence Model
  - Standard k–ε model was used to simulate turbulence and flow patterns within the kneading chamber.
- Material Properties
  - The working fluid was a mixture of water and glycerin, with identical initial mass fractions (0.5) used in both cases.
- Time Stepping and Solver Controls
  - Time step size = 0.5 seconds
  - Total steps = 60 steps (representing a simulation duration of 30 seconds)
  - Maximum iterations per step = 20

The performance of the two agitator designs was evaluated using the following simulation outputs.

1. Turbulent Kinetic Energy (TKE) – Used to measure the intensity of mixing and flow disturbances generated by each agitator.
2. Mass Fraction of Glycerin – Tracked to evaluate the distribution uniformity of the heavier fluid component, indicating the level of mixing achieved.

Simulation results after 30 seconds of kneading were compared to determining which design provided more effective and uniform mixing. The following figure 3.3 and figure 3.4 illustrate the differences in TKE distribution and glycerin dispersion between the two designs.

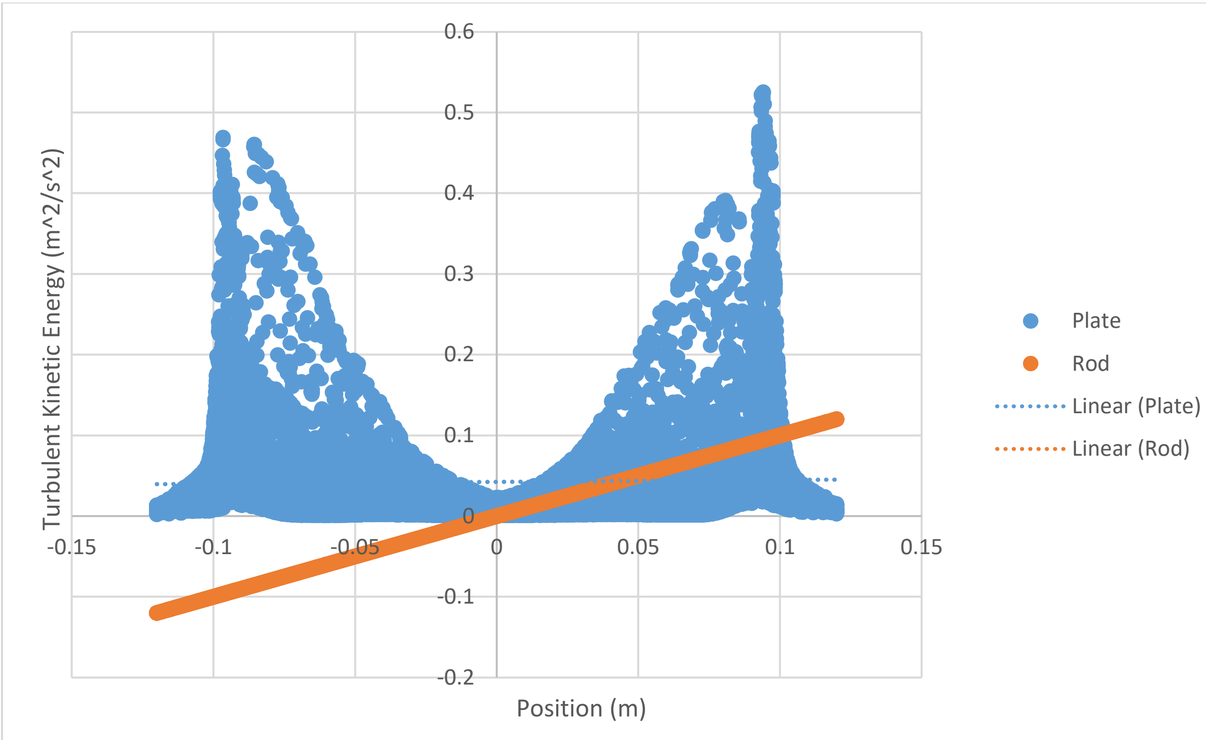


Figure 3.3 Turbulent Kinetic Energy Distribution in Plate Agitator and Rod Agitator Designs

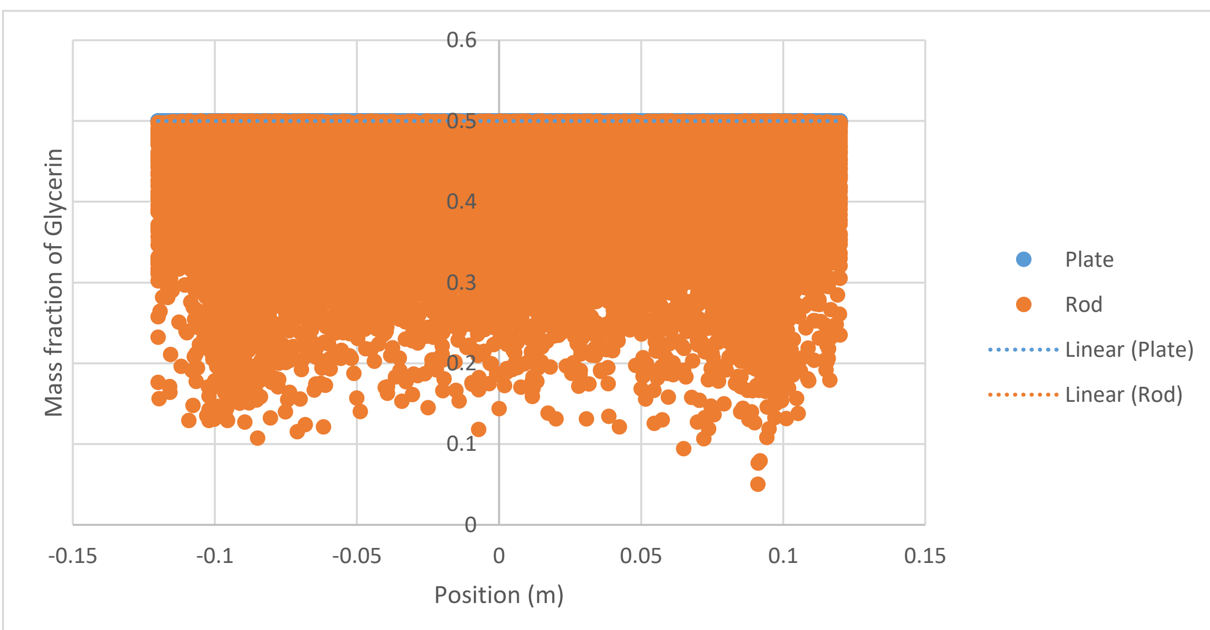


Figure 3.4 Distribution of Mass Fraction of Glycerin in Plate and Rod Agitator

3.2.3 Final Agitator Selection

According to the figure, the plate agitator has higher average turbulent energy, and it is distributed more inside the simulation area. From figure within 30 seconds mass fraction of glycerin is uniform in plate agitator compared to rod type. This proves that the plate embedded agitator generated higher turbulence and provided better mixing inside the kneading drum. Based on these results, the plate-embedded agitator was selected for the final design due to its superior mixing performance.

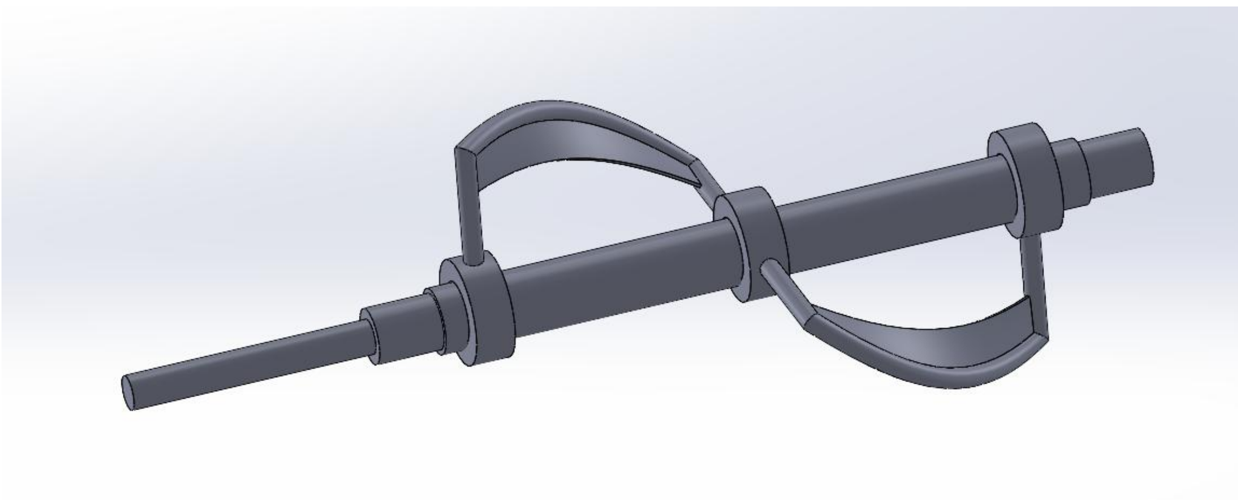


Figure 3.5 SolidWorks Model of the Final Design of the Agitator

3.3 Safety Factor Selection

In the design of the dough kneading machine, higher safety factors were intentionally selected due to the following reasons:

1. Limited Rheological Data in Literature

The mechanical and flow properties of flour vary significantly based on type, moisture content, and additives. However, available literature provides detailed rheological properties only for wheat flour, which was used as the basis for all torque and force calculations in this design. Since other flour types (e.g., rice, rye, or millet) may behave differently under stress and exhibit higher resistance to kneading, a conservative approach was taken by applying a higher safety factor to compensate for these data limitations [1],[5].

2. Simplification of Force Modeling on the Agitator

In this analysis, only the shear force acting on the agitator was considered when estimating torque and shaft stresses (due to unavailability of properties). In real operation, multiple types of forces act simultaneously[5]. These include:

- Compressive forces from the dough mass resisting displacement.
- Impact forces due to intermittent contact or sudden changes in dough consistency.
- Frictional forces between the agitator and bowl wall or between dough particles.
- Torsional shocks due to motor speed variations or dough lumps.
- Centrifugal and inertial loads caused by rotational motion, especially during startup and shutdown.

Since these forces were not explicitly modeled, the chosen safety factors of 3 and 4 ensures structural integrity under variable and unpredictable load conditions.

3.4 Material Selection

Since the machine is used for food processing, it is essential to use food-safe materials for all components which have direct contact with the dough. The ideal choice for such applications is Stainless Steel 304, which offers excellent corrosion resistance, durability, and compliance with food safety standards [9].

However, stainless steel is only available for bulk purchases. It makes high cost during the fabrication process of the protype. Therefore, alternative materials were selected for the prototype fabrication to ensure cost efficiency and accessibility during development. The selected materials for food contacting components are as follows.

1. Agitator – Mild Steel: Selected for ease of fabrication and adequate mechanical strength in prototyping.
2. Vessel – Zinc-Coated Aluminum: Offers moderate corrosion resistance and is lightweight, making it suitable for small-scale testing.
3. Bearing Brackets – Acrylonitrile Butadiene Styrene (ABS): A durable and easy-to-machine thermoplastic used for non-load-bearing structural parts.

3.5 Component Design

3.5.1 Agitator Rods

dough is a viscoelastic material, therefore force on the single plate is given by

$$F = \tau A$$

$\tau = shear\ stress\ of\ the\ dough$
$A = effective\ contac\ area$

Maximum shear stress for wheat dough is 50 kPa [3],[4].

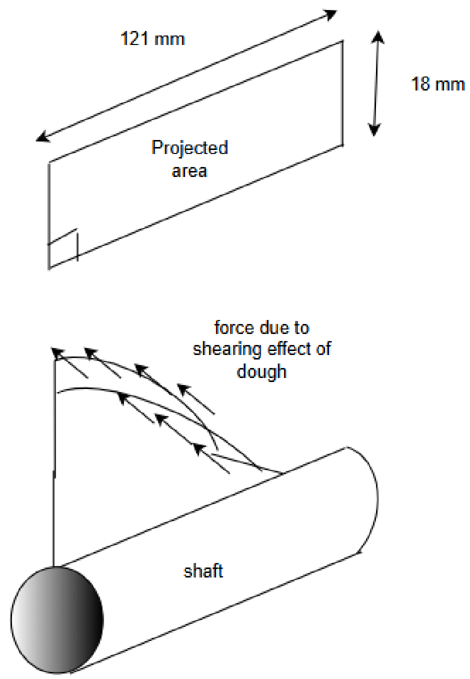


Figure 3.6 Sketch of Forces and Effective Area for Force Calculation

Considering the rotation of agitator, an effective area is calculated as below,

Effective contact areas for one curved blade considering both sides,

$$\begin{aligned} \mathrm{A_s} &= \text{plate area } \times 2 \\ &= 121 \text{ mm } \times 18 \text{ mm} \times 2 \\ &= 4356 \text{ m}m^2 \end{aligned}$$

Shear Forces per single blade,

$$\begin{aligned} F_{blade} &= \tau A_s \\ &= 50{,}000Pa \times 4.456 \times 10^{-3} m^2 \\ &= 222.8\ N \end{aligned}$$

Torque exerted on single rod can be calculated consider the free body diagram

$$2F_{rod} = F_{blade}$$

$$F_{rod} = 111.4\ N$$

Considering safety factor of 4 for selection of materials. Herer safety factor of 4 was considered due to unavailability of rheological properties other kinds of flour and doughs. Therefore, maximum allowable shear stress is,

$$\sigma_{\text{allow}} = \frac{200\ MPa}{4}$$
$$= 50\ MPa$$

Considering the area and minimum rod diameter can be calculated,

$$\sigma_{allow} = \frac{F_{rod}}{A}$$
$$A = \frac{111.4\ N}{50 \times 10^6 Pa}$$
$$d = 1.68 \times 10^{-3}$$
$$d = 1.68\ mm$$

Considering welding area capability, 5mm rods were selected for fabrication of the prototype.

3.5.2 Agitator Shaft

Torque on the Agitator in rotation,

$$T = 2F_{blade} \times r$$
$$= 2 \times 222.8N \times 0.018m$$
$$= 8.021Nm$$

Agitator plate assembly is connected to shaft which transmits power from large pulley.

Considering safety factor of 4 Allowable shear stress,

$$\tau = \frac{402\ MPa}{4}$$
$$= 100.5MPa$$

Using the torsion formula,

$$T_{max} = \frac{\pi \times \tau \times\ d^3}{16}$$
$$d = 7.47\ mm$$

Shaft is fixed using bearings. Therefore 10 mm diameter is selected as the smallest diameter of the shaft. Middle section of the shaft has 17mm diameter, which facilitates the fabrication process.

Figure 3.7 Fabricated Shaft of the Agitator

3.5.3 Selection of Bearings

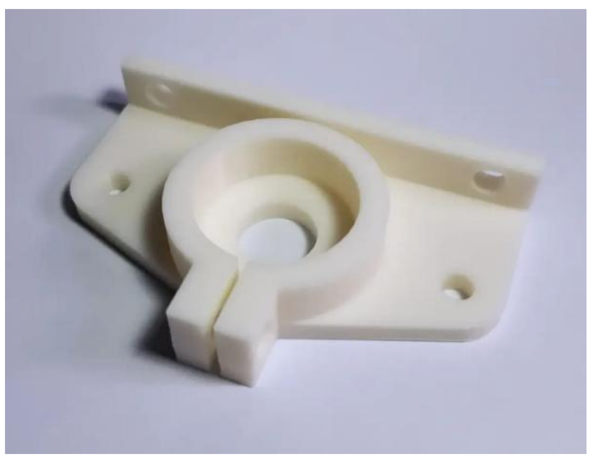
Bearings are placed in supporting the rotating shaft of the agitator, and the shaft of the large pulley. They must be selected with consideration for both radial and axial loads. In an industrial product, bearings are typically chosen based on load calculations and desired service life. However, since this phase of project involves a prototype. Long-term durability was not a primary constraint. Therefore, bearings were selected based on availability, compatibility with shaft diameter, and ease of installation [6],[7].

To accommodate both radial and axial forces that occur during the kneading operation, deep groove ball bearings were chosen, specifically bearing models

1. 6000 for large pulley shaft
2. 6003 for agitator shaft

These are widely available, cost-effective, and offer reliable performance under combined loading conditions[8].

To integrate the bearings into the machine frame, custom bearing mounts were designed and fabricated using additive manufacturing (3D printing). This allowed quick production of lightweight and dimensionally accurate amounts. The mounts were designed to be easily attachable to the frame and ensure proper alignment of the shaft during rotation. Figure 3.8 shows the bearing mount configuration used in the prototype.



Fabricated 3.8 Fabricated Bearing Mount

3.5.4 Kneading Vessel Design

The design of the kneading vessel needs to ensure effective mixing coverage and user-friendly operation. Due to the rotation pattern and coverage area of the selected agitator, a cylindrical drum was selected as the primary shape for the lower part of the vessel. The cylindrical geometry ensures consistent contact between the dough and the agitator.

To improve ergonomics during the loading and unloading of flour and dough, a cuboid shaped extension was added to the upper section of the vessel. This upper cuboid design provides a wider opening and flat surfaces that make handling easier. It also makes observation and cleaning of the interior easy.

Figure 3.9 Fabricated Vessel

3.6 Mechanical Transmission and Power System

3.6.1 Motor Selection

Motor was selected considering required power for rotation of agitator.

From the previous calculations,

$$torque\ of\ agitator = 8.021\ Nm$$

Required maximum rotational speed of the agitator is 130 rpm.

$$\begin{aligned} rotational\ velocity\ &= \ 2\pi \times f \\ &= 2\pi \times \frac{130}{60} \\ &= 13.61\ rads^{-1} \end{aligned}$$

Power required at maximum rotation speed, for

$$\begin{aligned} P &= T\omega \\ &= 8.021\ Nm \times 13.61 s^{-1} \\ &= 109.16\ W \end{aligned}$$

Considering the frictional losses and other negligence as described in Safety Factor section, the required power of the motor should have a higher safety factor. Therefore, safety factor was selected as 2.5.

$$\begin{aligned} Required\ rated\ power\ of\ motor &= \ 2.5 \times 109.16W \\ &= 272.9W \end{aligned}$$

Therefore 300 W motors should be selected.

Two main factors were considered in selecting the type of motor.

1. Ability to deliver the required torque
2. Support for variable speed and torque
3. Compatibility with the available power supply

Since this machine is intended for household applications, where a three-phase power supply is typically unavailable, the motor selection was focused on options that operate on a single-phase power supply[10]. This narrowed down the choices to the following three categories:

1. Single-phase induction motor
2. Single-phase synchronous motor
3. DC motor

A comparison of the characteristics of these motors, with emphasis on their suitability for this application is presented table 3.2.

Table 3.2 Comparison of Motors in Usage of the Machine

Feature	**Single-phase Induction Motor**	**Synchronous Motor**	**DC Motor (Brushed or Brushless)**
Speed Variation Availability	· Speed varies only slightly with load · External VFD needed for control	· Speed fixed by supply frequency · Difficult to vary without advanced control	· Wide, smooth speed control using voltage or PWM control
Starting Torque	· Moderate (capacitor-start types offer improved performance)	· Low – usually needs external starter or permanent magnets	· High (especially in brushed DC motors)
Speed Stability	· Poor – speed drops under load	· Excellent – maintains constant speed under load	· Moderate to excellent depending on control method
Cost	· Low – generally the most affordable motor type	· High – not cost effective for small scale applications	· Moderate – higher than induction motors but still affordable
Size and Weight	· Compact and widely available	· Bulkier compared to induction and DC motors	· Compact
Market Availability (300 W)	· Very high – commonly used in domestic appliances	· Low – rarely manufactured in small power ratings	· High – widely available in both brushed and brushless types

Considering these aspects mainly focusing on market availability, a 300 W DC motor was purchased from a second hand equipment supplier.

Figure 3.10 Purchased Motor

To verify the parameters tests were conducted using Bench DC supply, Tachometer, Ammeter and Voltmeter[10].

Figure 3.11 No Load Rotational Speed Test Using Tachometer

Table 3.3 Obtained Data from Motor Testing

Property	Value
Supply voltage	12V
No load rotation speed	2100 rpm
No load current	0.3 A
Winding resistance	4.5 Ω

3.6.2 Drive Mechanism

The initial drive system selected for the dough kneading machine was a gear setup, which could reduce motor speed and increase torque. To reduce costs and save time, the motor and gears were purchased from a second-hand equipment supplier, which helped avoid the need for custom gear fabrication. Only the gear housing needed to be fabricated for this setup. Helical gears were chosen because they produce less noise during operation and can handle higher torque compared to other gear types[6],[7].

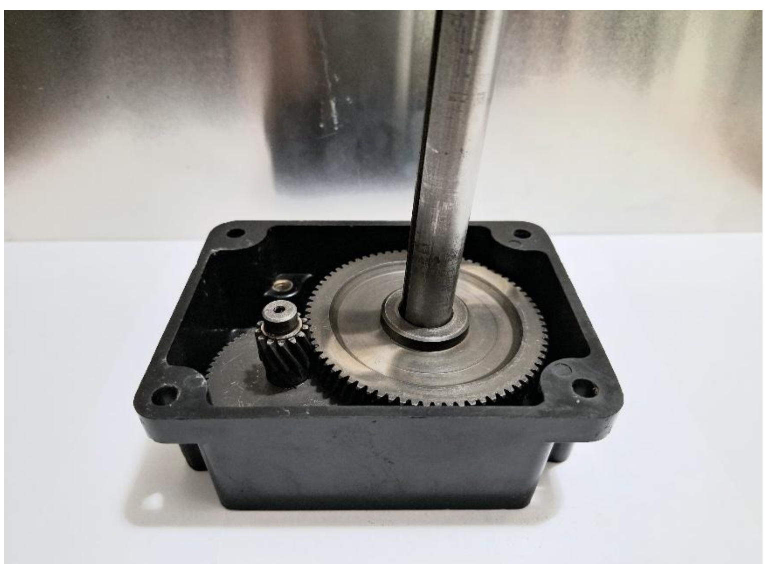


Figure 3.12 Helical Gear Wheels for Drive Speed Reduction

However, due to the breakdown of CNC lathe machines in the workshop, it was not possible to complete the required gear housing fabrication. As a result, an alternative solution was needed. A belt and pulley system were selected to replace the gear-based drive train. This system allowed the machine to continue functioning without depending on unavailable fabrication facilities, while still providing acceptable speed reduction and torque transfer for the application. Belt drive system,

For selecting the belt drive system, two belt types were introduced.

1. V- belt
2. Timing belt

Considering the high torque and low RPM requirements, a compact drive layout is necessary, and low maintenance is a priority. Therefore, a timing belt drive system is selected.

Selected motor had a maximum rotational speed of 2100 rpm at no load conditions. Therefore, timing pulleys were selected using standard sizes which have 11:70 grove ratios. [6].

Using the grove ratio,

$$
\begin{aligned}
Agitator\ no\ load\ speed\ &= \frac{11}{70} \times 2100rpm \\
&= 330\ rpm
\end{aligned}
$$

Large pulley was purchased and considering the speed ratio, the small pulley was designed and fabricated using additive manufacturing.

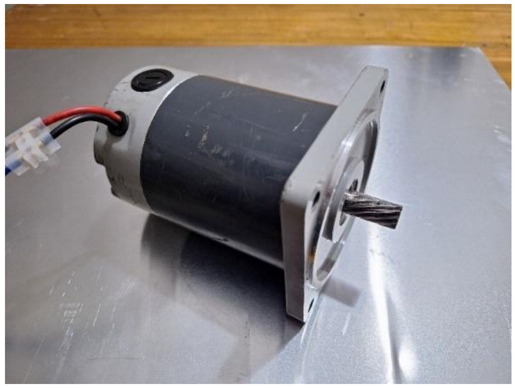


Figure 3.13 Helical gear teeth in the motor shaft

Shaft of the DC motor has helical gear teeth. That helical gear is useful in future developments as discussed in chapter 7. Therefore, instead of surfacing those gear teeth a small pulley with an integrated mounting part was fabricated using 3D printing using ABS.

Using the pulley grove ratio,

$$\begin{aligned} Torque\ on\ small\ pulley &= \frac{11}{70} \times 8.021\ Nm \\ &= 1.260\ Nm \end{aligned}$$

Using safety factor of 4,

$$\begin{aligned} \text{Design torque of pulley} &= 4 \times 1.260\text{Nm} \\ &= 5.04Nm \end{aligned}$$

Using this torque an Ansys simulation was done to verify that modeled pulley can withstand the torque of the belt.

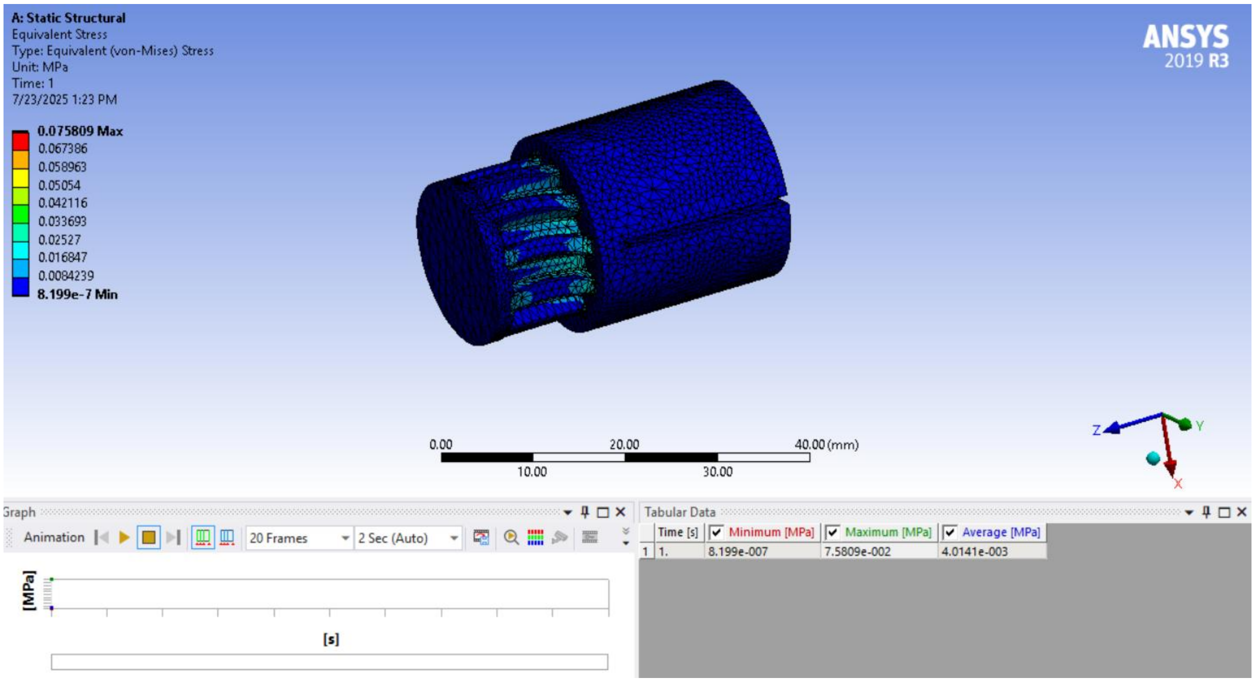


Figure 3.14 Stress Distribution of the Coupling

Maximum was 0.076 MPa, which is very less compared to yield stress of Acrylonitrile Butadiene Styrene (ABS). Therefore, it was used to additive manufacturing.

Figure 3.15 Fabricated Small Pulley

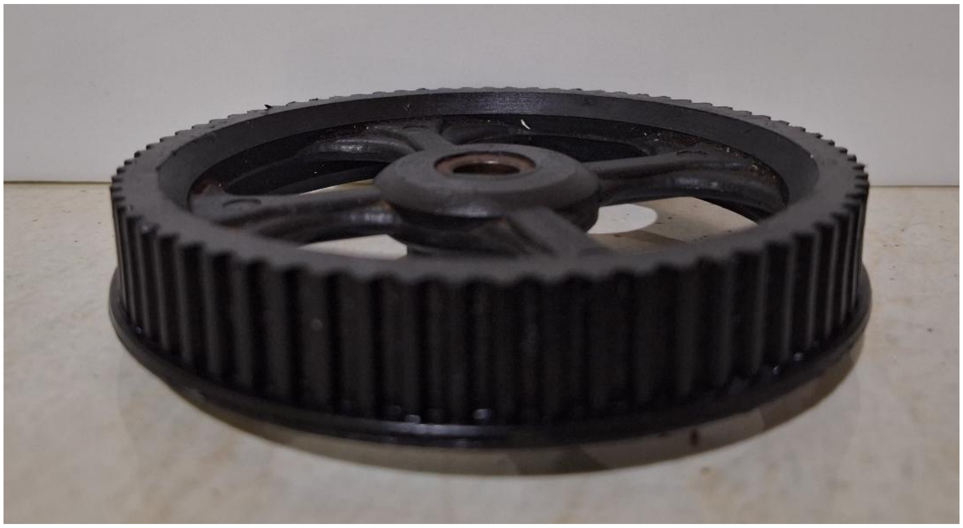


Figure 3.16 Purchased Large Pulley

Since maximum tension is due to torque of the large pulley, and it has 110 mm nominal diameter,

$$Maximum\ tension\ =\ T \times \frac{D}{2}$$
$$= 8.021Nm \times \frac{110\ mm}{2}$$
$$= 0.441N$$

Considering safety factor of 4,

$$ALlowable\ tension\ of\ belt = 4 \times 0.441N$$
$$= 1.76N$$

Selected timing belt is 210XL. It was selected using manufacturers data catalog which is shown below[11].

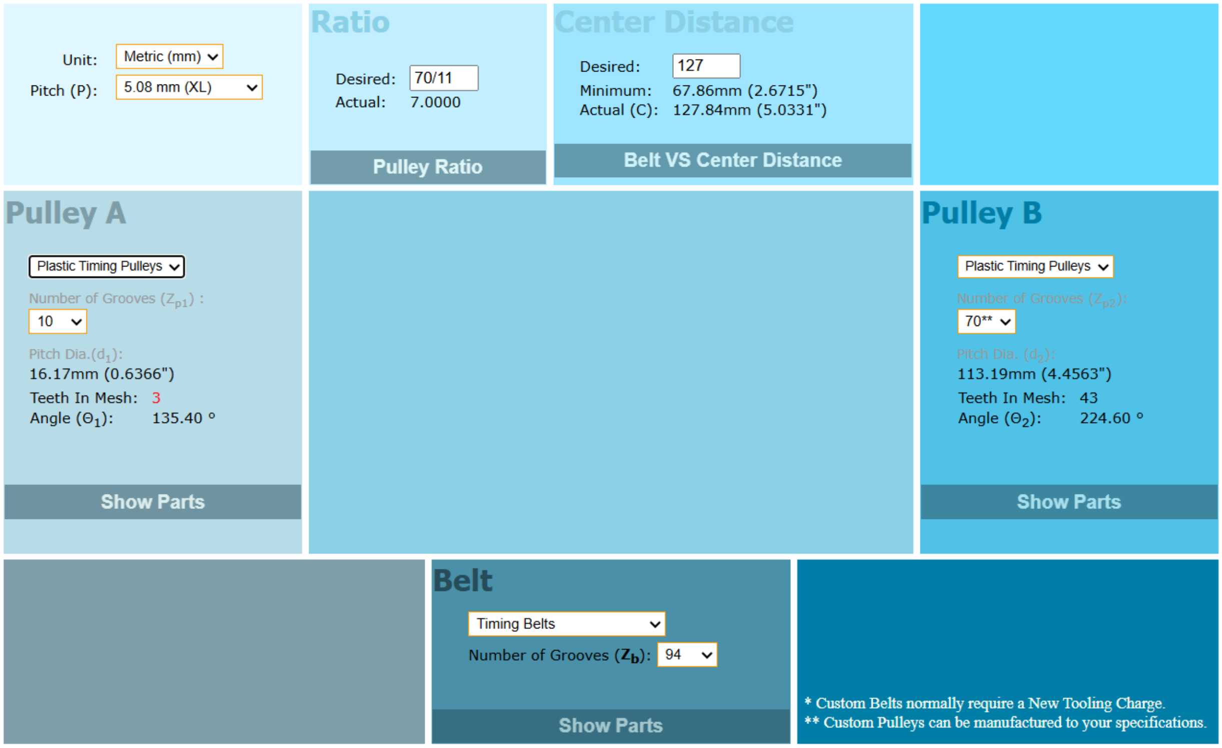


Figure 3.17 Interface of Timing Belt Selection Tool (https://sdp-si.com/tools/center-distance-designer.php)

3.6.3 Selection of Coupling

A shaft coupling was used to connect the agitator to the shaft of the large timing pulley. A self-adjusting coupling can transmit torque smooth and accommodate any minor misalignment. The selected coupling needed to withstand the torque generated during the kneading process without failure or excessive deformation.

Based on the torque requirements of the system which is 8.021 Nm. A standard flexible coupling was chosen from a commercial coupling manufacturer. According to the product specifications, the selected coupling can handle a maximum allowable torque of 10 Nm. Therefore, it provides an adequate safety margin over the expected operating torque of the prototype.

This selection allowed for quicker integration and avoided the need for custom fabricated coupling components. The coupling also allows easy disassembly during testing and maintenance.

Figure 3.18 Coupling Used for Connecting the Agitator Shaft

3.6.4 Power Supply Considerations

Power is supplied by a 10A DC power supply which can convert AC 230V into DC 12V.

Figure 3.19 Used AC DC converter

3.6.5 Speed Regulation

Speed regulation can be done by various methods. The best possible method was using a pulse width modulation(PWM) circuit[12]. Therefore, 10A PWM circuit which has the following specifications

- The input supply voltage range is 12V-40VDC.
- Power: 0.01-400w
- frequency 13khz
- PWM pulse width speed range: 10% – 100%
- Incorporate a 10A fuse, and with reverse connection power supply protection function.

Figure 3.20 Used PWM Controller

3.7 Modeling Tools

The whole design was modeled using SolidWorks 2023 version. Drawings which were used to fabricate the parts were attached in the appendices section.

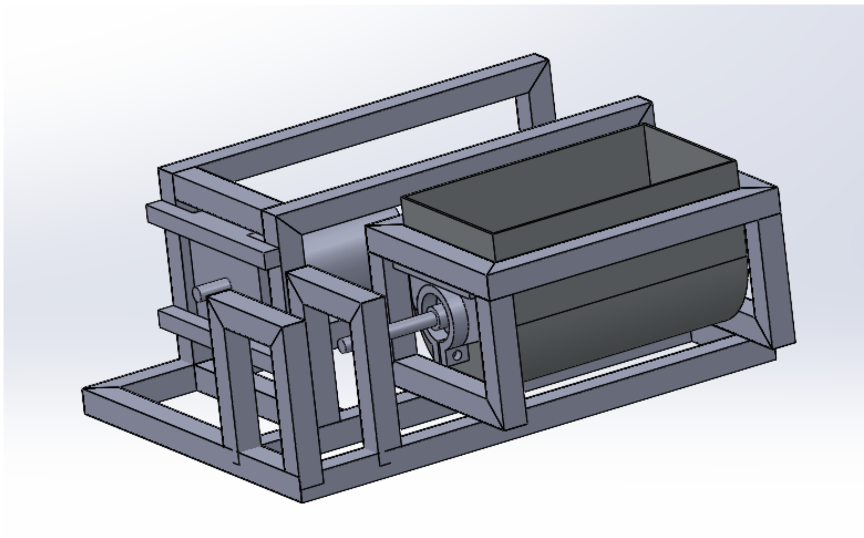


Figure 3.21 Solid Model of the Metal Structure

3.8 Fabrications

The prototype of the dough kneading machine was fabricated using a range of conventional and modern manufacturing processes. Each component was manufactured using appropriate techniques based on functionality, material type, required tolerances, and assembly needs. The table 3.4 summarizes the methods used for each major component

Table 3.4 Components and Their Fabrication Methods

Component	**Fabrication Methods**
Agitator	Boring, Facing, Sheet Metal Forming, Welding
Vessel	Sheet Metal Forming, Riveting, Adhesive Sealing
Frame	Arc Welding
Bearing Mounts	3D Printing (Additive Manufacturing, ABS)
Small Pulley	3D Printing (Additive Manufacturing, PLA/ABS)

This combination of processes allowed for a cost-effective, modular, and easily modifiable prototype suitable for testing and performance evaluation. Special attention was given to achieving tolerance, ease of assembly, and user safety during operation.

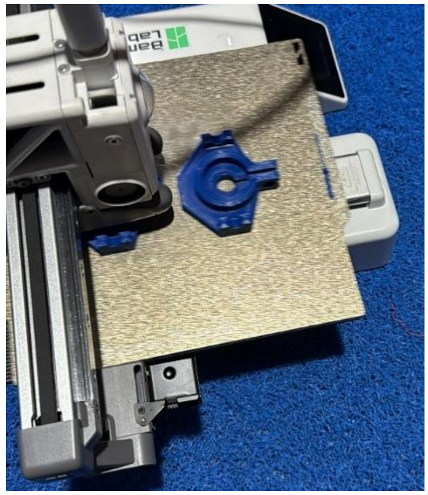


Figure 3.22 Additive Manufacturing the Bearing Bracket

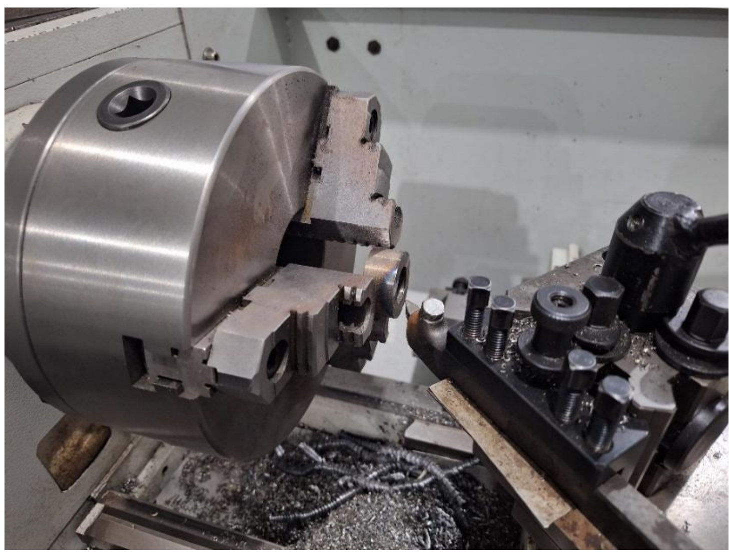


Figure 3.23 Facing the metal Components of the Agitator

3.9 Fabricated Prototype

The final fabricated prototype is shown in figure 3.24. External parts are painted, and components are covered to meet safety regulation and aesthetic appearance.

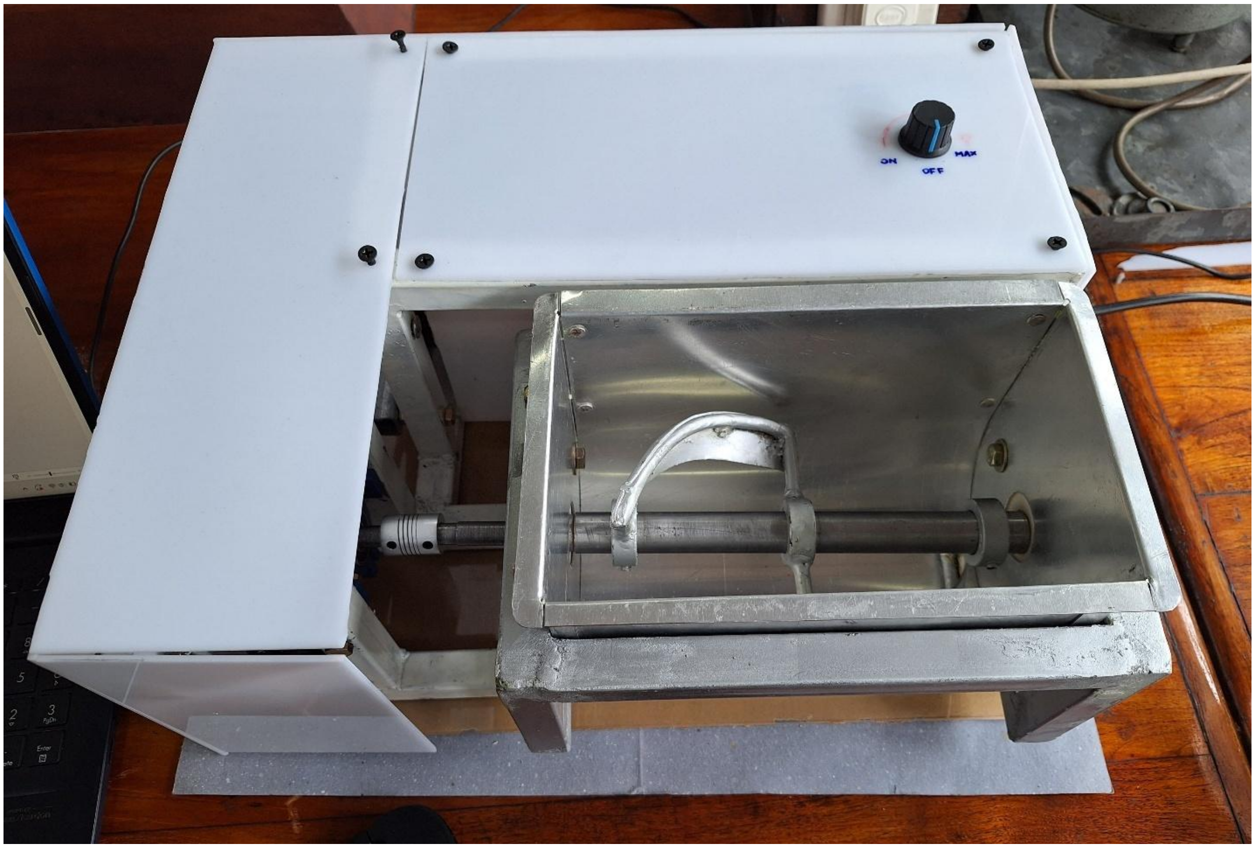


Figure 3.24 Fabricated Prototype

4. EXPERIMENT AND RESULTS

4.1 Objective

The objective of this experiment was to evaluate the performance of the developed dough kneading machine and compare it with existing kneading methods which are manual kneading and handheld mixer. The primary focus was to determine the time required by each method to achieve uniform mixing. It was measured by using food dye distribution as the visual indicator of mixing effectiveness.

4.2 Materials and Equipment

The following materials and equipment were used for the experiment.

Table 4.1 Used Material Quantities for the Experiment

Material	**Amount**
Wheat Flour	500 g
Water	270 ml
Food Dye	0.5 ml

Equipment

- Developed Dough Kneading Machine (prototype)
- Handheld Dough Mixer
- Stopwatch
- Measuring cylinder
- Weighing scale
- Mixing vessels

4.3 Experimental Setup

In each test, 500 g of wheat flour was placed in the mixing vessel. Then, 0.5 ml of food dye was dropped evenly across the surface of the flour to simulate visible non-uniformity.

Figure 4.1 Distribution of the Food Dye on Flour

Water (270 ml) was then added gradually and distributed to ensure even moisture. This same setup was applied across all three kneading methods to maintain consistent starting conditions

4.4 Testing Procedure

Each kneading method was operated until the food dye appeared fully and evenly mixed throughout the dough. The time taken to reach this state of uniform color was recorded using a stopwatch. The same observer evaluated all three tests to ensure consistent judgment

Figure 4.2 Manual Kneading Process

Figure 4.3 Handheld Mixer Kneading Process

Figure 4.4 Dye Distribution of the Developed Machine Vessel

Figure 4.5 Kneading Process of Developed Machine

4.5 Results

The times recorded for each kneading method to achieve uniform mixing are presented in table 4.2.

Table 4.2 Time to Achieve uniform Mixing Tested Methods

Method	**Time (Minute: Seconds)**
Manual Kneading	10:37
Handheld Mixer	5:04
Developed Kneading Machine	6:27

The results indicate that the developed dough kneading machine significantly reduces kneading time compared to manual kneading, offering a time saving of over 4 minutes. Although the handheld mixer was faster, the developed machine operated with less user involvement and produced consistent mixing results. This confirms the effectiveness of the design for home or small business use where ease of operation is important.

5. DISCUSSION

5.1 Assumptions Made

Throughout the design, simulation, and testing phases of the dough kneading machine, several assumptions were made to simplify the analysis and development process. These assumptions are listed below. These assumptions allowed the project to progress under simplified and controlled conditions. They help to have a reasonable level of accuracy for prototype development and performance evaluation.

5.1.1Material Consistency

All performance simulations and design calculations were based on the properties of wheat flour dough. It was assumed that other types of flour (e.g., rice flour, finger millet flour) would exhibit similar rheological behavior during kneading. Though their viscoelastic properties may vary.

5.1.2 Uniform Dye Distribution

During the performance test, food dye was used as a visual indicator to evaluate mixing quality. It was assumed that the distribution of dye across the flour surface and subsequent uniform coloration accurately represented the degree of dough mixing.

5.1.2 Neglecting Manufacturing Tolerances

During welding processes, small dimensional inaccuracies were assumed to have negligible impact on overall performance and assembly. Component alignment and clearances were considered ideal during design.

5.2 Design Limitations and Challenges

Although the development of the dough kneading machine met its primary objectives, several limitations and challenges were encountered throughout the design and prototyping process. These limitations highlight areas where the design can be refined to improve safety, performance, and user experience.

5.2.1 Material Substitutions in Prototype

Due to the high cost and bulk purchasing requirement of food-grade stainless steel (SS304), alternative materials such as mild steel, zinc-coated aluminum, and ABS plastic were used in the prototype. These materials are not ideal for long-term use in food processing and may affect hygiene and durability.

5.2.2 Manual Dough Removal and Loading

The current design requires the user to manually load raw materials and remove kneaded dough. The lack of an automated discharge system can reduce convenience, especially when handling sticky or high-moisture doughs. Removing of dough is difficult due to the agitator design and the location of the opening.

5.2.3 Vibration and Noise

Minor vibrations and mechanical noise were observed during operation, likely due to

1. imperfect shaft alignment
2. imbalance in the agitator
3. looseness in the 3D-printed pulley.

These factors can affect comfort and long-term reliability.

5.2.4 Short Operation Duration for Testing

The performance tests were conducted over a short time span, without evaluating long-term endurance, motor heating effects, or component fatigue under extended use.

5.3 Fabrication Difficulties

During the fabrication of the dough kneading machine prototype, several practical challenges were encountered. These difficulties appeared due to the limitations in material availability, fabrication tools, and precision handling of parts.

5.3.1 Welding Challenges

Arc welding was used for frame and agitator assembly. Difficulties were faced in achieving clean and accurate welds due to thin material sections, warping from heat, and alignment issues during welding of the agitator arms.

5.3.2 3D Printing Tolerances

The 3D-printed parts, including the bearing mounts and small pulley, required post processing. Inaccurate fits, slight warping, and layer misalignment in prints made assembly challenging. Additional standing and adjustments were required for proper function.

5.3.3 Misalignment in Drilling and Shaft Mounting

Drilling precise holes for bearing and shaft alignment using manual tools was difficult. Minor misalignment led to increased friction and vibrations during operation, affecting smooth rotation and bearing performance.

5.3.4 Sheet Metal Handling

Sheet metal forming for the vessel required manual bending and riveting. Maintaining consistent curves and achieving clean joints without specialized jigs or rollers was challenging. Some deformation occurred, which slightly affected the fit and finish.

5.3.5 Fastening and Assembly Issues

Assembling parts with bolts and nuts required careful alignment, especially around the bearing mounts and frame structure. The use of adhesives in the vessel seam area was selected due to difficulty in welding thin sheets. It introduced concerns about long-term bonding strength.

5.3.6 Limited Access to Tools

Fabrication was carried out using available workshop tools, which limited machining precision. Lack of access to CNC machines or TIG welding affected the quality and finish of components.

Despite these difficulties, the prototype was successfully assembled and functioned as intended during testing. These experiences provided valuable insight into the practical considerations that must be addressed in future designs for improved manufacturability and performance.

5.4 Performance Observations

The performance of the developed dough kneading machine was evaluated through experimental comparison with manual kneading and a handheld mixing machine. Several key observations were made during testing, covering mixing quality, time efficiency and user involvement.

5.4.1 Unloading and Cleaning

Due to compact design and current agitator is difficult to detach, unloading the processed dough and cleaning after the process is difficult.

5.4.2 Mixing Time Efficiency

The developed machine achieved uniform dough mixing in 6 minutes and 27 seconds, which is faster than manual kneading (10:37) and slightly slower than the handheld mixer (5:04). This result indicates that the prototype performs efficiently, balancing speed with mechanical consistency.

5.4.3 Mixing Effectiveness

In the end of the kneading process there were some unmixed flour particles in the edges of the vessel as seen in the figure

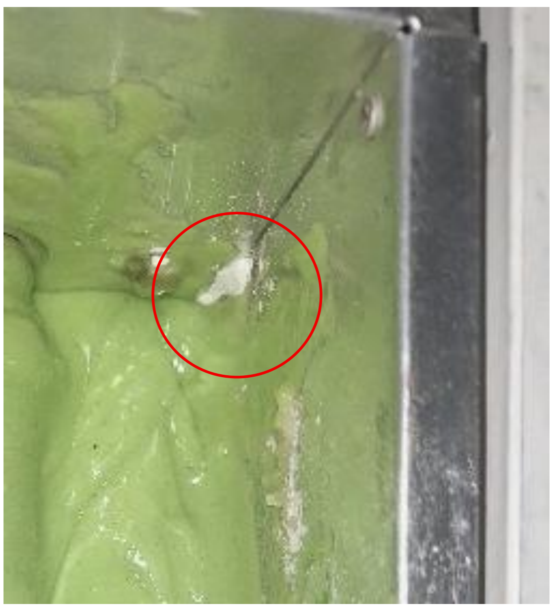


Figure 5.1 Unmixed Flour particles in the Edges of the Vessel

This shows that edges are not properly involved in kneading. Manually transferring those particle in to middle of the vessel is required.

5.4.4 User Involvement

One of the most noticeable benefits was the reduction in manual effort. Unlike manual kneading and handheld mixers, the developed machine required minimal user involvement. It makes more convenient for users of different age groups.

5.4.5 Motor and Transmission Response

The motor was able to maintain sufficient torque for dough movement without stalling. The timing belt drive system functioned effectively, with no slippage. However, there was a slight increase in belt temperature after prolonged use, suggesting tension or alignment adjustments may be beneficial.

These observations confirm that the developed prototype performs reliably under test conditions, meeting its primary design goals. With improvements, it can be further optimized for performance, safety, and user experience.

5.5 Summary of Learning Outcomes

The process of designing, fabricating, and testing the dough kneading machine provided valuable hands-on experience and insight across multiple areas of engineering practice. The key learning outcomes from this project are summarized below.

1. The project highlighted the importance of designing with manufacturing feasibility in mind. Several design features had to be adjusted based on material availability and limitations of workshop tools, emphasizing the real world constraints that affect theoretical designs.
2. The use of Ansys Fluent simulations to compare agitator designs demonstrated how computational tools can guide component selection before physical prototyping. It reinforced the value of simulation in reducing trial-and-error and optimizing design performance.

3. Practical knowledge in shafts, couplings, bearing selection, and power transmission (belt drives) was gained. Each decision required balancing theoretical calculations with practical factors like availability and ease of installation.
4. The project involved hands-on experience with milling, drilling, welding, 3D printing, and sheet metal work. It developed skills in aligning parts, managing tolerances, and solving unexpected assembly issues.
5. Several compromises had to be made due to limitations in budget, tools, and materials. Learning how to adapt designs, simplify components, and troubleshoot during assembly enhanced practical engineering judgment.
6. Setting up and executing a controlled experiment to compare kneading performance helped reinforce the importance of standardized testing, consistent evaluation parameters, and clear documentation of results.

This project served as a comprehensive learning experience, bridging the gap between academic knowledge and practical application, and provided a foundation for approaching future product development with confidence and clarity.

6. CONCLUSION

The primary aim of this project was to design, fabricate, and evaluate a small to medium-scale dough kneading machine that is affordable, easy to use, and effective for domestic and small business applications. The project successfully demonstrated the feasibility of using a horizontal kneading configuration with a plate-type agitator, which showed improved mixing uniformity through computational simulation and practical testing.

The machine has a 300W DC motor, a timing belt transmission system, and modular components manufactured through both conventional and additive processes. It achieved reliable performance with minimal user involvement, offering a noticeable reduction in kneading time compared to manual methods. Furthermore, the design emphasized safety, compactness, and adaptability for different flour types.

Although several challenges were encountered during fabrication, such as misalignments, welding difficulties, and material limitations, the overall prototype functioned as intended. The project outcomes validated the design choices made and highlighted the importance of balancing theoretical analysis with practical constraints.

This project not only delivered a functional prototype but also contributed to the understanding of small-scale food machinery design, simulation-driven optimization, and hands-on manufacturing. The lessons learned pave the way for future development and commercialization of an improved version of the dough kneading machine.

7. FUTURE WORK

7.1 Design Improvements

Although the prototype achieved its functionality, several design aspects can be used to improve usability, safety, and performance.

1. Using the available gear mechanism will give a compact design and improved efficiency compared to belt drive.
2. Redesign the agitator to allow easy removal for cleaning and maintenance. A quick-release mechanism could simplify unloading and reduce cleaning effort.
3. Unmixed flour particles can be stay in the edges of the vessel. Therefor the shape of the vessel and agitator should be improved to overcome this issue.
4. Integrate a tilting mechanism or bottom-opening system to dough removal will help for sticky or high-moisture doughs.
5. Use better shaft alignment techniques, balanced agitator blades, and damping supports to reduce operational vibration and noise.
6. Alternative for the steel frame can decrease the weight of the machine and it can make the machine more compact.

7.2 Material Upgrades

1. Replace mild steel and zinc-coated aluminum with Stainless Steel 304, ensuring long-term corrosion resistance and having food safety standards.
2. Replace adhesive bonding in the vessel with TIG welding or food-safe mechanical fasteners to ensure hygiene and durability.
3. Using machined or cast metal parts for components like the pulley and bearing mounts, will give better strength, dimensional accuracy, and long-term reliability.

7.3 Automation and Control Enhancements

The current machine operates manually with a PWM-based speed controller. To modernize and optimize the system.

1. A microcontroller-based interface (e.g., Arduino) will allow users to select kneading durations and speeds for different recipes.
2. Integrating a timer or torque based cut off mechanism can be used stop the machine automatically when kneading is complete.

7.4 Long-Term Testing and Evaluation

Testing in this project was limited to short, single-batch experiments. For validation and commercial feasibility, longer evaluations are needed

7.5 Scaling Up for Small Business Use

The current design serves small batch production. With further development, it can be scaled for small bakeries or commercial kitchens.

1. Increased Capacity - Use a larger vessel and more powerful motor to handle up to 5–10 kg of dough per batch.
2. Modular Construction - Redesign the frame and housing to allow for easy disassembly, upgrade, and transport.
3. Compliance with Food Industry Standards - Ensure that the final product design aligns food safety and machinery standards.
4. Market Oriented Packaging - Consider aesthetics, portability, and maintenance access in the external design to improve commercial appeal.

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