# *Chakli Making Machine for Household Use*

Design of Machine Components Project 1

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# I. PROBLEM STATEMENT

Design a suitable mechanical system for an electrically operated portable *Chakli* making machine for household use.

Specifications:

Capacity: 4 *Chakli* in less than 30 seconds.

Space constraints: 0.5 m X 0.5 m X 0.5 m

# II. SOLUTION

Application: Make spiral shaped *Chakli* from *Chakli* dough

Capacity: A batch of 4 in 25 seconds, 2.5 L (approx. 80 *Chakli*)

Space constraints: 0.5 m X 0.5 m X 0.5 m

Working condition: Electrically operated

# III. THEORY

*Chakli* is a widely eaten savory snack all over India. It is a spiky fried spiral made from flour of rice, Bengal gram and black gram. Though simple in concept, the actual process of making the spiral requires lot of practice and time. The proposed design solution is a portable machine for household use that can produce a batch of 4 *Chakli* in 25 seconds and has a capacity of holding 2.58 L of dough. The *Chakli* Maker is composed of two main assemblies-

a. Table moving in spiral motion
b. Dough extruder Assembly at the top

The table is a flat circular plate that moves along a spiral groove in a baseplate with the help of a rotating slider. The dough extruder uses a power screw to force the *Chakli* dough through 4 equally spaced nozzles on the base of the container.

The basic principle of working is,

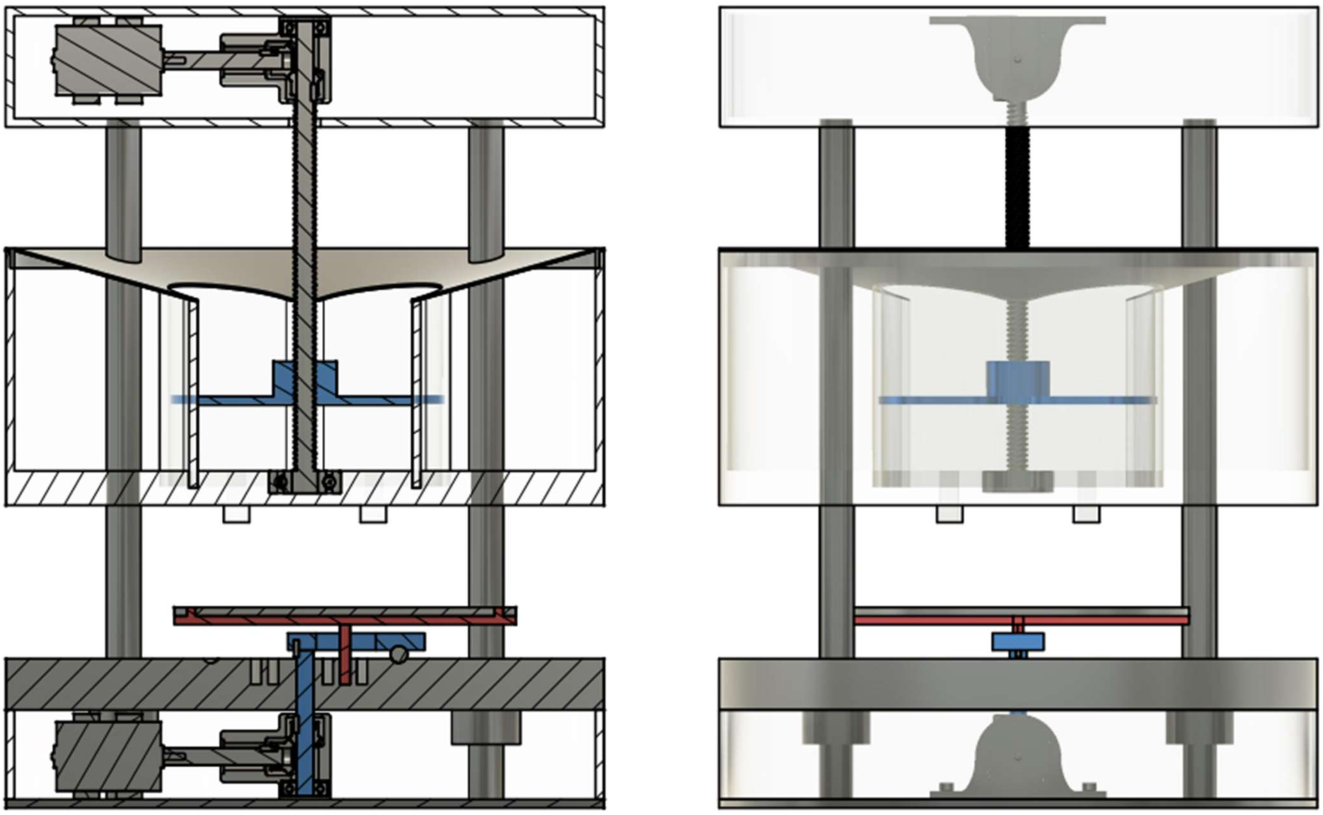
If extruded dough falls on a table moving in a spiral, the dough will form a spiral at the end of rotation. The table has a follower attached which can move in a spiral groove. The follower passes through a slotted slider which is connected to a shaft and can rotate about the central axis of the baseplate. When the slider is made to rotate it pushes the follower and subsequently the table along the spiral groove. This creates the desired spiral motion. The dough extruder uses a power screw in 1st mode of operation (rotating screw, translating nut) to press the dough out of four nozzles.

**Advantages:**

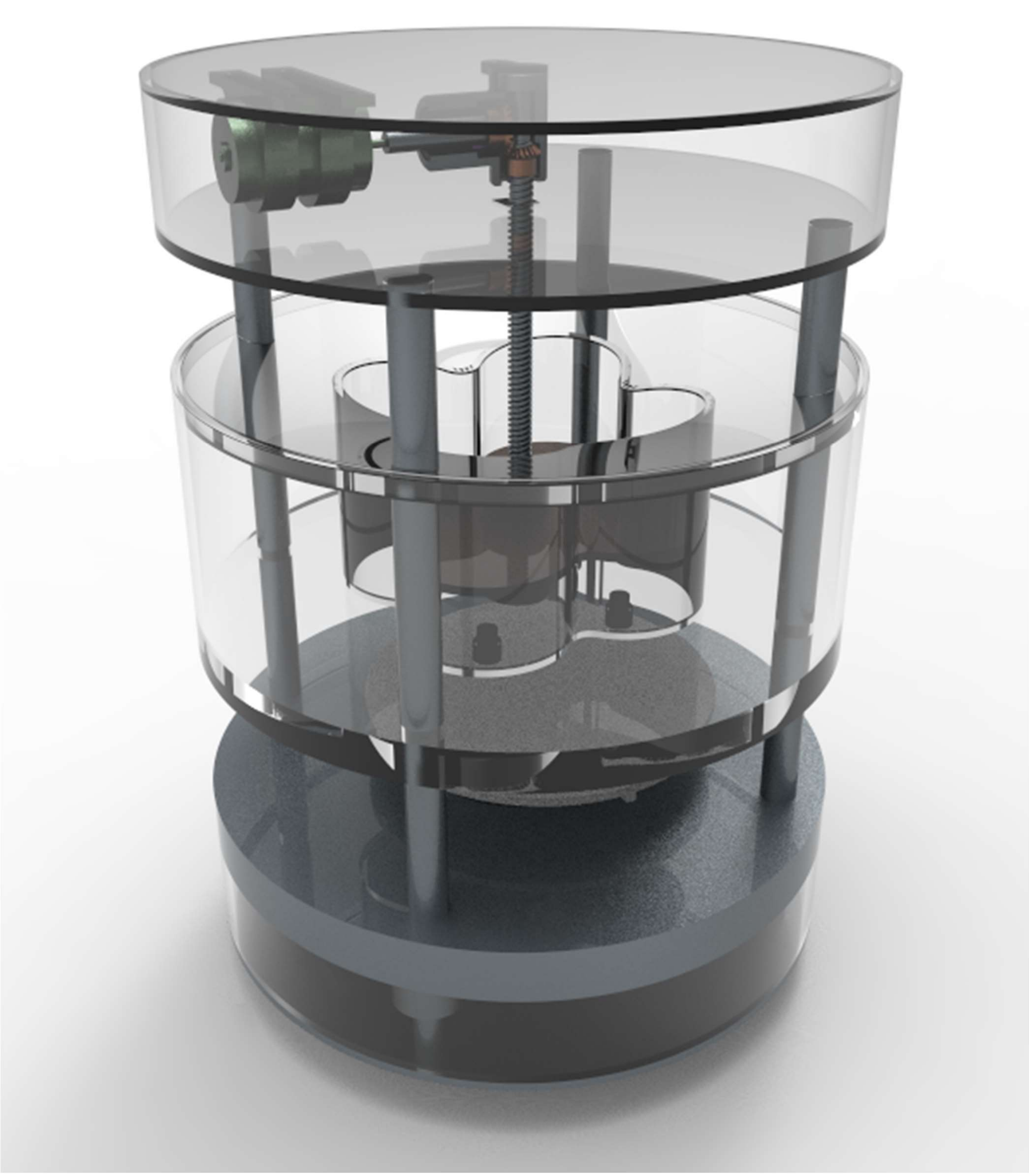
1. Simple to understand mechanism, can be easily maintained.
2. High Output and easy to use.
3. Perfect shaped *Chakli* can be obtained every time

**Disadvantages:**

1. *Chakli* of only one size can be made.
2. High friction in threads causes rapid wear of the screw or the nut.
3. The nut is usually made of soft material and needs replacement when worn out.
4. Machine is not as compact due to the power screw.



Orthographic views



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# IV. DESIGN PROCEDURE

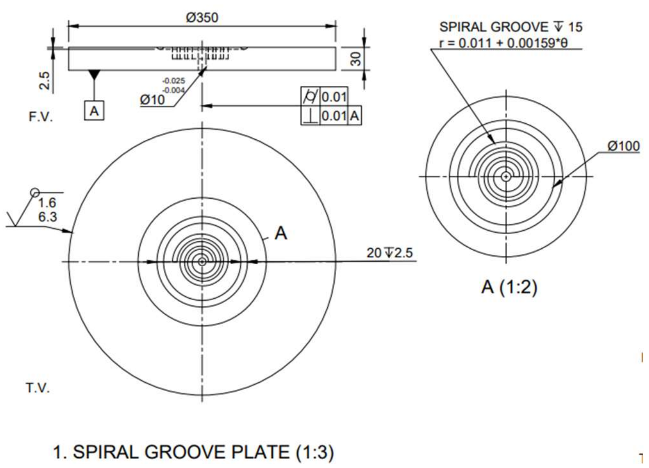
## A. Spiral Groove Parameters

The Archimedean spiral parameters are calculated after measuring the profile of *Chakli*,

$$r = 0.011 + 0.00159 * \theta \text{ m}$$

where, $\theta$ is the angular displacement

The spiral has 2.5 turns and a length of 37 cm, the groove is 6mm wide. A 5 mm wide circular groove of radius 80 mm has also been cut into the base plate to act as a bearing for the slotted slider and its shaft.




Orthographic views

## B. Follower and Table

The polyamide table is a circular plate of diameter 200mm and thickness 5mm capable of holding 4 *Chakli* at a time and can be clipped onto the follower frame. The follower is a cylindrical with one end being attached to the plus shaped follower frame via an interference fit.

Considering a total weight of *Chakli*, table and frame to be 2 kg, 19.6 N compressive load acts on the follower when the torque is 0.5 Nm

**Material Selection:**

Polyamide

**Material Properties:**

$S_{yt} = 70$ N/mm$^2$

$S_{sy} = 35$ N/mm$^2$

**Design Calculations:**

Diameter (d) = 6 mm

Area in shear (A) = $2\,\frac{\pi d^2}{4}$ = 56.55 mm$^2$

Radial distance for torque application = 11 mm

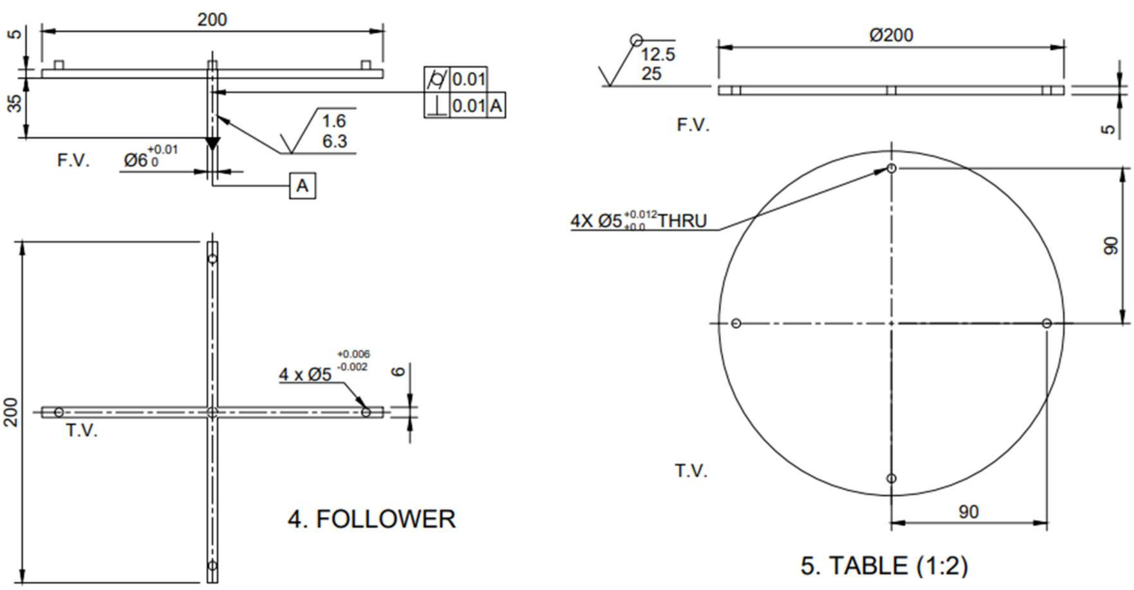
Tangential force (F) = $\frac{\text{Torque}}{\text{Radius}}$ = 45.45 N

Shear stress = $\frac{\text{Force}}{\text{Area}}$ = <u>0.8038 N/mm$^2$</u>

Compressive stress = $\frac{\text{Force}}{\text{Area}} = \frac{2*9.81}{\text{Area}}$ = <u>0.6939 N/mm$^2$</u>

Total stress,

$$\sigma_{\max} = \frac{\sigma_c}{2} + \sqrt{(\frac{\sigma_c}{2})^2 + \tau^2} = \underline{1.22\ \text{N/mm}^2}$$




Orthographic views

## *C. Rotating Shaft and Slot*

The rotating shaft is used to provide rotational motion to the slotted slider.

**Material Selection:**

Polyamide

**Material Properties:**

$S_{yt}$ = 70 N/mm$^2$

$S_{sy}$ = 35 N/mm$^2$

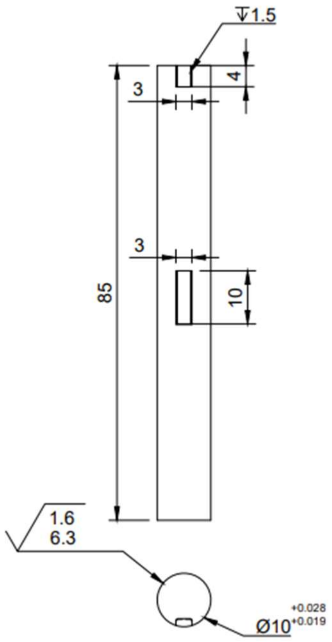
**Design Calculations:**

Diameter (d) = 10 mm

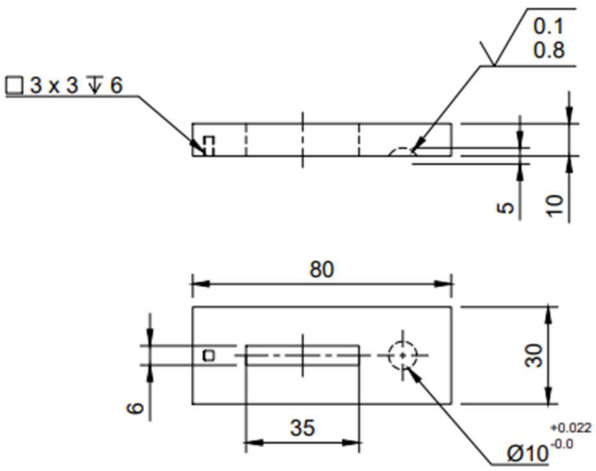
Torsional shear stress $\tau = \frac{M_{t*r}}{J}$ = $\underline{3.31\ \text{N/mm}^2}$

Factor of safety ($f_s$) = 10.57

Rotating slot plate is attached to the shaft with a parallel sunk key. The plate provides a path for the slider to slide and follow the spiral motion path.




5. SHAFT




2. ROTATING SLOT (1:1)

Orthographic views

## *D. Parallel Sunk Key*

**Material Selection:**

Polyamide

**Material Properties:**

$S_{yt}$ = 70 N/mm$^2$

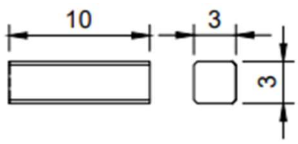
$S_{sy}$ = 35 N/mm$^2$

**Design Calculations:**

Tangential force = 100 N

Selected key dimensions –

Width = 3 mm




ALL CHAMFERS EQUAL 0.5 X 45°

6. PARALLEL KEY

Orthographic views

Height = 3 mm

Length = 10 mm

Keyway depth = 1.8 mm

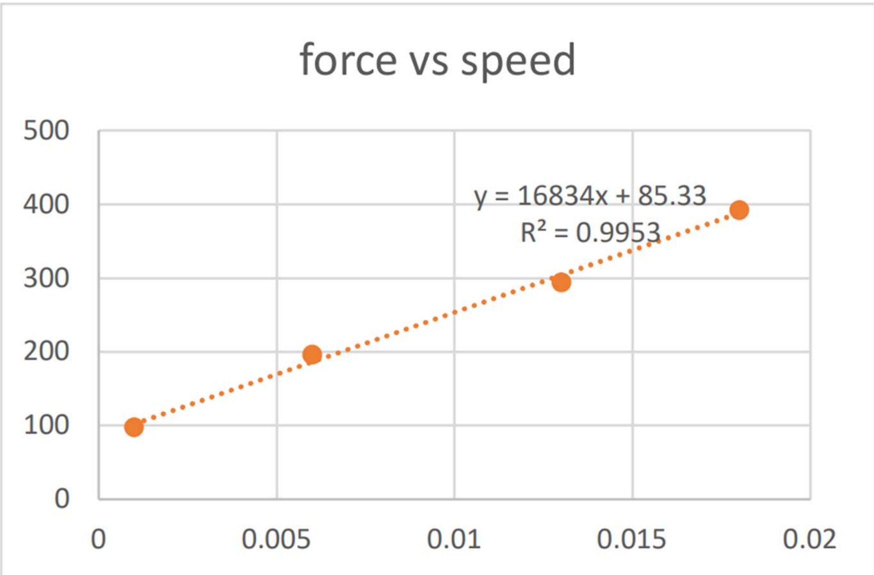
Shear stress = 0.0083 N/mm$^2$

Compressive stress = 27.78 N/mm$^2$

## *E. Extrusion Force Calculations*

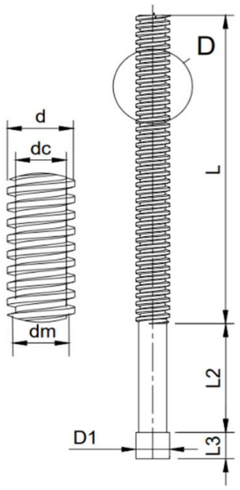
The force required to extrude the dough was measured experimentally and a speed force relationship was deduced.

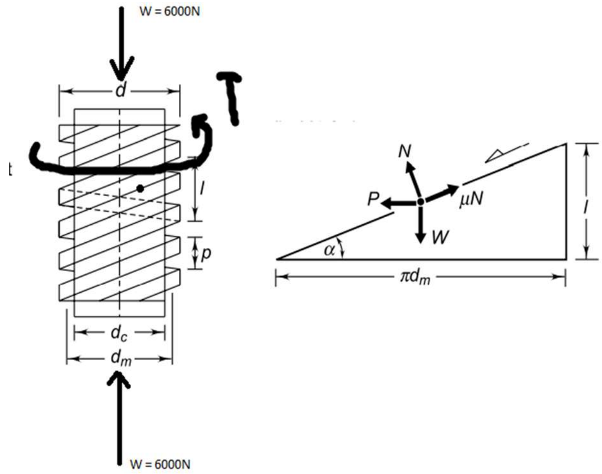
| Force of extrusion | | Speed of extrusion | |
|---|---|---|---|
| kgf | N | cm/s | m/s |
| 10 | 98.1 | 0.1 | 0.001 |
| 20 | 196.2 | 0.6 | 0.006 |
| 30 | 294.3 | 1.3 | 0.013 |
| 40 | 392.4 | 1.8 | 0.018 |




Considering speed of extrusion to be **0.0148 m/s** the required force for an area of **0.02m$^2$** is **1800N**

## *F. Power Screw*




Design parameters

**Material Selection:**
Steel 30C8
Steel is chosen as it is the recommended material for power screws.
The grade is chosen after various trials.

**Material Properties:**
Tensile Yield Strength ($S_{yt}$) = 400 N/mm$^2$.

**Design Calculations**

Diameter, pitch, and number of starts of screw-
Compressive stress experienced by lower portion of screw,

$S_{yc} = S_{yt} = 400 \text{ N/mm}^2$

$\sigma_c = \frac{S_{yc}}{f_s} = \frac{400}{3} = 133.33 \text{ N/mm}^2$

An ISO Metric trapezoidal threaded power screw of nominal diameter (d) of 16 mm, pitch (p) of 4 mm and triple start thread is selected. A pair of case-hardened steel screw and bronze nut is suggested

**Standard size of power screw selected – Tr 16 x 12 (P4)**
Lead of screw,

$l = 3p = 12 \text{ mm}$

Mean diameter of screw,

$d_m = d - 0.5p = 14 \text{ mm}$

## Torque required to extrude dough

Helix angle,

$$\alpha = \tan^{-1}\frac{l}{\pi d_m} = 15.26°$$

Thread angle for ISO Metric Trapezoidal threads is $\theta = 15°$

Considering average friction coefficient between steel screw and bronze nut = 0.08,
Friction angle,

$$\varphi = \tan^{-1}\mu = \tan^{-1}(0.08) = 4.571°$$

Since friction angle (φ) < helix angle (α),
The power screw is non-self-locking. Thus, no force is required to overcome friction in the threads, force required to extrude the dough is,

$$P = \frac{W(\mu \sec\theta - \tan\alpha)}{(1 - \sec\theta \tan\alpha)} = 654.98\text{N}$$

Turning Moment

$$M_t = P\frac{d_m}{2} = 4584.94\ Nmm \ \approx 5\ Nm$$

## Stresses in power screw-

Core diameter,

$$d_c = d - p = 11.5\ \text{mm}$$

Compressive stress,

$$\sigma_c = \frac{W}{\frac{\pi}{4}d_c^2} = 17.3295\ \frac{N}{mm^2}$$

Torsional stress,

$$\tau = \frac{16M_t}{\pi d_c^3} = 15.3535\ N/mm^2$$

Total stress,

$$\tau_{max} = \sqrt{(\frac{\sigma_c}{2})^2 + \tau^2} = 17.6297\ N/mm^2$$

According to maximum shear stress theory,

$$S_{sy} = 0.5\ S_{yt} = 200\ N/mm^2$$

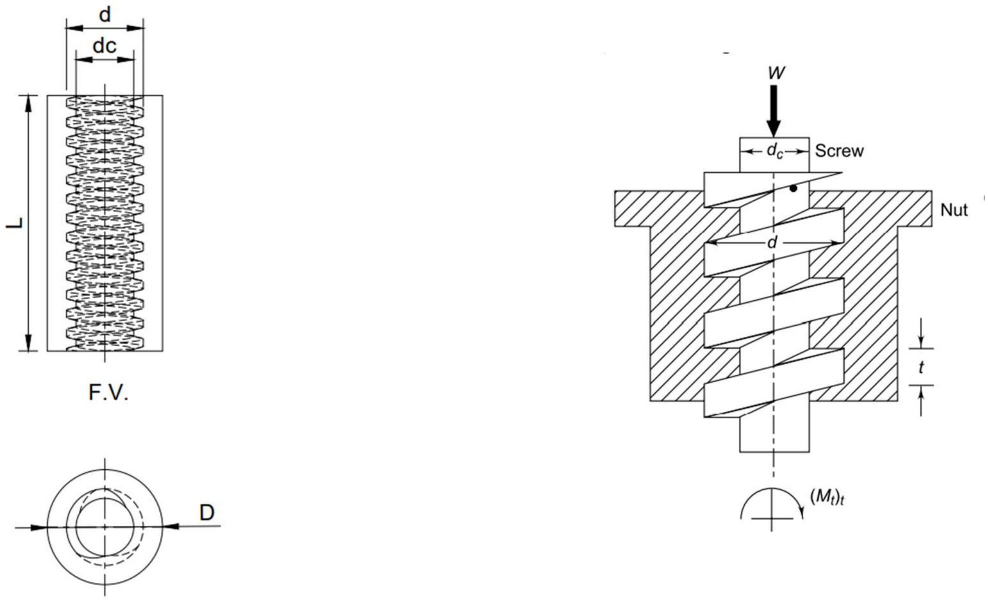
$$f_s = \frac{S_{sy}}{\tau_{max}} = 11.34$$

## Efficiency of the power screw-

$$\eta = \frac{W * \tan\alpha}{P} = 74.97\%$$

## *G. Power Screw Nut and extruder plate*

**Material Selection:**
Bronze is selected as it is recommended nut material for steel screws.




Design parameters

## Length of nut-

Unit bearing pressure ($S_b$) for steel screw and bronze nut is 18 N/mm$^2$
Number of threads,

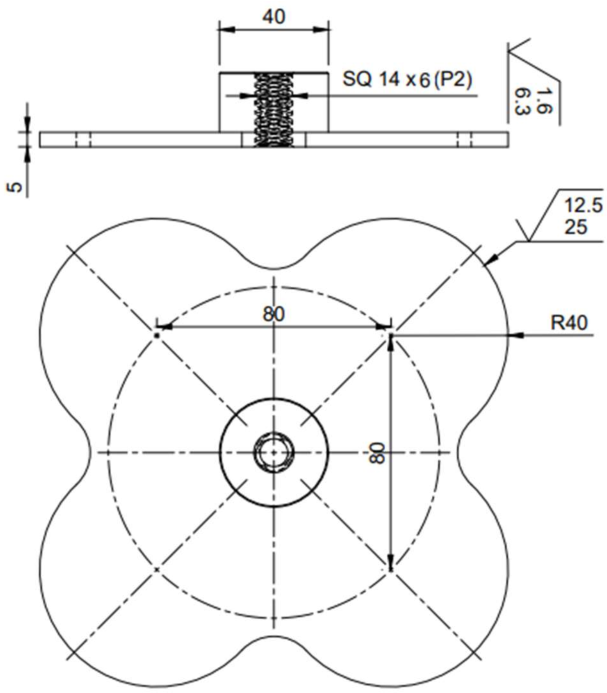
$$z = \frac{4W}{\pi\, S_b(d^2 - d_c^2)} = 0.909 \approx 1 \text{ threads}$$

Length of nut,
$L = zp = 11.5$ mm

## Shear stresses in screw nut-

$$\tau_s = \frac{2W}{\pi d_c p z} = 8.6647 \text{ N/mm}^2$$

$$\tau_n = \frac{2W}{\pi d p z} = 8.303 \text{ N13/mm}^2$$




14. LEAD SCREW NUT

Orthographic view

## *H. Motor Selection*

| | Power screw | Table |
|---|---|---|
| Speed (rpm) | 74 | 6 |
| Torque (Nm) | 5 | 0.5 |
| Power (Watt) | 40 | 0.3 |

The motor operation timings can be synchronized with the use of a microcontroller. The mode of power screw control will allow the user to completely retract the extrusion plate (lead screw nut) from the container and add the dough balls to it. The second mode of synchronous motion will start the motion of both the assemblies together. The microcontroller will enable the machine to pause with preset delay value after a batch of 4 *Chakli* is produced. This time delay will be used by the user to remove the batch from the table or the further operation to start.

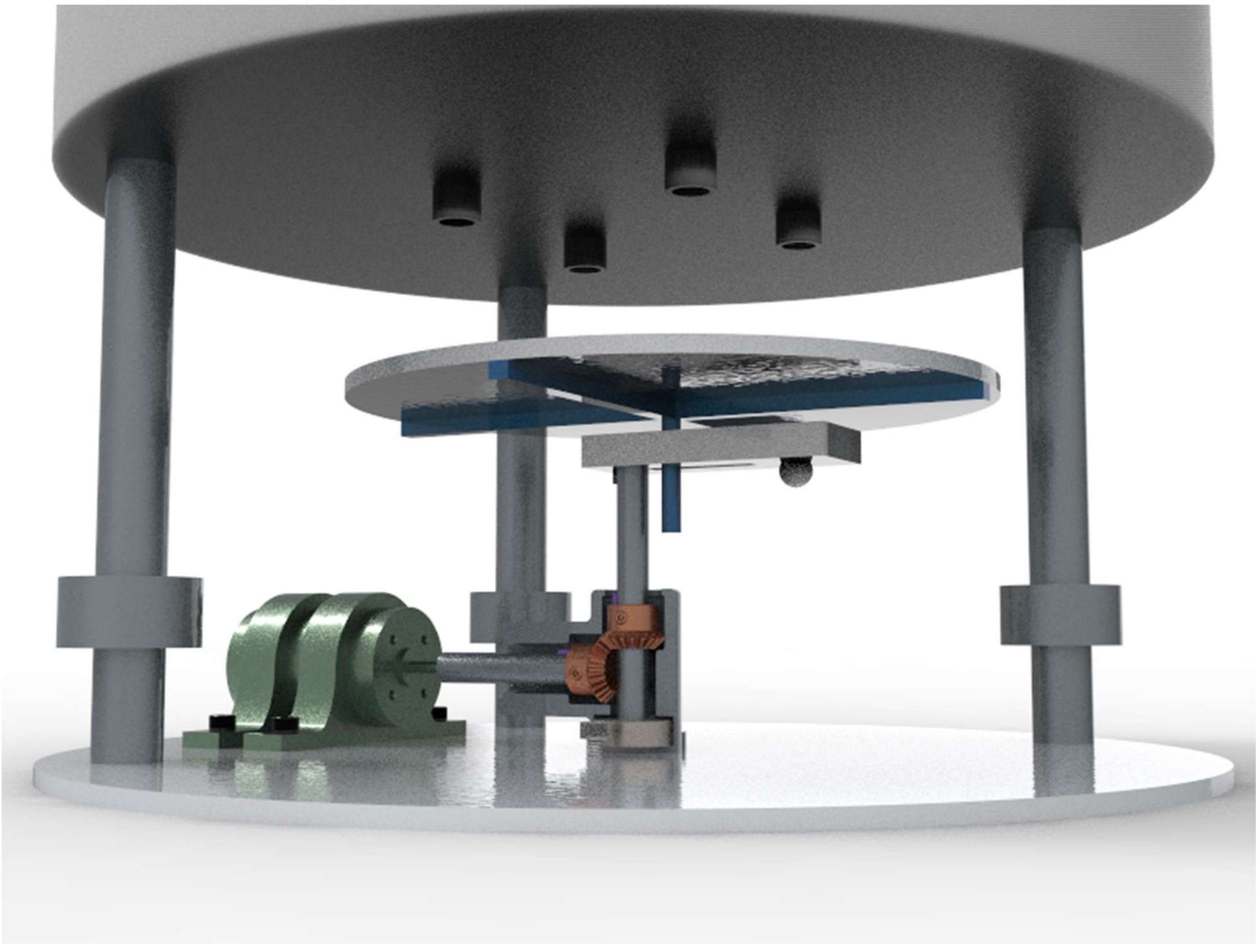
# V. RESULTS

Components

| Part Name | Description | Material | General Dimensions (mm) |
|---|---|---|---|
| Lead screw | Tr 16 x 12 (P4), | Steel 30C8 | Ø16 x 283 |
| Lead screw Nut and Extruder plate | Ø40, Tr 16 x 12 (P4) | Bronze | 160 x 160 |
| Screw Bearing | SKF 6000 | Steel | Ø 26 |
| Container | Deep Drawn | Aluminum 19000 | 170 x 170 |
| Frame Supports | Stepped Cylindrical Column | Aluminum 19000 | Ø 20 x 395 With step of Ø40 for 30 mm |
| Parallel Key | Plastic molding | Polyamide | 10 x 3 x 3 |
| Table | Plastic molded | Polyamide | Ø 200 |
| Follower and follower frame | Plastic Molded | Polyamide | Follower: Ø6 x 35 Frame: 200 x 200 x 6 |
| Slider ball Bearing | Casted | High Carbon Steel | Ø 10 |
| Rotating slot | Plastic Molded | Polyamide | 80 x 30 x 10 With slot L = 35 |
| Spiral Groove Plate | Plastic Molded | Polyamide | Ø 350 |

Fits Table

| Part Name | Description | Fit |
|---|---|---|
| Spiral Groove Plate – Frame Supports | Press Fit | H7/r6 |
| Rotating Slot – Follower | Easy Running | H8/e8 |
| Lead screw – Screw nut | Normal running fit | H7f7 |
| Miter Gear – Slider Shaft | Press fit | H7/r6 |
| Slider Shaft – Bearing | Loose Running fit | H8/d9 |
| Follower – Table | Press fit | H7/r6 |



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# VI. REFERENCES


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