ME 322 : Machine Design

Conversion of Rice Straws into Disposable plates

A Project report submitted by :

(Team : Cobra)

Sanu Sourav 210103097

Rajeev 210103087

Nitin Kumar 210103079

Saurabh Kumar 210103099

DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI

GUWAHATI – 781039, INDIA

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DECLARATION

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Sanu Sourav 210103097

Nitin Kumar 210103079

Rajeev 210103087

Saurabh Kumar 210103099

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ABSTRACT

With the world's eyes turned towards sustainable solutions, our endeavour embarks on a transformative journey, seeking to breathe new life into an age-old agricultural byproduct: rice straws. This project focuses on addressing the environmental challenges posed by rice straw waste by proposing a sustainable solution through the conversion of rice straws into disposable plates. In a country where the burning of rice straws contributes significantly to air pollution and poses health risks to millions, our project takes a proactive stance. With the increasing demand for eco-friendly alternatives to traditional disposable products, this project explores the feasibility of utilizing rice straws, a byproduct of rice cultivation, as a raw material for manufacturing disposable plates. The proposed method involves the design and implementation of a simple machine capable of efficiently processing rice straws into sturdy and biodegradable plates.

CONTENTS:

1. MOTIVATION:

In the heart of India's agricultural belt, the annual ritual of stubble burning in Punjab and Haryana casts a choking haze over Delhi, a stark reminder of environmental negligence. Our project is a response to this urgent crisis, driven by the imperative to offer a sustainable alternative. By repurposing rice straws into disposable plates, we not only mitigate air pollution but also address the pressing need for eco-conscious solutions. It's a call to action, a testament to innovation's power in the face of adversity.

Fig : stubble burning and its consequences

Fig. : Daily news headlines of pollution during winter

1.1. India: A Major Rice Producer

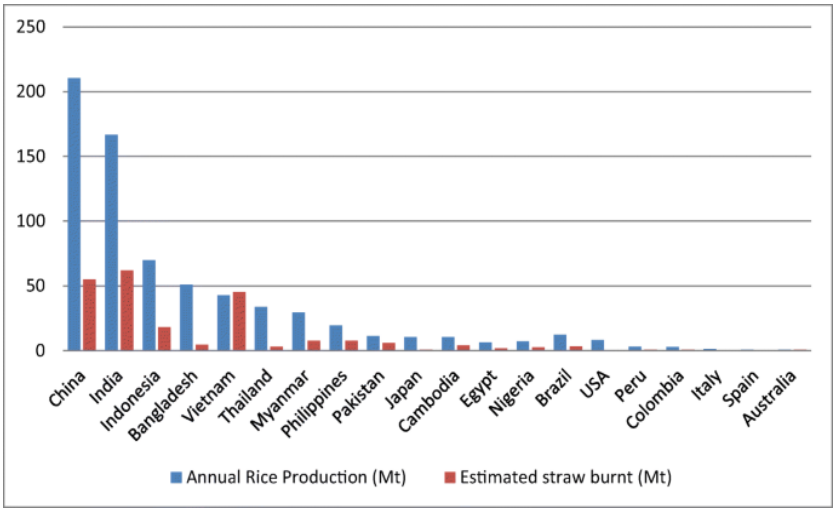

Fig. Statistics showing world's major rice producers

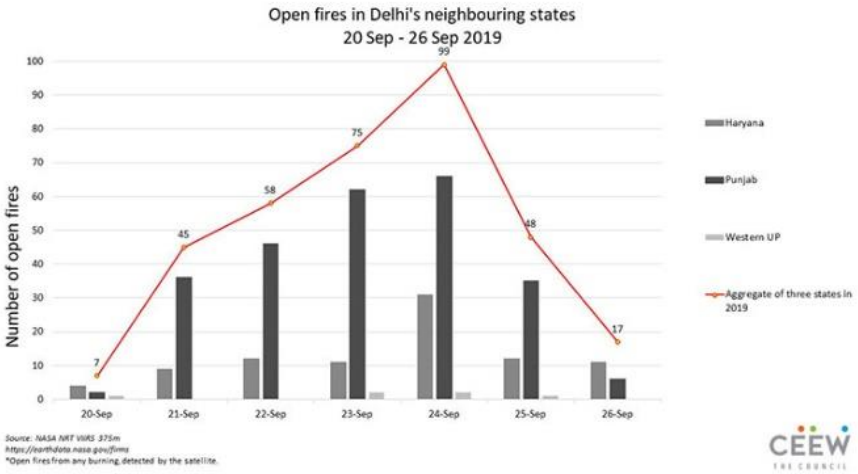

Fig. Open fires in Delhi's neighboring states

- India ranks among the top producers of rice globally and therefore it is important to deal with its waste and its in huge quantity.
- The post-harvest season in states like Punjab and Haryana witnesses a significant amount of rice straw leftover in the fields
- Traditional agricultural practices often involve the burning of rice straw as a quick and inexpensive method of clearing fields for the next planting season
- The dense smog resulting from stubble burning poses severe health risks to millions of people, particularly in densely populated urban areas like Delhi.

2. Introduction :

- Pollution: India is producing 26000 tones of plastic waste everyday. It has impacted our environment and health drastically as
    - contamination of water by microplastics seepage into ground water
    - Diseases like cancer, obesity, DNA damage etc.
    - Sanitation and fire in landfills have become common.
- Burning rice husk by farmers is a serious concern for controlling air pollution.
- Burning 1 kg of rice straw emits ~ 1460g CO2, 1.20g CH4, 0.007g N20, 34.7g CO
- These are direct threat to global warming and other environmental issues.
- Finding alternative for burning of rice straw is urgently required. One of the possible way is to convert these waste rice straws into useful products.
- Our Aim is to focus on conversion of rice straws into biodegradable paper which in turn could be converted into disposable plates.
- Rice straw, a byproduct of rice cultivation, is commonly burnt in fields after harvesting, contributing to severe air pollution.
- Lack of efficient disposal methods and commercial applications results in widespread burning, particularly in northern India.

  Research Innovation:

  1. Introduction of a commercially viable small-scale on-field utilization method for rice straw.
  2. Utilization of refiner mechanical pulping to convert rice straw into paperboard and food-serving bowls.

  Product Development:

  1. Rice straw paperboard meets Grade-III Kraft paper standards, offering a sustainable alternative for various applications.
  2. Molded bowls provide an eco-friendly replacement for disposable plastic food containers.

3. Problem Statement :

- **Aim** : Conversion of rice straws into disposable paper plates .

Making paper plates from rice husk holds immense potential for addressing several pressing issues:

- **Farmer Welfare :** By repurposing rice husk into paper plates, farmers can generate additional income streams while reducing waste. This not only supports their livelihoods but also incentivizes sustainable agricultural practices.
- **Controlling Air Pollution :** Utilizing rice husk for paper plate production mitigates the need for burning agricultural waste, thereby reducing air pollution levels caused by stubble burning. This contributes to cleaner air and improved public health, particularly in regions prone to high pollution levels.
- **4R Policy and Sustainable Development Goals (SDGs):** Embracing the principles of the 4R policy (Reduce, Reuse, Recycle, and Recover), this initiative aligns with SDG 6 (Clean Water and Sanitation) and SDG 13 (Climate Action). Furthermore, by promoting sustainable practices and reducing carbon emissions, it contributes to achieving the 1.5-degree goal outlined in the Paris Agreement.
- **GOI's Panchamrit Scheme and Net Zero Carbon Emission:** Integrating into the Government of India's Panchamrit Scheme and striving towards net zero carbon emission goals, the utilization of rice husk for paper plate production supports national initiatives aimed at environmental sustainability and climate change mitigation.
- **Controlling Deforestation:** By substituting wood pulp with rice husk as a raw material for paper plates, this initiative helps mitigate deforestation pressures. By preserving forest ecosystems and biodiversity, it contributes to the conservation of natural resources and promotes ecological balance.

4. Literature Review :

Introduction:

- Topic: *"Conversion of rice straw into disposable food-serving bowl via refiner mechanical pulping: an environmentally benign approach to mitigate stubble burning and plastic pollution"*.
- Authors: Shashank Saini · Ashish A. Kadam · Vivek Kumar · Kirtiraj K. Gaikwad · Surendra Pratap Singh · Dharm Dutt

Studies and Key Findings:

- Highlights the process of conversion of Rice straws into paperboard and food serving bowl using refiner mechanical pulping.
- Refiner mechanical pulping proved successful in adding value to rice straw.
- Tensile and burst index of paperboard equivalent to Grade-III Kraft paper.
- Water and grease resistance significantly improved through sizing process.
- Internal sizing with 2% AKD followed by 12 g·m^−2 coating of PVA provided optimum water and grease resistance.
- Environmentally benign process proposed as an alternative to stubble burning and plastic pollution.

5. Market Survey :

- **MARKET SIZE :** Paper plates manufacturing is rapidly rising industry and currently have a CAGR of 5.5% with a market of 5 billion USD.
- **COMPETETIVE ANALYSIS :** Currently there are various companies in paper plate manufacturing like – Atri leaf, Woodkq etc but manufacturing paper plate from rice straw has advantage in terms of competition.
- **PRICE SENSTIVITY :** Price of a 5.5 inch plate cost around Rs 135 for 1000 pieces.

- **DISTRIBUTION CHANNELS :** Both E-commerce and wholesale options are available with Pre-established transportation chains.
- **AUDIENCE REVIEW :** With increasing awareness about environmental problems everyone prefer to buy Bio-degradable products. Choosing paper instead plastic has become a moral obligation also it has its own cultural significance of being close to nature.
- **MARKET POTENTIAL :** Product have both Rural and Urban market and is used in social functions, religious gathering, parties, marriages, sweet shops etc. As it is easy to transport and handle its demand is certain to increase in near future.
- **GOVERNMENT INCENTIVES :** GOI actively promote sustainable and eco-friendly MSMEs by providing subsidised credit, Technological support, TAX benefits like section 80 JJA of IT act 1961.

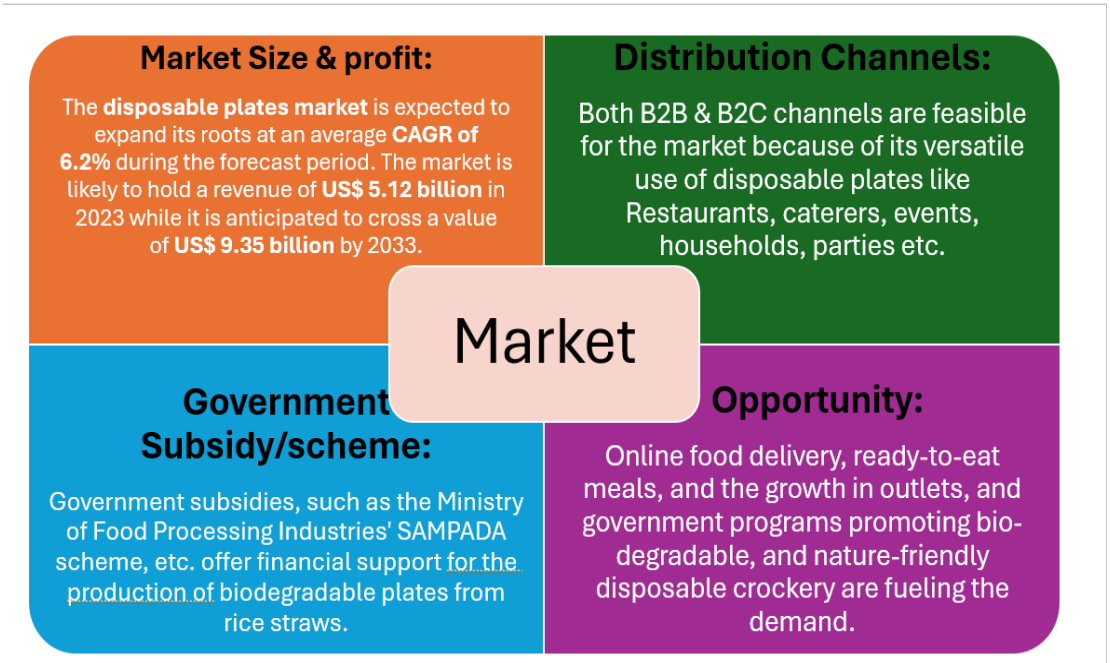

Fig. Market survey

6. Implementation Method :

6.1. Material Preprocessing:

- The rice straws are obtained from the fields after harvesting of the crops.
- Process of obtaining the rice straws into compressed form is done by using machines like **Baling machines**.
- This compressed form of the material is easy for transportation and storage purpose.

Fig. Different types of bailing machines

6.2. Method:

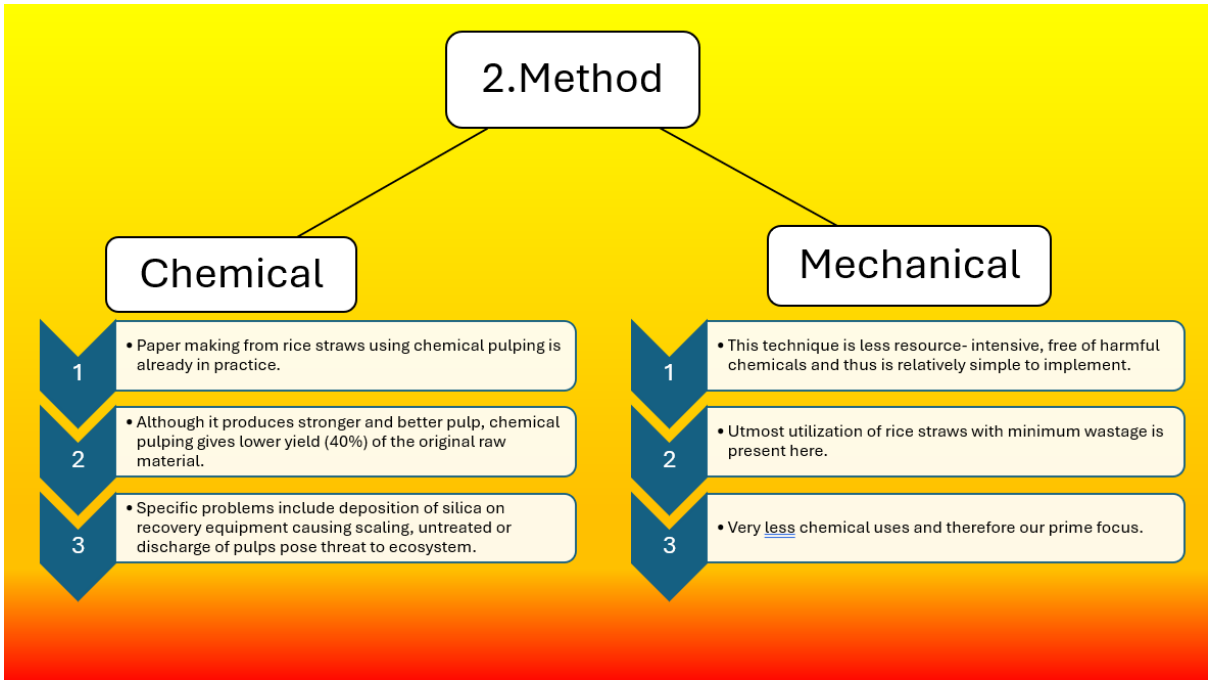

Fig. : Two types of methods

6.2.1 Mechanical Method:

Step 1: Characterization of raw materials:

- Long strands of rice straw were cut into 2 to 4 cm long pieces and were used as raw material in this work.
- The raw material was grinded in a ball mill to size 40–85 mesh and was used for chemical analyses.
- Alcohol-benzene soluble content, hot water-soluble content, lignin content, and ash content were determined as per TAPPI standard methods TAPPI T 204 cm-97, TAPPI T 207 cm-99, TAPPI T 222 om-02, and TAPPI T 211 om-02, respectively.

Fig. Chaff cutter

Step 2: Refiner Mechanical Pulping (RMP)

This includes two processes:

- Hydro-thermal Treatment
- Mechanical treatment (refining)

After the characterization of raw materials as in step 1, it is ready for the next step. In the next step these finely cut raw materials are now washed properly to remove dirt and other macroscopic impurities. After cleaning is completed, it is sent for hydro-thermal Treatment where it is treated with hot water for a specified period of time and there again after removing water from the mixture, it is grinded to get a fine paste like texture in the refining process. Followed by refining we add binding reagent (mustard cake) to get the strength for binding of particles.

Step 2.1: Hydro-thermal Treatment:

1. **Setup:**
    1. Utilized an electrically heated, rotating batch digester (reference: Model No. UEC-2015).
    2. Capacity: 1.5 liters.
2. **Treatment Conditions:**
    1. Rice straw treated with water.
    2. Temperature range: 65 to 155 °C.
    3. Water to raw material ratio: 5:1.
    4. Duration: 180 minutes.
3. **Optimization Method:**
    1. Identification of optimum temperature critical for treatment effectiveness.
    2. Various properties evaluated to determine optimal conditions.
4. **Key Results:**
    1. Optimal temperature determined based on tested properties.
    2. Findings crucial for enhancing efficiency and applicability of rice straw treatment process.

Temperature (°C)	Time to temperature (minutes)	Gauge pressure ($kg \cdot cm^{-2}$)
65	16	-
80	20	-
95	33	-
110	40	0.52
125	50	0.8
140	90	6.5
155	120	7.5

Table: Digester conditions for hydro-thermal treatment

Step 2.2: Mechanical Pulping (Refining)

Refinement Process:

- Equipment Reference: 12-inch single disc atmospheric laboratory refiner (Model 105A).
- Manufacturer: Sprout Bauer Combustion Engineering, Inc.
- Operation: Two-stage refinement process.
- Clearance between rotor and stator refiner plates:
    - Stage 1: 15 thou.
    - Stage 2: 8 thou.
        - 1 thou = 0.001 in.

Objective:

- Achieve a °SR(Schopper-Riegler) range between 35 and 40.
- **SR (Schopper-Riegler) Values:** Measures pulp freeness in papermaking. Higher SR values indicate greater fibre separation and drainage ability. Controlled SR values crucial for refining process optimization.

Pulp Treatment:

- Washing: Tap water and muslin cloth used for washing.
- Squeezing: Removal of excess water.
- Crumbling: Breaking down the refined pulp into smaller particles.
- Air-drying: Processed pulp dried under atmospheric conditions.

Binding Reagent Used : Mustard Cake

Additional Reagent to be Used : Bleaching reagent, water proofing (according to literature) ,however these haven't been included in the project because of safety concerns as it will be used to serve foods and hence the next step of the project.

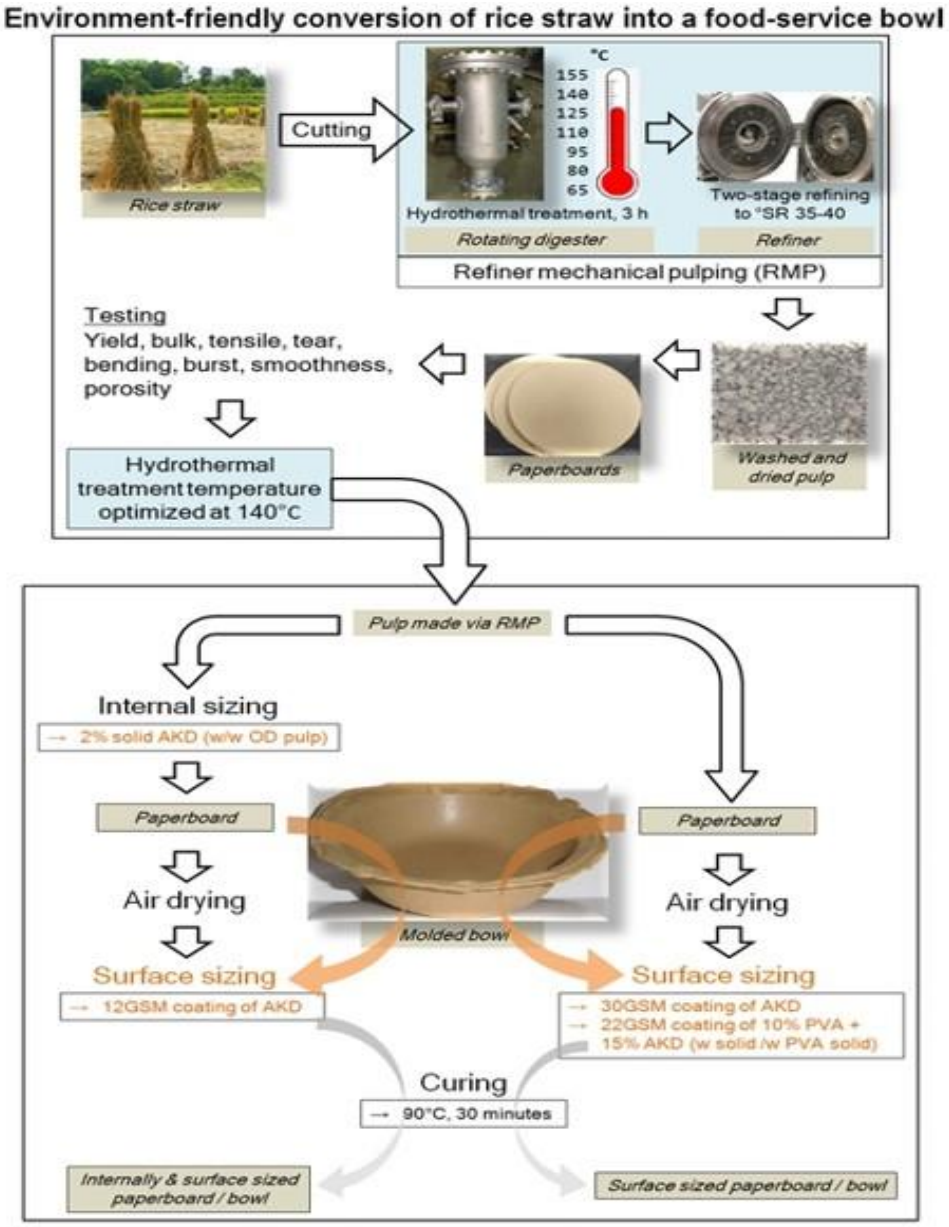

Fig. Conversion steps

Source: Conversion of rice straw into disposable food-serving bowl via refiner mechanical pulping: an environmentally benign approach to mitigate stubble burning and plastic pollution

Authors: Shashank Saini, Ashish A. Kadam, Vivek Kumar, Kirtiraj K. Gaikwad, Surendra Pratap Singh, Dharm Dutt

6.2.2 Chemical Pulping(#):

1. **Kraft Pulping Process:**
    1. Chopped rice straw cooked in a digester using Kraft pulping.
    2. Utilized 8% active alkali (NaOH + Na2S) concentration.
    3. Parameters:
        1. Maximum temperature: 160°C (reached in 60 minutes).
        2. Time at temperature: 90 minutes.
        3. Liquor to raw material ratio: 5:1 in the digester.
2. **Optimization Strategy:**
    1. Conditions selected aimed for minimum alkali charge, temperature, and time.
    2. Objective: Achieve satisfactory pulp and sheet formation.
3. **Comparison with Literature:**
    1. Rodriguez et al. (reference [*]) reported:
        1. Alkali concentration: 10%.
        2. Temperature: 170°C.
        3. Duration: 60 minutes.
4. **Pulp Treatment:**
    1. Washed cooked pulp using tap water and muslin cloth.
    2. Squeezed, crumbled, and air-dried under atmospheric conditions.
5. **Paperboard Sheet Preparation:**
    1. Handmade paperboard sheets prepared in the same manner.

*Rodriguez A, Moral A, Sánchez R et al (2009) Influence of variables in the hydrothermal treatment of rice straw on the composition of the resulting fractions. Bioresour Technol 100:4863–4866. https://doi.org/10.1016/j.biortech.2009.04.030

this method has not been utilized but we only focussed on mechanical method which is very new to the industry

7. Making of Paper Board from pulp:

- **Paperboard Sheet Preparation:**
    - After getting the pulp we put this pulp on a simple plane board after removing excess water and then pressed slightly to give a fine layer and also to squeeze the extra water content and together with binding reagent particles forms a sheet after drying
    - This process is speed up by using temperature for drying and equipment for sheet preparation:
- **Equipment & Preparation Reference:**
    - Laboratory hand-sheet former (Model 1092, MAVIS Engineering Corporation Limited, India).
    - Laboratory handmade paperboard sheets with a grammage of 200 g·m^−2.
    - Prepared from RMP pulp at optimum hydrothermal treatment temperature.
    - Method to be followed TAPPI standard method (TAPPI T 205 sp-02).
- **Sheet Moulding Process:**
    - Wet pulp pad cushioned with blotter paper on one side.
    - Sandwiched between two stainless steel bowls for moulding and water removal.
    - Moulded and squeezed.
- **Drying process:**
    - Bowl-shaped wet pulp pad air-dried.

Dimensions:

Main Equipment - 30.0 x 53.0 x 140.0 cm.,
Couching Roller - 44.0 x 10.0 x 15.5 cm.

Fig. *HAND SHEET FORMER (TAPPI TYPE) UEC-2005 A*

8. Design of Machine:

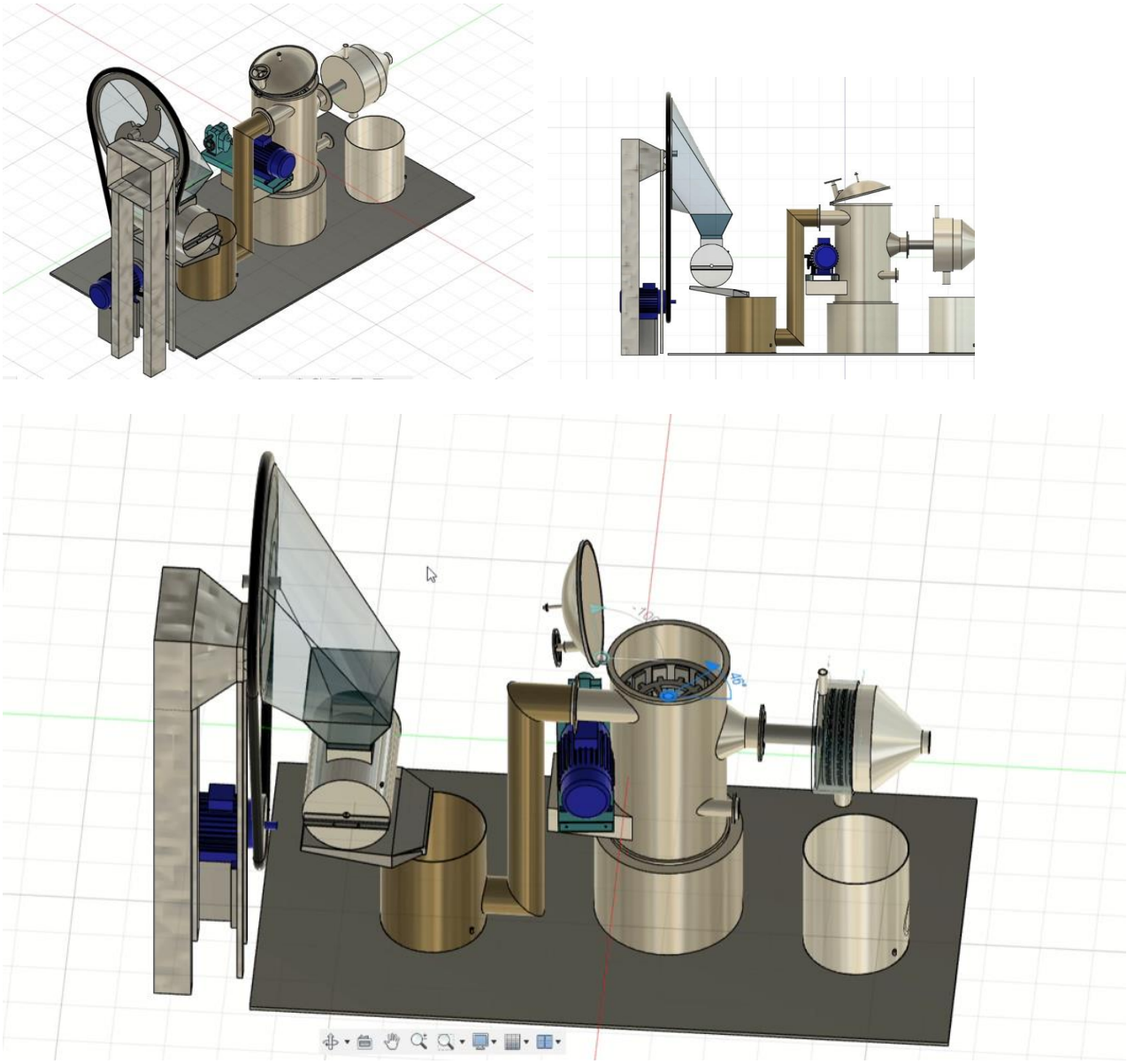

Fig. Design of Machine to generate pulp.

8.1 Dimensions:

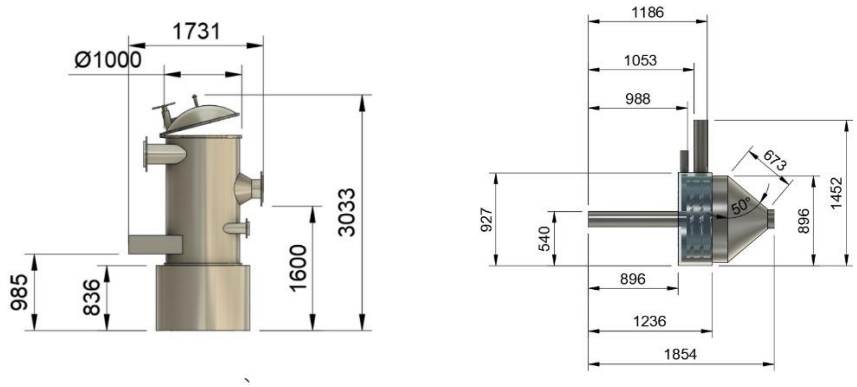

Fig. : Dimensions of Rotatory digester and refiner

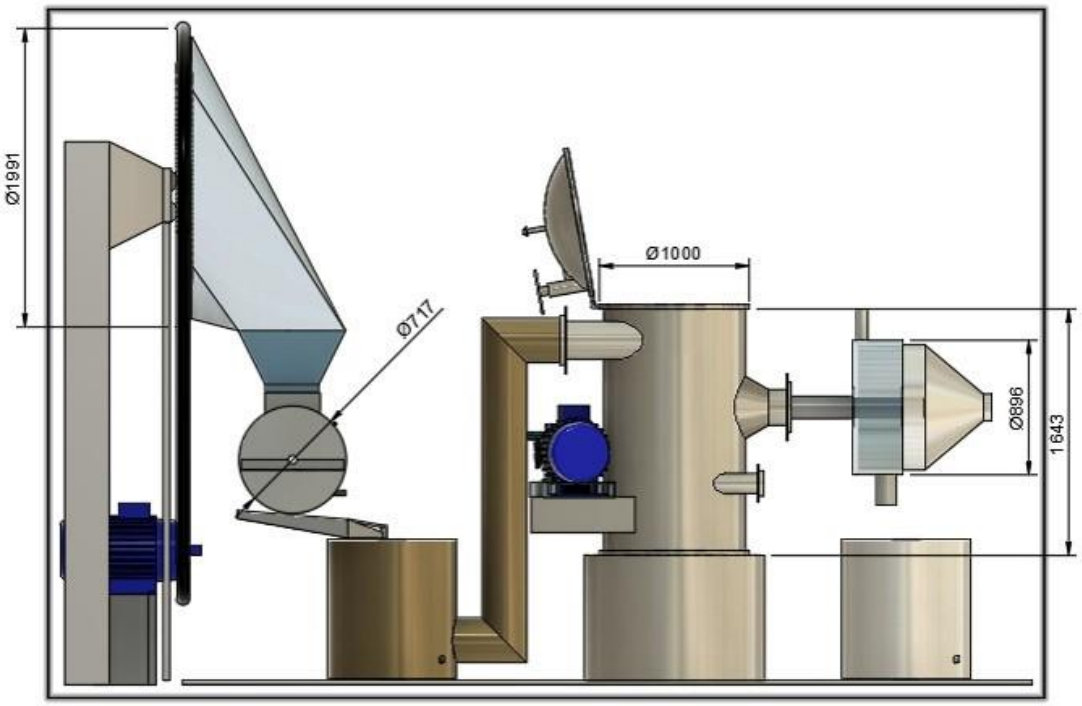

Fig. Dimensions of entire design

9. An Overview : Hand Made Bowls using Mechanical Method

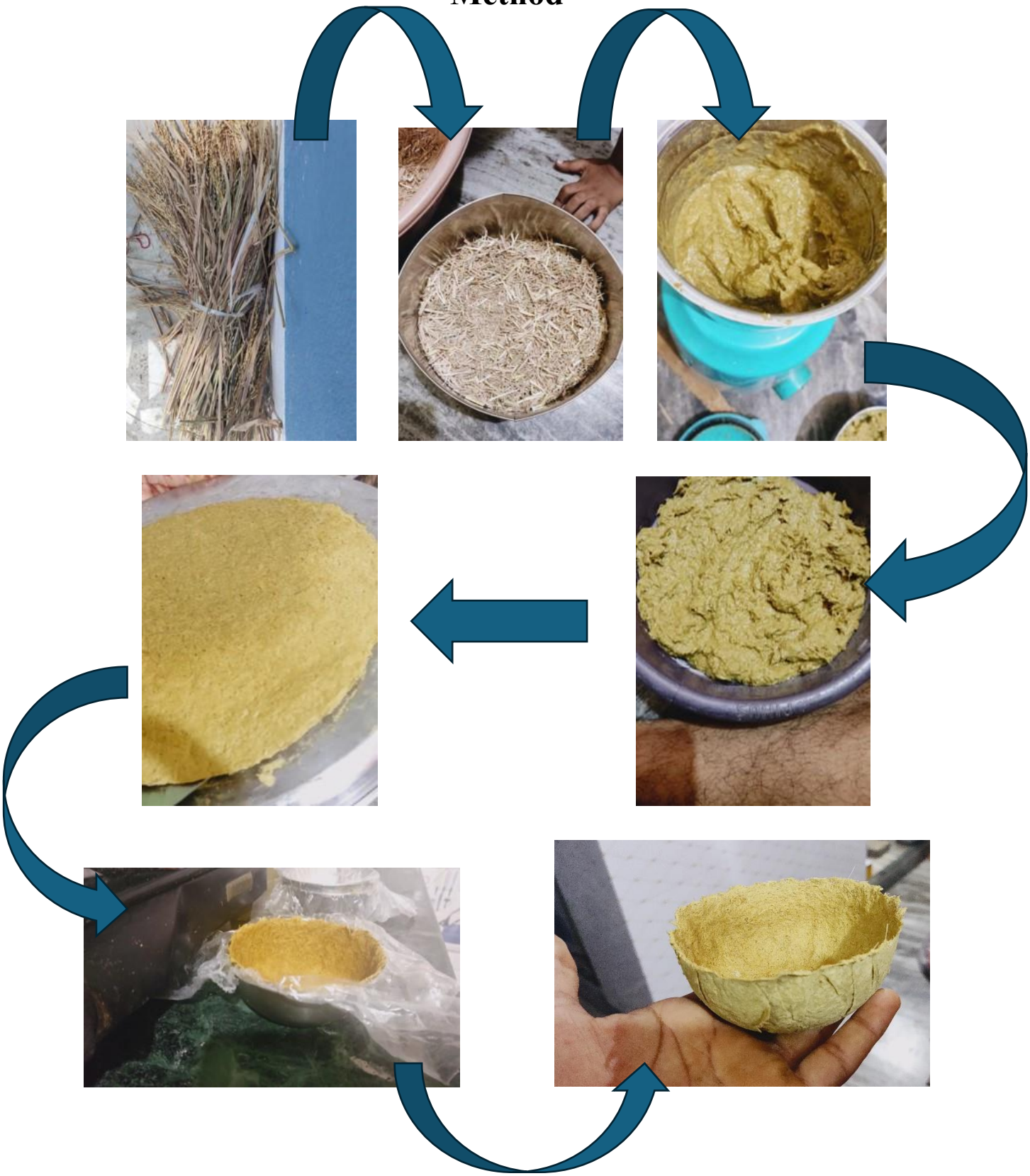

Fig. Hand made bowl using Mechanical Method (working procedure)

10. Machine Cost Analysis (Capital):

Parts	Price Estimated in INR	Specifications
Coarse Chaff Cutter • Motor • Blade cost	**3500** 2500 1000	Total 1.5 hp Stainless blades
Fine chaff cutter • Motor • Structure frame • Blade cost	**8000** 4000 2000 2000	Total 3 hp Steel/other metal alloy 2 stainless steel blades
Rotating Digester • Rotating Drum • Support structure • Heating System • Others	**8000** 3500 1000 2500 500	Total - - - -
Refiner	**5000**	-
Pumps	**6000**	-
Pipes, Valves, Safety, Control etc.	**3500**	-
Miscellaneous (5 percent)	**1700**	-
Total	**35700**	

10.1 Daily Costs :

Electricity cost:

- Total Electricity required : 1.5 hp + 3 hp + (4 + 4.5)KW + 30 KW = 43KW
- Operating time of each component per day (Assuming 2 cycles/day)
    - Cutter : 2 hrs
    - Rotating Digester : 6 hrs
    - Refiner : 2 hrs

- Total Electricity Used = 175 units/day
- Electricity charges (assuming) = Rs.6/unit
- Total electricity bill = Rs 1050/day

- **Raw Material Cost** : Rs. 12/ kg

CAD Design Link :

https://a360.co/3wQAFSi