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Design and Development of a Manually Operated Hydraulic Corn Husk Cup Making Machine

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Abstract:-The Corn Husk Cup Maker outlines the design and implementation of a manually operated hydraulic corn husk plate making machine, aimed at addressing the environmental and economic challenges posed by single-use plastic pollution. Leveraging the abundant agricultural waste of corn husks, the machine transforms this byproduct into biodegradable plates, offering a sustainable alternative to conventional plastic disposables. The integration of hydraulic technology ensures precise molding and high-quality production, accommodating both small-scale and large-scale manufacturing settings. Beyond its environmental benefits, the project presents economic opportunities for farming communities by monetizing agricultural waste, contributing to their economic sustainability. This initiative represents a significant step towards a circular economy, promoting resource efficiency and reducing the ecological footprint of human activities in the food packaging industry.

Keywords: Corn Husk, Biodegradable Plates, Hydraulic Technology, Sustainable Manufacturing, Circular Econom.

1. Introduction

In recent years, the detrimental effects of plastic pollution on the environment have garnered increasing global attention, leading to a growing demand for sustainable alternatives across industries[1]. Among the many single-use plastic products contributing to environmental harm, disposable plates stand out as major pollutants in landfills and oceans. This urgency has sparked innovation in eco-friendly packaging and dining solutions, driving the search for alternative materials and manufacturing processes[2-5]. In response, the development of a hydraulic-powered corn husk plate-making machine represents a ground-breaking initiative that blends agriculture, technology, and sustainability. By utilizing corn husks—an abundant agricultural by-product typically discarded after harvest—this project aims to transform a waste product into a valuable resource that could help reduce environmental damage. The use of hydraulic technology not only provides an efficient method for processing corn husks but also emphasizes the focus on energy-efficient and resource-conserving manufacturing. Additionally, this project offers significant economic potential by providing farmers and communities with a new revenue stream[6]. Traditionally seen as waste, corn husks can now be repurposed into biodegradable plates, offering a dual benefit of waste reduction and income generation. This not only helps mitigate environmental harm but also supports the economic sustainability of farming communities. Beyond creating biodegradable plates, the project symbolizes a shift toward a circular economy, where waste is repurposed into valuable resources, minimizing the ecological footprint of human activity. As global societies grapple with the consequences of overconsumption and waste, initiatives like the hydraulic-powered corn husk plate-making machine stand as proactive steps toward a more sustainable future[7-9]. This introduction provides an overview of the environmental context, the motivations behind the project, and its broader implications for sustainable development. By highlighting the challenges posed by plastic pollution, the need for innovative solutions, and the economic opportunities for communities, the introduction sets the stage for an in-depth exploration of the project's objectives and methodology[10].

2. Design of Corn Husk Cup-Making Machine Matrix Material

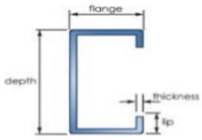
The corn husk cup-making machine has been developed based on a detailed CAD design, with multiple iterations made to finalize the specifications. The machine operates at a set temperature, and the corn husk material has been tested at temperatures of 110, 115, and 120 degrees Celsius. As depicted in Figure 2.1, the cups are formed by heat pressing the corn husk using a hydraulic jack that exerts a pressure of 5 tons [11].

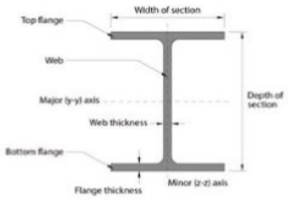
When the temperature is set below 100 degrees Celsius, the heating of the band heaters takes significantly longer, leading to delays in the cup-making process. Additionally, the moisture in the corn husk is not fully removed at lower temperatures. This residual moisture content can result in the growth of fungi and bacteria, compromising the quality and durability of the cups[12-13].

Fig 2.1. Corn husk heat pressed at different temperatures. (From left) 115, 120, 110, 100 degrees Celsius.

The machine frame is constructed using a combination of I-section and C-section members as shown in Fig.2.2. The I-section members serve as the vertical supports, while the C-section members function as the horizontal components[14-16]] The centroids of both types of members have been calculated. The entire frame is joined using arc welding.Fig.2.3 shows shear force and bending moment diagrams.Fig.2.4(a) and (b) shows hydraulic press calculation and motor calculations respectively.

C-Section
A = 26tf + (h-2tf) tw
A=2x50x6+(100-2×6)6
A = 1128mm²
P = 4b + 2h - 2tw
P = 4 * 50 + 2 * 100 - 2b
P = 388 mm





I-section
I_{x} = (b * h ^ 3)/(12) - ((b - tw) * (h - 2t_{b}) ^ 3)/(12)
I_{x} = ((100) ^ 3 * (50))/1 - ((50 - 6)(100 - 2 * 6))/12
Ix=1667936mm = 1.6x10^6mm
A1=100x6=600mm
A2=38x6=228mm²
A3=100x6=600mm²
y1=6/2=3mm
y2 = 19 + b = 25mm
y3= 6 + 38 + 6 = 47mm
X = A1x1+A2x2+A3x3/A1+A2+A3=50mm
Y=A1y1+A2y2+A3y3/A1+A2+A3=25mm

Fig 2.2. Calculation of frame sections (C-section and I-section)

E *f_{y} = 0
P.+ R_{h} = 210N
M = O (Cw + ve)
150N * 250 + 30 * 500 - R_{b} * 500 = 0
37500+15000= 500R_{b}
R_{b} = 105N
R_{A} = 210 - R_{b}
R_{A} = 105N
SF at A=75N
SF at C = - 75N
BMD
E_{A} = E _{B} = 0
BMD at C = 150N * 250mm
c = 37500N-mm

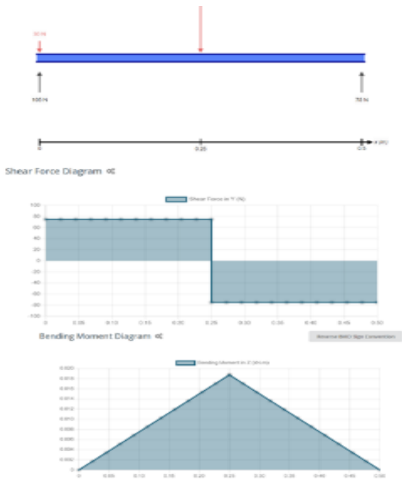


Fig.2.3. Shear force and bending moment diagram (SFD and BMD)

The bending moment is 37500 N-mm. The bending stress is calculated keeping the factor of safety as 3.

Σu= ultimate strength=450Mpa. Σy=Yield strength=250Mpa (Mild steel).

M/I=Bending stress/Y; M=Bending moment: I=area moment of inertia; Y= centroid:

37500/1.6*10^6=X/50:

Bending stress= 117.2 N/mm^2

Allowable stress=Sy/FOS=250/3=83.33MPa:

Hydraulic Press Calculation

Cylinder: 25x20x5 cm (LxWxH) Jack weight: 1.25 kg.
Minimum height: 10 inches
Cylinder holding beam=? ; Load capacity=5 ton.
1) Bore end & Rod end : The diameter of the cylinder does not very to (PB=PR)
A=(π/4)D^2 ;D=3cm;A=(π/4)(3x10)^2= $7.06m^2$ = 7.06*10^-4 mm^2
P=F/A=5000/7.06 *10^-4=708.21 kg/cm^2 = 7082152.97 kg/mm^2.
2) For one stroke the cylinder moves:
1.5cm = 15mm if speed = 1 cm/sec. = 10mm/sec.
Time = 16sec .
Stroke length = 16cm ;
Time = 16/1.5 = 10.66 sec. Speed = 1.5m/sec Q= A*V
Q=7.06×60=423.6cm^3= 0.04236mm^3(for 1 minute)
Q=7.06×16= 112.96 cm^3 = 0.011296mm^3 (for 1 stroke)
Q=0.011296/1000=1.1296*10^-5

Fig.2.4(a). Hydraulic press calculation

iii) Motor calculation.

KW=(P*Q)/(612*η)= (708.21*0.11293)/(612*0.8) = 0.1635 kW
i.e. 163.35

1HP=745.7W.
. For a motor power rating of 163.35W

1HP------745.7W
X-------163.3542
X=163.35 /745.7
X= 0.2199HP ~0.22 HP

Fig.2.4(b). Motor Calculation

3. Water Absorption Test

The water absorption test is a crucial evaluation method used across industries to assess a material's ability to absorb water under specific conditions. By conducting this test, manufacturers can gauge durability, ensure quality control, and make informed decisions regarding material selection for various applications. Understanding a material's water absorption properties helps predict its behaviour in real-world conditions, prevent damage, and optimize product performance and longevity[17-18].

Ten samples of different layered corn husk cups are undergoing testing[19]. Initially, the dry weight of each corn husk cup is measured, and the readings are recorded as shown in Fig 3.1 and Fig 3.2. Subsequently, all ten samples are immersed in a trough of water. Due to their low density, the corn husk cups attempt to float, necessitating the addition of weight. The cups undergo testing at intervals of 2, 3, 5, 10, 15, and 20 minutes. Throughout the testing process, the values of the dry weight and wet weight are meticulously compared for analysis[20].

Fig.3.1. Dry weight and wet weight of corn husk cup being measured.

Fig.3.2. Sample after being immersed in water.

4. Measuring of Thickness of the Corn Husk Cup

The corn husk thickness is gauged using a digital micrometre, which is a precision measuring device. The thickness of the cup varies depending on the number of layers added to it. This variation occurs at a micro-scale, particularly between cups with two and three layers. To ensure accuracy and uniformity, measurements are taken at three random points along the edge of the cup, forming an imaginary triangle. This method guarantees that any additional layers applied are uniformly pressed by the die. Similarly, the thickness of the cup's throat or neck portion is also measured, and the readings are recorded for further analysis (fig.4.1,4.2, and 4.3).

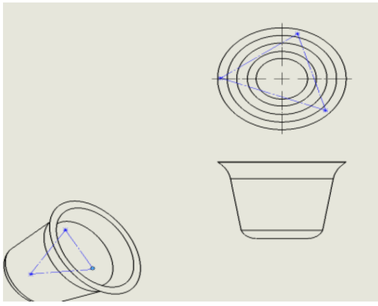


Fig.4.1 Thickness of the corn husk cups is taken 3 random points forming a triangle.

Fig.4.2.: Thickness of sample edge measured. (0.700mm)

Fig.4.3: Same sample but different side of the edge. (0.516mm)

5. Results and Discussions

The corn husk cup-making machine, developed according to CAD designs and iteratively refined, was tested at temperatures of 110, 115, and 120 degrees Celsius. The hydraulic jack applies a pressure of 5 tons during the heat pressing process, as illustrated in Fig.5.1.

Key Observations:

1. Temperature Below 100°C:

- Excessive time consumption by band heaters.
- Incomplete moisture removal, leading to potential fungal and bacterial growth.

2. Temperature of 110°C:

- Cups exhibited a soft texture with a relatively fine finish.
- Moderate efficiency in moisture removal and production time.

3. Temperature of 115°C:

- Improved texture and finishing quality of the cups.
- Enhanced moisture removal, reducing the risk of microbial growth.
- Increased production efficiency.

4. Temperature of 120°C:

- Optimal results with the best texture and finish of the cups.
- Complete moisture removal, ensuring microbial resistance.
- Maximum production efficiency observed.

Testing revealed that the optimal temperature for the corn husk cup-making machine is 120 degrees Celsius, achieving the best balance of quality, moisture removal, and production efficiency. Operating below 100 degrees Celsius is not viable due to inefficiency and risk of microbial growth. The study underscores the importance of precise temperature control in producing high-quality, durable corn husk cups.

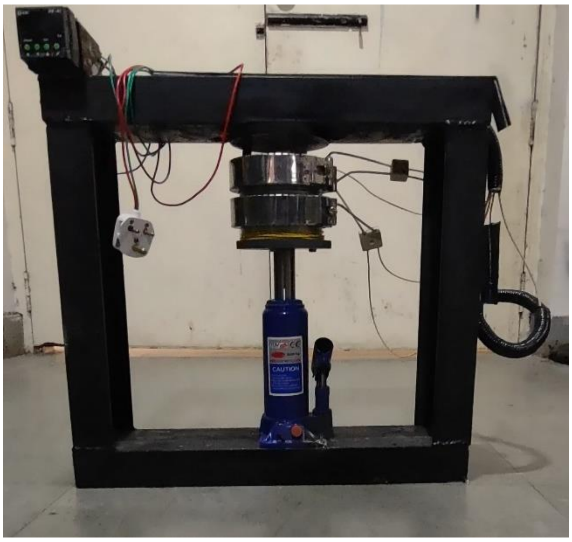


Fig.5 .1: Finalfabricated model of the Machine

6.Water Absorption Test Results:

The water absorption test evaluated ten samples of corn husk cups with varying layers, measuring their dry and wet weights at intervals of 2, 3, 5, 10, 15, and 20 minutes as shown in table 6.1.

Table 6.1Water absorption test results

SL NO.	CORN HUSK CUPS (In-terms of Layers added)	Dry weight (g)	Immersion Duration (min)	Wet weight (g)
1.	3 layers:1	3.4018	2	5.6893
2.	3 layers:2	2.323	3	6.8190
3.	3 layers:3	3.0195	5	8.7320
4.	2 layers:1	1.4993	10	3.4780
5.	2 layers:2	1.1510	10	3.4680
6.	2 layers:3	1.2119	15	4.9187
7.	3 layers:4	2.6063	15	4.838
8.	3 layers:5	2.1857	20	6.2671
9.	3 layers:6	2.3157	20	7.0935
10.	3 layers:7	2.656	20	6.969

3.Measuring thickness of the corn husk cup results:

The thickness measurements of corn husk cups, gauged using a digital micrometer, reveal micro-scale variations across different layers. Measurements were taken at three points along the edge and throat of each cup.

Edge Thickness (Average):

- 2 Layers (I): 0.724 mm

- 2 Layers (II):0.716 mm

- 3 Layers (I): 0.706 mm

-4 Layers (II):0.694 mm

Throat/Neck Thickness (Average):

- 2 Layers (I): 0.715 mm

- 2 Layers (II): 0.709 mm

- 3 Layers (I): 0.784 mm

- 4 Layers (II): 0.709 mm

Conclusion

The development of the Hydraulic Operated Corn Husk Cup Making Machine represents a pivotal advancement in the realms of agricultural and sustainable technology, addressing the urgent need for eco-friendly alternatives to single-use plastic in food packaging. By transforming agricultural waste into biodegradable cups, this innovative machine not only mitigates the environmental impact of plastic pollution but also provides an additional income source for farmers, thereby supporting the economic sustainability of farming communities.

Throughout the design and development process, several critical objectives were accomplished. The machine's hydraulic operation ensures efficient, reliable performance and seamless production of corn husk cups at scale, enhancing productivity while minimizing energy consumption. Its user-friendly design promotes ease of operation and maintenance, encouraging widespread adoption and empowering users across various skill levels to engage in sustainable manufacturing practices.

A key achievement of this project is the utilization of corn husks as a raw material. Repurposing agricultural waste not only reduces environmental impact but also aligns with the principles of a circular economy, where resources are maximized, and waste is minimized through continuous reuse and recycling. Additionally, the machine's versatility allows for customization according to specific production requirements, ensuring flexibility to meet diverse market demands.

In conclusion, the Hydraulic Operated Corn Husk Cup Making Machine stands as a significant stride towards sustainable manufacturing practices. By leveraging renewable resources and innovative technology, it provides a viable solution to the pressing challenges of plastic pollution while fostering economic opportunities in agriculture. Continued research and development in this field promise even greater advancements, paving the way for a more sustainable and resilient future.

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