

A novel energy efficient machine for plate manufacturing from areca palm leaf sheath

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An efficient, high performance and user-friendly hand-operated machine for bowl and plate manufacture from areca palm leaf sheath has been designed. New machine is very effective, as production time of bowl (15 cm diam) has reduced by 50% and that of plate (30 cm diam) by 30% in comparison to existing pedal-type machine. Cost of new machine is 50% less than existing machine.

Keywords: Areca palm leaf sheath, Bowl and plate manufacture, New hand-operated machine

Introduction

Leaf of areca tree (*Areca catechu* L.) is a hard material (good tensile strength), slow in biodegradation and has low calorific value¹. About 1000 million leaf sheaths (2,33,000 tonnes) are available annually in India alone²⁻⁴. Areca leaf sheath (cellulose, 43%) by digestion using sulphite process at 162°C for 3.5 h gives a pulp (yield, 36-40%), which in admixture with other pulp can be used for making packing paper boards^{5,6}. It is used to manufacture decorative vaneer panels and picture mounts⁷. Arecanut shows hypoglycemic effect, mitotic activity, antihelminthic activity, cholinomimetic activity etc⁸.

Existing pedal-type machine, which is used to manufacture bowl/plate from areca leaf sheath, consists of a set of die-punch, cutter, a foot lever (to lift die), and a frame⁹. It has following drawbacks: i) Performance of cutter is unsatisfactory; ii) High force is required to operate machine; iii) Structure of machine is large; iv) Operation in standing position is inconvenient especially for physically handicapped persons; v) Excessive operation leads to back pain and fatigue; and vi) Die shapes are not standardized.

This study presents design and development of an energy efficient, hand operated machine (fabricated at IIT Guwahati) for bowl and plate manufacture from areca palm leaf sheath.

Design of New Machine

New machine (Fig. 1) consists of one set of die-punch, two sets of heater coil in case of electricity based machine, die heating by LPG gas burner and punch heating by heater coil in case of gas based machine, rack and pinion system, besides supporting plates and hand wheel. New machine (Fig. 2) operates on the principle of rack and pinion system. This machine reduces force needed to move punch and thus protects machine operator's back from excessive strain. In this work, 4 sets of die-punch have been designed and fabricated. The design of shaft (length, 620 mm; diam, 20 mm) and key (6 mm×6 mm) to fit pinion is very important for smooth operation of machine. At the end of shaft, one hand wheel is fitted for lifting purpose. Material selection for machine fabrication is very important (Table 1).

Machine Operation

New hand-operated machine is clamped on a bench using 4 nuts and bolts, and machine becomes ready for use. It is recommended that before start of operation,

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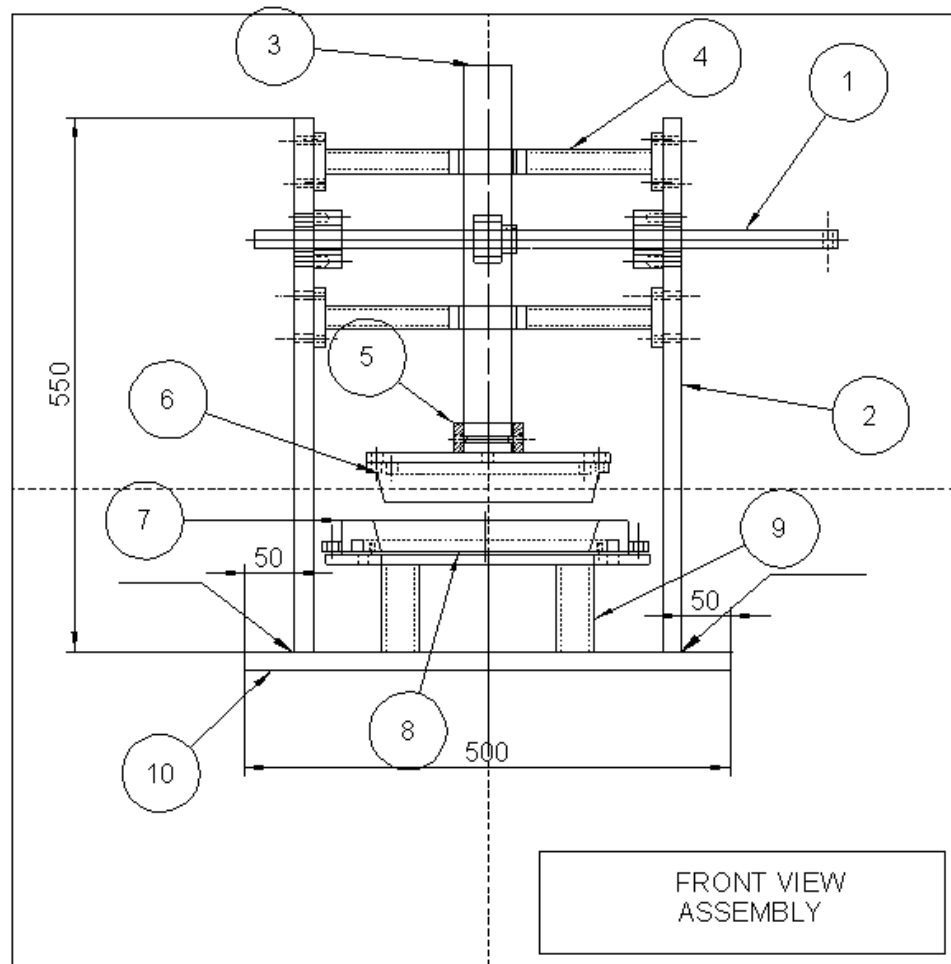


Fig. 1—Front view of new machine

heating of die-punch has to be done. Die-punch set can be changed depending upon availability of raw material and market demand.

Electricity-based Machine

In electricity-based machine, to produce a single product, initially thermostat for both die and punch must be adjusted to required temperature. Temperature and time of production required to produce a single product varies with product size. After cutting raw material in a predefined size, product has to be put in machine for shaping. After placing raw material, punch has to move with hand wheel and to hold punch for a particular time, one lock is fitted at upper supporting plate.

Gas-based Machine

In gas-based machine, die is heated by liquefied petroleum gas (LPG) (one LPG burner is fitted below machine) and punch is heated by heater coil (one heater

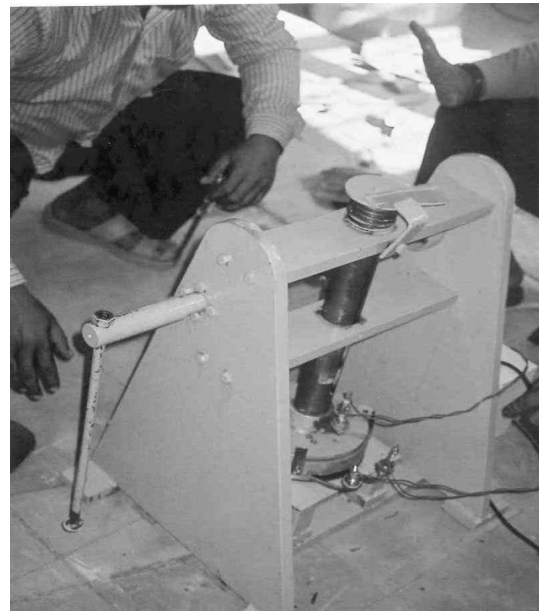


Fig. 2 —Novel hand-operated machine

Table 1—Raw material for fabrication of new machine

Sl No.	Particulars	Material	Justification
1	Frame	Mild steel	To make strong structure and cost effectiveness
2	Die-punch	Aluminum	For higher conductivity (201 W/m-K) and specific heat (913 J/kg-K)
3	Rack and pinion	Mild steel	For longer life of both rack and pinion and low cost
4	Shaft	Mild steel	
5	Supporting plate	Mild steel	
6	Heater coil	Stainless steel	For uniform heating of die-punch and to avoid corrosion
7	Hand wheel	Mild steel	For low cost
8	Spring for backward movement of shaft	Spring steel	Helpful during backward movement of punch
9	Lock	Mild steel	For low cost

Table 2—Variation of moisture with temperature at different time of operation of machines

Sample	Temperature, °C		Time, min	Moisture content after production, %	
	Punch	Die		Old machine	New machine
1	80	45	1	11.10	8.33
2	80	45	3	8.23	6.87
3	110	45	1	10.56	8.92
4	110	45	3	8.10	6.89

coil is fitted inside punch). To initiate operation, LPG heats for 15 min in full opening. Rest procedure is same as that for electricity-based machine.

Design of Cutter

In existing machine, performance of cutter is not suitable and same cutter cannot be replaced after damage. Mechanics of cutting areca leaf sheath is very difficult since sheath becomes elastic during heating. In this study, two cutters have been developed; one cutter (diam, 16.00 cm) was fitted in new machine and other cutter (diam, 19.30 cm) was fitted in a fly-press machine. Performance of both cutters (blade angle, 35–45°) is found to be very effective. Blade is made from C 40 or EN 28 material and cutter holder from mild steel. Cutter is fitted with areca leaf plate-manufacturing machine and completes cutting of sheath in three strokes by rotating punch thrice. Damaged cutter can be interchanged easily, since blade is fitted with three screws. In case of fly-press machine, a minimum of 3 pieces of sheath cutting is possible in a single stroke.

Results and Discussion

Different temperatures (70°, 80°, 90°, 100°, and 110°C) were maintained for a particular operation at different period of time. Before operation of both machines, moisture content of all samples were as follows: sample 1, 16.75; sample 2, 15.20; sample 3, 18.30; and sample 4, 19.15%. Temperature of both die and punch and time of operation for the production of plate (diam, 25 cm) show that good quality products (Table 2) were obtained with samples 3 and 4 for both pedal type (Fig. 3a) and novel machine (Fig. 3b). For a good quality product, following parameters have been found optimum: punch temperature, 110–115°C; die temperature, 35–40°C; time of operation, 60–90 s; and moisture content of raw areca sheath, 14–17%. For new machine, required production time is lesser as compared to existing machine. Moisture removal rate is also found to be faster in existing machine.

Optimum parameters required to produce a good quality product in case of 25 cm diam plate are as follows:

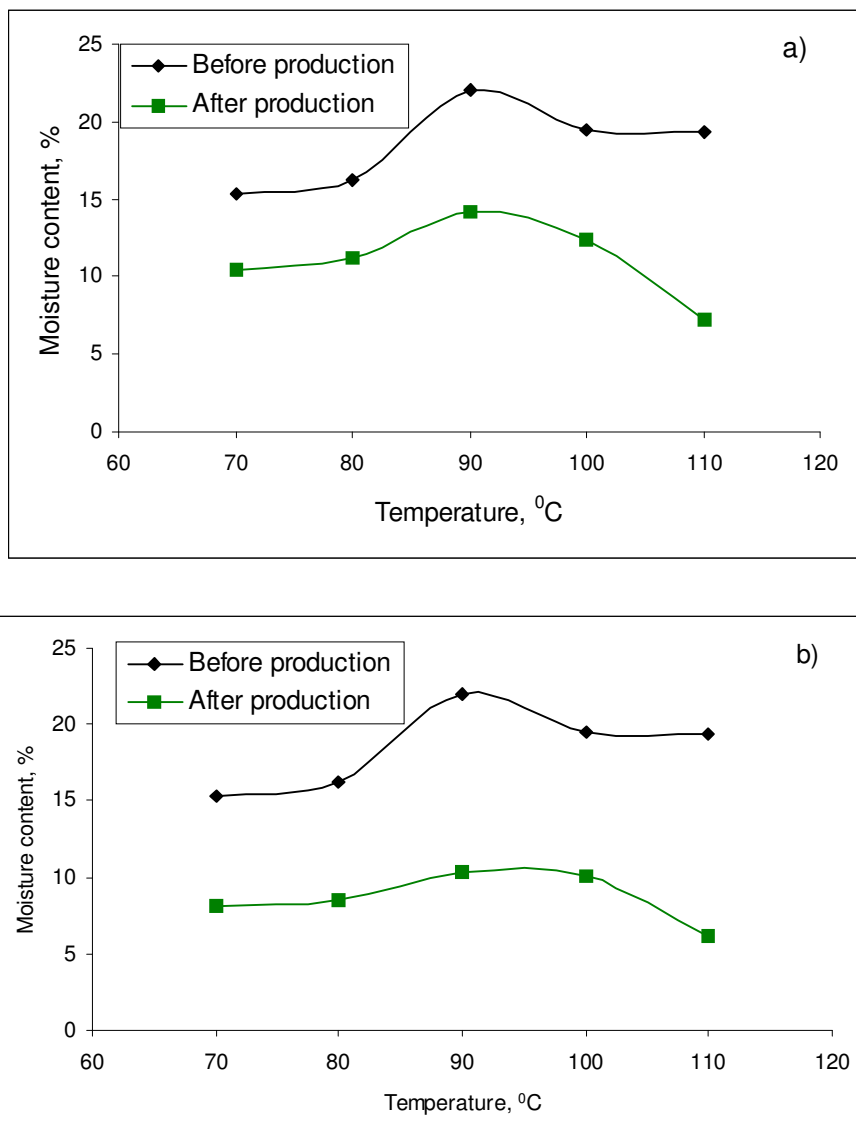


Fig. 3—Variation of moisture content with temperature of punch (die temp. 40°C) for a holding time of 1 min:
a) Pedal-type machine; b) Novel (hand-operated) machine

holding time, 1 min; temperature for punch, 100-108°C; temperature for die, 35-40°C; and moisture content of areca sheath, 14-18%. Minimum and maximum force (measured with spring dynamometer) required to lift paddle is found to be 500 N and 1560 N respectively for existing machine, whereas 50% less force is required for new machine. It is observed that time of production in the cases of bowl (diam, 15 cm) and plate (diam, 30 cm) has been reduced by 50% (existing, 40 s; new machine, 20 s) and 30% (existing, 80 s; new machine, 55 s) respectively by new machine in comparison to existing machine. As heater is continuously operating in both types of machines, increase in production rate reduces energy requirement. Thus, new machine is an

energy efficient machine in comparison to existing machine (Table 3).

Quality of areca leaf sheath varies with locations and seasons. In this study, locally available raw material, collected during July, has been used. Strength of areca leaf sheath collected from local village near IIT Guwahati has been calculated. Strength along sheath direction and transverse direction is found to be 136.36–163.63 N/mm² and 0.18 N/mm² respectively. Handling of new machine is very easy since weight of the machine is only 82 kg. It is recommended to lubricate rack and pinion system once after every 96 h of used. Over-heating of die-punch should be avoided for long-life and corrosion-free machine.

Table 3—Technical comparison of machines

Sl. No.	Old machine	New machine
1	Leg operated	Hand operated
2	Operation in standing position	Operation can be done in sitting position also
3	Prone to back strain	Operation in sitting position can prevent strain/fatigue of the operator. From ergonomic point of view, a sitting position will give more comfort than a standing position
4	Crank-lever mechanism was used to operate the machine	Rack and pinion system is used. Overall fabrication cost of proposed machine is reduced by 31% as compared to existing machine. Further, since overall size gets reduced, material cost also gets reduced
5	Product quality is less than new machine	Product quality is better than old machine
6	Single machine limited to single type of product only	Same machine can be used to produce multiple types of products
7	Time consuming	Time of production is less
8	Big size	Small size
9	Not suitable for physically handicapped persons	Suitable for physically handicapped persons. New machine is a table mounted hand operated type; depending upon height of operator, machine can be clamped on a table or bench
10	Minimum force required to operate machine is 500 N	Minimum force required to operate machine is 300 N

Conclusions

New machine is very effective in terms of cost, productivity, quality, versatility, space required, and ease of operation for normal as well as physically handicapped people with leg deficiency. New machine minimizes fatigue and can be operated in seating position. Time of production for bowl (diam, 15 cm) has been reduced by 50% and that for plate (diam, 30 cm) by 30% in comparison to existing machine. Optimum parameters for good quality product are: punch temperature, 110-115°C; die temperature, 35-45°C; moisture content of raw sheath, 14-17%; and production time, 40-60 s. Strength of sheath has been found to be 1500-1800 N in sheath direction and 86 N in transverse direction. Cost of new machine is 50% less than that of existing machine. Single machine can be used for manufacturing variety of products by interchanging set of die-punch. An efficient cutting process has been developed for cutting of sheath. Experiments show that with the help of new cutter, cutting of 3 pieces of areca leaf sheath are possible in a single stroke at a time.

Acknowledgement

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