DESIGN AND DEVELOPMENT OF COCONUT FIBER EXTRACTION MACHINE

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Abstract

The scope of this project was to design and develop a coconut fiber extraction machine for farmers and small scale coir industries in India to provide an effective solution to the difficulties in existing process, reduce time and labour cost and to develop a compact coconut fiber extraction machine which could be used in remote villages so that unutilized husks from such areas could be tapped and fiber could be made available to the Coir Industry directly. This project was taken up to develop a promotional strategy for a new innovation and generate public awareness regarding the availability of a coconut fiber extraction machine in the market at a reasonable cost.

The project began with collection of information and data on user lifestyle and current process by which they perform their job. The current difficulties were analyzed. Interviews were held with users. A comparative bench marking study was done on similar processes used in other similar extraction processes. Along with this an ergonomic simulation was made to understand the user difficulties and manufacturing methods to get an overview to provide solution to the user to suit their requirement.

Concepts were generated keeping benchmarked product in view. Five concepts were generated with different functions and operating processes for coconut fiber extraction machine. Final concept was selected by considering the users' operating environment and maintenance, which could be used in small scale coir industries and in the farm sector. Considering the users' needs and buying capacity, a prototype was fabricated. This machine works with gear mechanism, in which 2 barrels rotates in opposite direction to extract fiber from coconut. Cutting pins are inserted in indexed holes to separate fiber and to give linear motion to coconut shell.

Validation was carried out with the user group and the feedback was positive. It was noticed that there is potential market for this product. Further work could be carried in terms of aesthetics, material and weight reduction by adopting advanced manufacturing techniques.

Key Words: Coconut, Coir, Fiber Extraction, Ergonomics, Industries

Nomenclature

F	Force (N)
N	Speed (RPM)
T	Temperature (ºC)
kg	Kilogram
mm	Millimeter
t	Tonne

Abbreviations

PDS	Product Design Specification
QFD	Quality Function Deployment

1. INTRODUCTION

The thickest and most resistant of all commercial natural fibers, Coir is a coarse, short fiber extracted from the outer shell of coconuts. India is the largest coir producer in the world accounting for more than 80 per cent of the total world production of coir fiber [1]. The coir sector in India is very diverse and involves households, co-operatives, NGOs, manufacturers and exporters. Coconuts are grown in more than 93 countries in the world and therefore there is considerable scope to develop coir industry in further countries [2].

Fiber Extraction is the processes of fiber extraction are varied, and depend on the effectiveness of the wet processing such as bleaching and dyeing of coir and also varied end uses. The traditional production of fibers from the husks is a laborious and time consuming process. After separating of the nut, the husks are processed by various retting techniques generally in ponds of brackish waters (for three to six months) or in backwaters or lagoons. This requires 10-12 months of anaerobic (bacterial) fermentation by retting [3], the husks are softened and can be decorticated and the fiber is extracted by beating, which is usually done by hand. After hackling, washing and drying (in the shade) the fibers are loosened manually and cleaned. The remaining residual pith - which was previously considered a waste problem - has recently found new profitable markets as a peat moss substitute for horticultural production. Traditional practices of this kind yield the highest quality of (white) fiber for spinning and weaving. Retted fibers from green husks are the most suitable fibers for dyeing and bleaching. For the production of more coarse brown yarns shorter periods of retting may be applied. These find an increasing outlet in geo-textile applications. Alternatively, mechanical processes using either de-fibering or decorticating equipment process the husks after only five days of immersion in water tanks. Crushing the husk in a breaker opens the fibers. By using revolving "drums" the coarse long fibers are separated from the short woody parts and the pith. The stronger fibers are washed, cleaned, dried, hackled and combed as shown in Figure 1.

Fig. 1Traditional and Mechanical Fiber Extractions [1]

2. LITERATURE REVIEW

2.1 Coconut

Coconut (Cocos) grows in more than 80 countries in southern and south-western Africa, Latin America and Asia. "Cocos" is old Spanish/Portuguese language and means "grinning face", which refers to the facial expressions at the "top" of the coconut's hard shell from which it sprouts. Coconut palms have a total production of coconut fruits of more than 60 million tons per year. The Philippines is the largest producer followed by Indonesia and India, but also Thailand, Malaysia, Sri Lanka, Ghana, Ivory Coast, Tanzania and Brazil are major producers of coconuts [3]. The parts of the coconut are as shown in Figure 2.

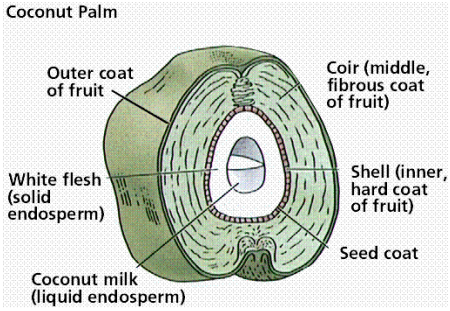


Fig. 2 Coconut and its parts [3]

2.2 Details of Patents

Chandra Dinanath [4] A machine specifically designed to remove the husks from the coconut fruit including a plurality of rollers rotating in opposite directions effectively toward one another wherein each roller includes a plurality of penetrating spikes sharpened to penetrate and effectively engage the husk portion of the coconut fruit (Figure 3). The interaction of the rollers in combination with the gripping action of the spike serves to tear away the husk from the nut leaving the nut intact.

This invention relates to a machine for removing the husk from the nut portion of a coconut fruit in a manner which leaves the nut intact and insures that the husk is separated from the fruit and from the dehusking machine itself.

Gilles Durand [5] A machine (Figure 4) for removing the fibrous casing, said fill, the coconut, characterized in that it comprises: a system of continuous operation does not require stopping for loading the direction of chains pins guided nut which cause three rotary blades are designed to cut the floss after its ternary system and allowing the lifting of the three posts Boure by letting out the retractable nuts.

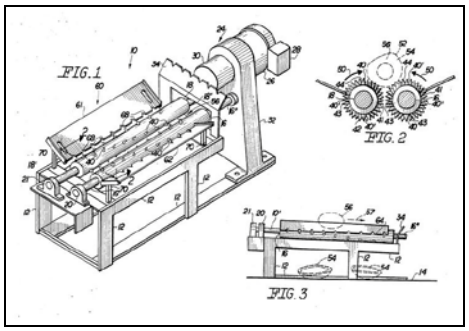


Fig. 3 US Patent US 4708056 A [4]

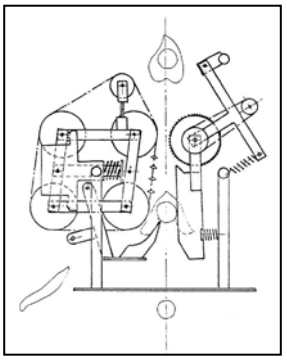


Fig. 4 EP 0188949 A1 [5]

2.3 Summary of Literature review on Coconut Fiber extraction machine

Literature study is carried out based on the existing patents on coconut fiber extraction machine, study gives opportunity to develop a compact coconut fiber extraction machine which could be used in remote villages so that unutilized husks from such areas could be tapped and fiber could be made available to the Coir Industry directly.

3. DATA COLLECTION

In competitive market Product design is one of the essential to success the product, Product design involves research and on existing designs or products, GEMBA study to be conduct while doing product design more ever designer should understand the concepts and basic requirements of the end user as well manufacturer also.

3.1 Coconut growing states in India

Coconut production plays an important pole in the national economy of India. According to figures published in December 2009 by the Food and Agriculture Organization of the United Nations, India is the world's third largest producer of coconuts, producing 10,894,000 tons in 2009. Traditional areas of coconut cultivation are Kerala (45.22%), TamilNadu (26.56%), Karnataka (10.85%), Andhra Pradesh (8.93%) and also Goa, Orissa, West Bengal, Pondicherry, Maharashtra and the island territories of Lakshadweep and Andaman and Nicobar [6].

3.2 Coir (Coconut Fiber)

COIR is a versatile natural fiber extracted from mesocarp tissue, or husk of the coconut fruit, the general process of which is shown in figure 5. Generally fiber is of golden color when cleaned after removing from coconut husk. Coir is the fibrous husk of the coconut shell. Being tough and naturally resistant to seawater, the coir protects the fruit enough to survive months floating on ocean currents to be washed up on a sandy shore where it may sprout and grow into a tree, if it has enough fresh water, because all the other nutrients it needs have been carried along with the seed. These characteristics make the fibers quite useful in floor and outdoor mats, aquarium filters, cordage and rope, and garden mulch. The husk contains 20% to 30% fiber of varying length.

3.3 Flow Chart for Coir Fiber Extraction Process (Figure 5)

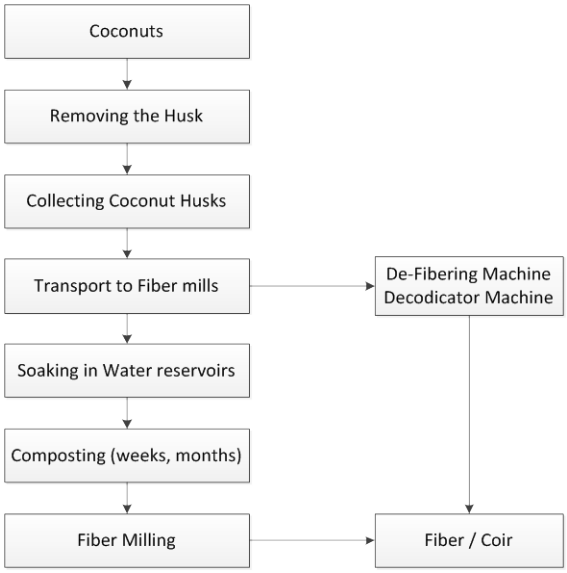


Fig. 5 Flow Chart for Coir Fiber Extraction

3.4 Coconut De-Husking Method

Mechanical De-husker

The user of mechanical De-husker method as in Figure 6:

1. Farmers – A skilled husker can manually split and peel about 2,000 coconuts per day
2. Households – 1-2 coconuts per day
3. Hotels – 10-20 coconuts per day

Fig. 6 Mechanical De-husker

Automatic De-husker

The main users of this type of application practices are by Oil extracting, fertilizer and food industries, etc. with the use of coconuts in mass quantity every year. These machines can process 2,000 coconuts per hour as shown in Figure 7.

Fig. 7 Automatic De-husker [6]

3.5 Coconut Fiber Extraction Mills

The husk is collected from the de-husked source and transported to Fiber extraction mills / industries for further processes. Husks are buried in pits dug along riverbanks, immersed in water-filled concrete tanks, or suspended by nets in a river and weighted to keep them submerged. The husks typically soak at least six months. Based on the fiber quality and usage the fiber extraction processes are defined.

3.6 Market Study

Coir industry in India provides employment to the tune of five lakhs people approximately of which 3.60 lakhs people belong to Kerala alone. About 80% of them are women. The women are mostly engaged in fiber extraction and spinning and men work in the coir products sector. The industry concentrated in Kerala but spread over in other States like Tamilnadu, Karnataka, Orissa, Andhra Pradesh etc. The development of industry is mainly concentrated in the area of coconut cultivation and availability of coconut husk.

Production of coir fiber is of the order of 4.2 lakhs metric tons and production of coir yarn is of the order of 2.8 lakhs. The coir products and rope account for 2.00 lakhs tones. The white coir fiber produced in Kerala is of superior quality to brown coir fiber produced in other States mainly Tamilnadu. The cost of white fiber is double to the cost of brown fiber. In view of this consumption of white fiber is declining. The total output of coir and coir products in India estimated to be around Rs.1500.00 crore including exports of Rs.350.00 crore.

Total cost of machineries and equipment used for De-fibering unit is as show in Table 1:

Table 1. Market Study [7]

Particulars	Cost (in Rs.)
Crusher (10 HP)	3,50,000
Soaking Tank	4,00,000
Defibering Machine (10 HP)	3,75,000
Revolving Screener including motor (2 HP)	90,000
Turbo Double Cleaner (20 HP and 15 HP)	3,00,000
Hydraulic bailing press (2 HP)	2,50,000

3.7 User Study

User study is done by observations of coconut de-husking in remote locations, villages, where farmers used to de-husk the coconuts by manual. The Steel spear is the tool used by farmers to de-husk the coconuts. An experienced worker can de-husk approximately 1000-1500 nuts per day with the use of this tool. Other than Steel spear, Lever operated de-husker is well reaching user in rural market and it is used more often by farmers.

Pedal operated De-husker is refined design of lever operated coconut de-husker and it is designed for the application of farmers. This will help farmers in reducing de-husking time and increase in productivity. It is portable in design and height of the de-husker can be adjusted as per user requirement. The availability and marketing of this product is not reaching user in rural areas.

Coconuts in the husk are very bulky. The de-husked fiber is being transported in trucks or carts to the fiber/ coir industries for the fiber extraction process.

3.8 Key Findings

With User observation and feedback by Questionnaires and suggestion from user a few key findings have been arrived.

- The process needs a skilled labor
- Difficult to get labor on time.
- Difficult to fix it in dry land.
- Difficult to stand and De-husk for long time.
- Difficult to transport
- Direct fiber material can be supplied, instead of raw husk.

3.9 Customer Voice

Collected feedbacks from user have been converted to Technical voice through flowchart for understanding its design factors & requirements are as shown in Figure 8.

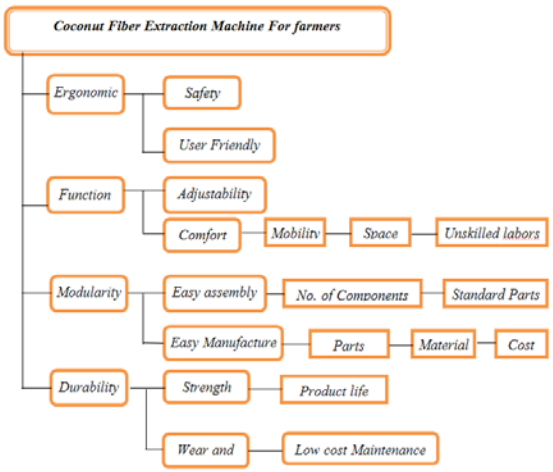


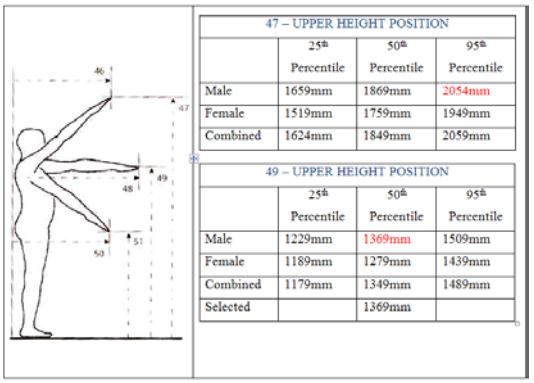
Fig. 8 Object Tree Mapping

4. ERGONOMIC CONSIDERATIONS

This is the Branch of Ergonomics that address and deals with measurement of the human external body dimension in static and dynamic condition. The Anthropometry points as shown in Figure 9 have been considered for Coconut fiber extraction machine which help in deciding its dimension (Figure 10).

5. QUALITY FUNCTION DEPLOYMENT (QFD)

Quality function deployment (QFD) is a "method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process".



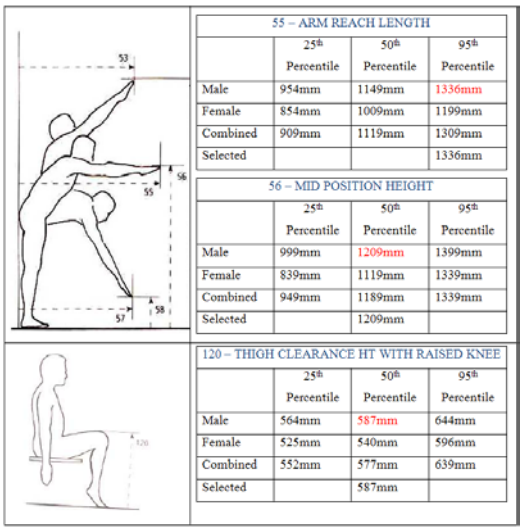
47 – UPPER HEIGHT POSITION

	25th Percentile	50th Percentile	95th Percentile
Male	1659mm	1869mm	2054mm
Female	1519mm	1759mm	1949mm
Combined	1624mm	1849mm	2059mm

49 – UPPER HEIGHT POSITION

	25th Percentile	50th Percentile	95th Percentile
Male	1229mm	1369mm	1509mm
Female	1189mm	1279mm	1439mm
Combined	1179mm	1349mm	1489mm
Selected		1369mm	

Fig. 9 Ergonomics Consideration [8]



55 – ARM REACH LENGTH

	25th Percentile	50th Percentile	95th Percentile
Male	954mm	1149mm	1336mm
Female	854mm	1009mm	1199mm
Combined	909mm	1119mm	1309mm
Selected			1336mm

56 – MID POSITION HEIGHT

	25th Percentile	50th Percentile	95th Percentile
Male	999mm	1209mm	1399mm
Female	839mm	1119mm	1339mm
Combined	949mm	1189mm	1339mm
Selected		1209mm	

120 – THIGH CLEARANCE HT WITH RAISED KNEE

	25th Percentile	50th Percentile	95th Percentile
Male	564mm	587mm	644mm
Female	525mm	540mm	596mm
Combined	552mm	577mm	639mm
Selected		587mm	

Fig. 10 Ergonomics Consideration [8]

5.1 QFD Results

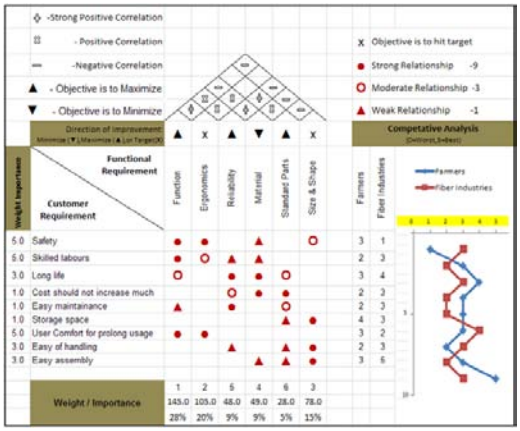
QFD are obtained from inputs from farmers and coir industries as shown in Table 2. QFD house results simple, functional, ergonomics are top priorities as shown in Figure 11.

- Machine should be compact
- Functionality
- Safety
- Easy for assemble
- Easy for maintenance
- Low cost
- Good Ergonomics

6. PRODUCT DESIGN SPECIFICATIONS (PDS)

Product Design Specification will give clear idea for the designer to understand the required specification to design the product. Based on the QFD results, which are derived from the vendors and customer voices market study, user study, PDS will be generated. Here are some of the major criteria considered for product design specification as shown in Table 3.

Table 2. Quality Function Deployment



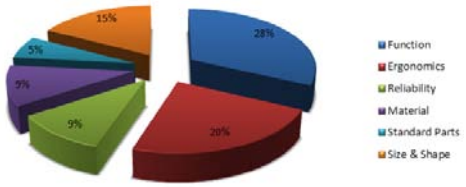


Fig. 11 QFD Results

Table 3. Product Design Specification

SL. No	Description	Specification
1	Name	Coconut Fiber extraction Machine
2	Model	CFEM-PKY001-2014
3	Mechanism	Gears and Pulley with belt drive
4	Target Customer	Farmers or small scale Coir industry
5	De-Fiber Process	Motor operated
6	De-Fiber Function	Automatic / Rotary handle operated / Pedal operated / Spring actuated
7	Material	EN-08 for Shaft, Stainless Steel for Cutting tips, Steel for Fabricated body
8	Manufacturing	Machining, Indexing, Bending and Fabrication
9	Safety	Avoid sharp corners, Safety guards
10	Cost	Approx. 12000/- INR
11	Life of the product	2-3 years
12	Motor Specification	¼ HP Single phase AC motor, heavy duty, 1440 RPM
13	Major Pulley diameter	12” (12-B single)
14	Minor Pulley diameter	2” (2-B single)
15	Pulley Ratio	1:6
16	Working RPM	240 RPM
17	Weight	55 KG
18	Production Rate	100 coconuts per hour

7. CONCEPT GENERATIONS AND SELECTION

After all the necessary study and understanding the customer needs, based on the major requirements concepts are generated. For generating these concepts or proposal ready considered all the points jotted out in QFD and product design specification (PDS).

Five concepts generated with various factors which meets the demands like functionality, safety and cost. Final concept selected for the working prototype manufacturing. This concept selected based on the dot selection method.

7.1 Concept-1, Handle operated

Manual operated coconut fiber extraction machine is considered as first concept, here handle is used to rotate, for which gears assembled, one gear will give drive to other gear, and Barrel rotates in opposite direction with the help of these gears. Coconut with untapped husk is placed in between barrels. Round coconut shell is removed by hand after the operation and separated fiber material is collected in sack below as shown in Figure 12.

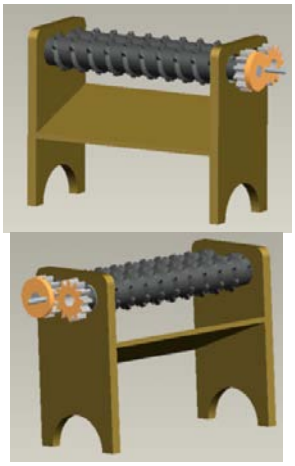


Fig. 12 Concept-1 Handle operated

7.2 Concept-2, Handle operated

As name indicates in this concept sewing machine type paddling mechanism is attached to the base of the machine, with the help padding drive is given to gears. Handle is also used to start rotation, one gear will give drive to other gear, and Barrel rotates in opposite direction with the help of these gears. Coconut with untapped husk is placed in between barrels. Round coconut shell is removed by hand after the operation and separated fiber material is collected in sack below as shown in Figure 13.

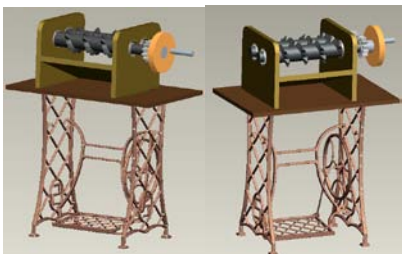


Fig. 13 Concept-2 Sewing Machine Type

7.3 Concept-3, Cycling Type Operated

As name indicates in this concept cycling type paddling mechanism is attached to the base of the machine, with the help padding drive is given to gears. Paddle with chain gear will give to drive to small chain

gear sprocket, small chain gear sprocket is attached with large wheel, and large wheel will give drive to the smaller wheel with the help of belt drive, which is connected to gears. Barrel rotates in opposite direction with the help of these gears. Coconut with untapped husk is placed in between barrels. Round coconut shell is removed by hand after the operation and separated fiber material is collected in sack below as shown in Figure 14.

7.4 Concept-4, Motor Operated Type-1

Motor operated type-1 coconut fiber extraction machine, in this type motor is attached at the base, smaller pulley at the motor end gives drive with the help V-belt to bigger pulley which is connected to gear. One gear will give drive to other gear, and Barrel rotates in opposite direction with the help of these gears. Coconut with untapped husk is fed from one end in between barrels and round coconut shell is moved automatically towards other end and is collected in the tub after the operation and separated fiber material is collected in sack below.

In this concept helical serrated teeth is engraved / Brazed on barrel surface to remove fiber and to give linear motion to coconut shell to exit. Helical serrated teeth play the major role in this type as shown in Figure 15.

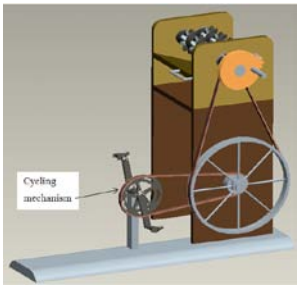


Fig. 14 Concept-3, Cycling Type

Helical serrated teeth

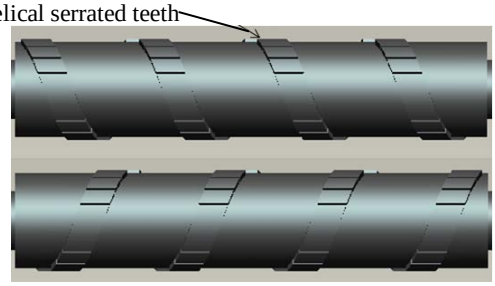


Fig. 15 Concept-4, Motor Operated Type-1

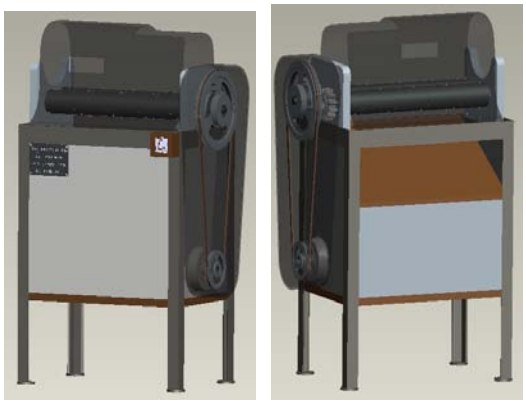
7.5 Concept-5, Motor Operated Type-2

Motor operated type-2 coconut fiber extraction machine, this is also same as concept-4, motor is attached at the base, smaller pulley at the motor end gives drive with the help V-belt to bigger pulley which is connected to gear. One gear will give drive to other gear, and Barrel rotates in opposite direction with the help of these gears. Coconut with untapped husk is fed from one end in between barrels and round coconut shell is moved automatically towards other end and is collected in the tub after the operation and separated fiber material is collected in sack below.

In this concept cutting pins has been press fitted on indexed hole on barrel surface as shown in figure 7.5, cutting pins helps to remove fiber and to give linear motion to coconut shell to exit. Cutting pin indexing angle and distance plays the major role in this type as shown in Figure 16.

7.6 Concept Selection (Pugh's Chart)

Concept selection is done based on Pugh's chart, Sugarcane crusher is used as a Datum for generating the concepts, main selection criteria is functionality, Safety, Cost and the Reliability. Based on this criteria's Concept-5 is selected for model making prototype as shown in Table 3.



Helical Pressed Pins

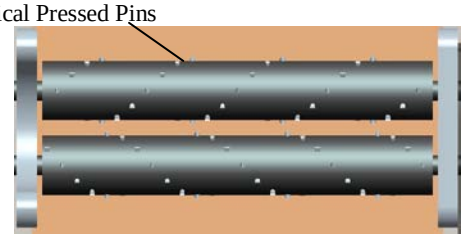


Fig. 16 Concept-5, Motor Operated Type-2

Table 3. Pugh's Chart

Sl. no.	Selection Criteria	DATUM	Concept-1	Concept-2	Concept-3	Concept-4	Concept-5
1	Function		S	S	+	S	+
2	Safety		S	S	+	S	+
3	Reliability		+	-	+	+	+
4	Cost		-	-	-	-	-
	Σ+		1	1	2	1	3
	Σ-		1	1	2	1	1
	ΣS		2	2	0	2	0

7.7 Final Concept

Reviewed each concept and analyzed thoroughly. Based on weighted ranking method Motor operated Type-2 concept is selected and finalized for model making as shown in Figure 17.

7.8 Detail Deisgning

Assembly drawing and drawings for final concept is done. All dimensions are in mm. below are the drawings released related to the final concept of coconut fiber extraction machine as shown in Figure 18.

8. MODEL MAKING

8.1 Raw Material and Standard Parts

Raw materials used for development of model as shown in Figure18:

- Round Rod – Dia 63x600 and 650 length
- Rectangular – 200x175x20
- Sheet material for fabrication

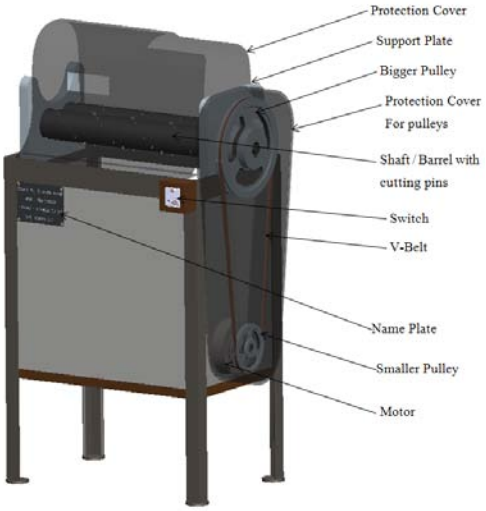


Fig.17 Final Concept

8.2 Machining and Assembly

Selected the material, size and standard parts, and identified the industry to proceed with machining. Various machining processes were carried out for development of working prototype model for coconut fiber extraction machine. Turning the round raw material and milling the rectangular work piece were main and initial machining operation. Cleaned raw material and maintained the sizes accordingly as shown in Figure 19 and assembly as shown in Figure 20.

8.3 Fabrication and Painting

Sheet material is fabricated to Stand or base of the machine with the tack welding. Latches and inches were also welded and assembled for protection cover. For partial maintenance in emergency condition latches and inches are provided for protection cover. Hand grinder is used to give finish for tack weld portions. After fabrication of the product, it is taken for painting. Based on the industrial design and modules studied, painting color is selected for this product and painting is done as shown in Figure 21.

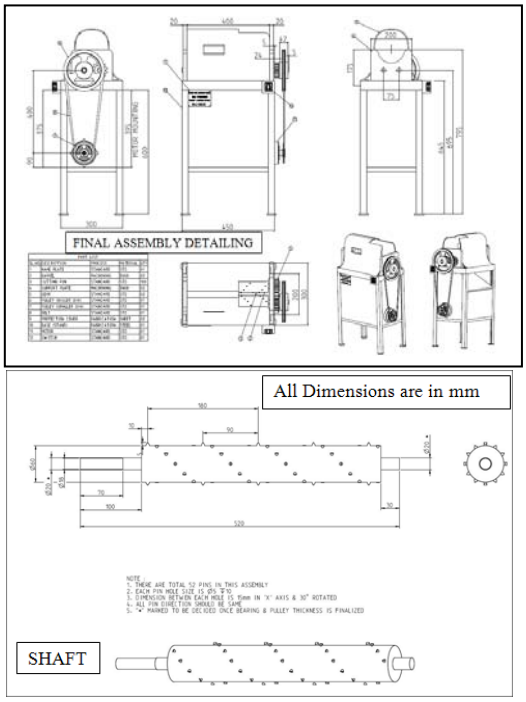


Fig. 18 Detail Designing

Fig. 19 Raw Material

8.4 Final Working Model

Final working model is as shown in Figure 22.

9. PRODUCT VALIDATION

After manufacturing working model, product was validated by checking its features and some of the key functions. Below are the some of the functions are checked.

As a part of product feedback and validation, product was validated. Complete demo of work model and Coconut fiber extraction process with the help of product was presented in front of few customers. They were very impressed with product and collecting process. Below are the comments.

- Working length to increase
- RPM reduction
- Pin pitch reduction

Fig. 20 Machining and Assembly

Fig. 21 Fabrication and Painting

10. CONLUSIONS

10.1 Summary

The project comprises of research and user study. Literature study is carried out based on the existing patents on coconut fiber extraction machine, and it is observed that there are difficulties for remote village to supply unutilized husks to coir industries directly. So there is a need to give solution to overcome their difficulties and to arrive at solution, importance is given towards users operating environment and mainly towards constrains like Safety, Function and reliability.

Fig. 22 Final Working Model

QFD and PDS helped in generating concepts. Benchmarking of existing products is also carried in existing Coir industries. Model making gave an opportunity to learn model making techniques, manufacturing process and difficulties involved during this processes. It helped to understand about each and every process that carried out from start to completion of the prototype work model of coconut fiber extraction machine.

Concepts were generated keeping benchmarked product. Five concepts are generated with different function and operating process for coconut fiber extraction machine. Final concept is selected by considering the user's operating environment and method, which can be used in small scale coir industries and in the farm. That means it should be easy to maintain. Considering the user's buying capacity a true scaled product is fabricated.

10.2 Conclusions

Below are some of the conclusions based on new derived process and new designed product & its functions.

- Based on the Design concepts and development, output of the product. This product can de-fiber 100 coconuts per hour and it will be good for Farmers and small scale coir industries.
- Easy to assemble.
- Easy Maintenance
- About the market, this model is compact with good range of productivity with low cost and safety.

17.3 Recommendations for future work

- RPM to be reduced to 120rpm
- Indexing pitch has to decrease
- Length of the shaft can be increased
- Pitch between the shaft can be reduced by 5mm
- Hollow Shaft (tube) can be used.
- As we are offering this product with new design to farmers and small scale coir industry, need to undergo further refinement.

18. REFERENCES

[1] MSME, *Evaluation Study of Domestic Market Development Assistance Scheme implemented by Coir Board*, http://msme.gov.in/Coir%20Board-

Impact-Domestic-Market-Assistance-Scheme.pdf. Retrieved on15th Jan. 2014.

[2] Food and Agricultural Organization of the United Nation, www.fao.org/economic/futurefibres/ fibres/coir/en, Retrieved on 15th Jan. 2014.

[3] Palm Shells, *Coconut Palms*, http://www.palmshells.com/cocoshells.html, Retrieved on 15th Jan. 2014.

[4] Chandra Dinanath, *Coconut dehusking machine*, US patent US4708056, www.google.co.in/patents/US4708056, 28 Jan. 1987.

[5] Gilles Durand, *Apparatus for Dehusking Coconuts*, EP0188949, *Coconut breaking machine*, US patent US3605834, http://www.google.co.in/patents/US3605834, 20th Sep. 1971.

[6] Coconut Machines, www.coconutmachine.com/index.php?mid=72, Retrieved on 15th Jan. 2014.

[7] Coir Machines, *Coir Fibre Extraction Machinery*, http://www.coirmachines.net/coir-fibre-extraction-machinery.html, Retrieved on 15th Jan. 2014.

[8] Debkumar Chakrabarthi, *India Anthropometric Dimensions*, NID, Ahmedabad: National Institute of Design, pp100, 1997.