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Designing and Manufacturing of Bamboo Processing Machine

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Abstract— *This document describes about designing and manufacturing of bamboo processing machine having three functions, namely; splitting, grinding and sanding bamboo surfaces. It helps to avoid a tedious and time taking manual bamboo processing. Three people can work at the same time when a need arise. It is designed considering safety factors and ergonomic considerations. The machine is robust in design having low sound, and good aesthetic so as to look attractive and durable while giving service. Designing and fabricating such type of machine is important so as to save money and it avoids from buying individual machine.*

For the purpose of convenience, focusing on the need assessment of the project, developers are using exploratory research method. Exploratory research made by conducting focus group interviews to get detail information. Developers used four data gathering techniques (tools), namely; oral questions, direct observation, document analysis and questionnaires (closed and open questionnaires) to understand current problems of bamboo processing activities and for the need of this machine.

After the quantitative and qualitative data are gathered from those sources developersreached at conclusion to designed and manufactured bamboo processing machine as a solution to facilitate bamboo products. The findings indicate that, there is lack of bamboo processing machine and having high demand of it.

In general, according to the newly designed and manufactured bamboo processing machine, it can perform manual splitting, grinding bamboo knots and sanding bamboo surfaces. For the future it can create job opportunity to the society.

Keywords—Designing, Manufacturing, bamboo processing, splitting and grinding knots, all cost are in Birr (Ethiopian currency).

I. INTRODUCTION

1.1 Background

Machinery from various sources has become operational in recent years for the primary processing of bamboo by bamboo processing machine (BPM). The main requirement is for an optimal configuration of machinery with adequate performance and productivity in a cost effective manner to process bamboo culms to slivers and slats for different applications.

In Ethiopia, from time to time forests are destructing in rural areas, if this continuous in the same manner; there will be change to bad weather conditions. Even though forests are declining, on the other hand, our country has good bamboo substituting resources, so it is better to use bamboo substituting wood forests. Bamboo is a renewable plant belonging to grass and its growing rate is faster than wood. Now a day's our government also focused on bamboo plants and initiating investors to invest in the area to process bamboo for different uses, this project will contribute significant role for the improvement of bamboo products since wood lumber is expensive and also forests are declining, many SMEs emerge to use bamboo for different furniture makings. Thus, this Bamboo Processing Machine will help them for facilitating and improving their productivity.

The International Network for Bamboo develops, provides and promote appropriate technologies and other solutions to benefit people and the environment [1].

Bamboo is one of the oldest building materials used by mankind the bamboo Culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. Examples of bamboo products are food containers, skewers, chopsticks, handicrafts, toys, furniture, flooring, pulp and paper, boats, charcoal, musical instruments and weapons [2].

In Asia, bamboo is quite common for bridges, scaffolding and housing, but it is usually a temporary exterior structural material. In many overly populated regions of the tropics, certain bamboos supply the one suitable material that is sufficiently cheap and plentiful to meet the extensive need for economical housing. Bamboo shoots are an important source of food, and a delicacy in Asia. In addition to its more common applications, bamboo has other uses, from skyscraper scaffolding and phonograph needles to slide rules, skins of airplanes, and diesel fuels [3]. Extractives from various parts of the plant have been used for hair and skin ointment, medicine for asthma, eyewash, potions for lovers and poison for rivals. Bamboo

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ashes are used to polish jewels and manufacture electrical batteries. It has been used in bicycles, dirigibles, windmills, scales, retaining walls, ropes, cables and filament in the first light bulb. Indeed, bamboo has many applications beyond imagination. Its uses are broad and plentiful. With the advancement of science and technology and the tight supply of timber, new methods are needed for the processing of bamboo to make it more durable and more usable in terms of building materials. Studies have been done on the basic properties, and processing bamboo into various kinds of composite products. More studies are needed to aid and promote its application in the modern world.

Machinery from various sources has become operational in recent years for the primary processing of bamboo. The base requirement is for an optimal configuration of machinery with adequate performance and productivity in a cost effective manner to process bamboo culms to slivers and slats for different applications [5].

1.1.1 Processing Characteristics of Bamboo

Because of the special structure of bamboo, the processing and utilization methods for bamboo plants have their own characteristics that are different with woody plants. They are as follows:

(1) Bamboo stems are small in diameter, hollow inside, thin in wall, large in taper, and different in component between inner, middle and outer layers. The diameter of most of Phyllostachyspubescent, which is larger in diameter among bamboo plants, ranges from 70 mm to 100 mm with average wall thickness less than 10 mm. A few of bamboo species are small in diameter ranging from 30 mm to 50 mm with mean wall thickness 4 – 6 mm. (2) Most of bamboo products can be manufactured with machines, but a few procedures or products can't avoid of handwork.

Consequently, the production rate of bamboo industry is several times even ten times less than that of wood industry.

(3) Because the outer skin and inner players of a bamboo Culm can't be wetted by adhesive, the very portion that can be used is mainly the middle portion of bamboo wall. So the utilization percent of bamboo is much lower, ranging from 20% to 50% of volume or weight.

(4) Bamboo is difficult to be dealt like wood, which can be manufactured into boards or blocks of large size. It is usually machined into strips of 20 mm to 30 mm wide by 5 mm to 8 mm thick that can't be used directly.

(5) The difference, not only in structure but also in chemical composition, between bamboo and wood is obvious because bamboo contains much more nutrition substances such as hemicelluloses, starch, protein, sugar etc. As a result, bamboo products have lower resistance against insects and fungi.

1.1.2 Importance of Bamboo in Ethiopia

Although bamboo is not an integral part of the economy of Ethiopia, it plays a very important role socially, economically and ecologically in areas where it occurs naturally and where it is planted. Both the highland and lowland bamboos are such a versatile type of resources that they can be used in many ways. Their paramount importance and multifaceted use in different parts of the country are reported.

Bamboo is the main material for the construction of houses, animal sheds, fences and beehives at Asossa Zone and in different parts of Ethiopia [6, 7]. In the case of towns, some people are using bamboo's furniture due to less cost than wood products. Some people are producing bamboo furniture for their source of income. Even though, using bamboo products are increasing time to time in Ethiopia, quality of bamboo product's surface finish is poor being manual worked. The researchers initiated to design and fabricate this bamboo processing machine in order to solve the existing problem of poor quality bamboo products.

1.2 Statement of the problem

Processing bamboo is a tedious, manual task or Bamboo processing by hand is a time consuming and difficult process. Using a short local machete (heavy knife), workers in Ethiopia hack away the protruding nodes of the bamboo, and rub the silica away with rough hand tools. However, their imprecise and irregular methods are crude and extremely time-consuming. The surface of bamboo is naturally coated with protective silica, giving it its sheen (shine). The silica must also be filed away in order to prepare its surface for texturing and for receiving paint. .

The main problems are poor quality surface finish of bamboo and the exhausting manual task of bamboo processing activities.

1.3 Objective

1.3.1 General Objectives

The general objective of this project is:

- To design and manufacture bamboo processing machine that can manual splitting, bamboo knot, grinding and polishing bamboo surfaces.

1.3.2 Specific Objectives

The following are the specific objectives of the project:

- To design machine elements.
- To design and manufacture bamboo splitter.
- To fabricate different machine parts like shaft, pulley, and the like.
- To reduce cost by using local available materials. It is beneficial being creating local market.
- To adapt technology.
- To transfer technology to SMEs.
- To develop designing and manufacturing skills.
- To manufacture from locally available materials.

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- To substitute other import bamboo machines. This is beneficial to save foreign exchange currency.

II. METHODOLOGY

2.1 Material

For the purpose of convenience, focusing on the need assessment of the project, developers are using exploratory research method. Exploratory research might involve a literature search or conducting focus group interviews. The exploration of new phenomena can help the researcher's need for better understanding and test the feasibility of a more extensive study, or determine the best methods to be used in a subsequent study. For these reasons, exploratory research is broad in focus and provides definite answers to specific research issues. The objective of exploratory research is to identify key issues and key variables. Developers used four data gathering techniques to understand current problems of bamboo processing and for the need of this machine; the researchers collected data by interviewing, direct observation, document analysis and questionnaires (closed and open questionnaires). The interview will be from different private sectors and customers. The documents which are analyzed for the project are internet, and many types of reports and researches about bamboo processing machine.

After the quantitative and qualitative data are gathered from those sources developers designed and manufactured bamboo processing machine as a solution to facilitate bamboo products and to avoid exhausting and time consuming of grinding or polishing activities.

2.2 Target Groups

The target group is, for those who are working directly on bamboo furniture for unskilled, semi-skilled and technically trained persons and who will be worked on bamboo furniture makings.

2.3 Sample and Sampling Technique

Sampling involves selecting relatively small number of elements from the large defined group of elements and expecting that the information gathered from small group allow generalization to be made about the larger group of population. (Research method for construction 3rd edition)

The sampling units are the defined target population elements available for selection during the sampling process. In this research, Adama Town bamboo furniture workers are selected purposely as the total population since the result can be considered for the whole bamboo workers in the country.

A total of 20 numbers of bamboo workers are selected from the population of 40 number of bamboo workers including SMEs at Adama Town that are currently working in the field of bamboo furniture makings.

The reason why Adama Town is selected for this study is because the town is near to the university and due to limited budget; the researchers couldn't include other places. The sampling is selected by using systematic random sampling method. The sample ratio can give sufficient information because it is taken 50% out of total population.

III. DESIGN ASPECTS

3.1 General Considerations in Machine Design

- Type of load and stresses caused by the load.
- Motion of the parts or kinematics of the machine.
- Selection of materials.
- Form and size of the parts and
- Use of standard parts and safety operations, etc.

This newly designs of bamboo processing machine focus on three functions that can grind, polish and manual splitting of bamboo. Starting from the idea of design principles and functional requirements the researchers designed the parts of the machine based on the design procedures.

3.2 Designing Power

There are two types of electrical motors, namely alternative current motor (AC) and direct current (DC). Developers selected AC motor for bamboo processing machine having 220 to 380V considering functional requirements and the availability of Ethiopian Electrical power so as to get more energy and to work for 8 hours continuously.

The power is designed based on the required functions by referring wood work machines and estimating the required force for operating grinding and polishing of bamboo and it is calculated based on the following steps using standard table of (ISO V belt products of Goodyear). The power selected for this project is 1.5Kw.

a. Determine appropriate service factor

A belt drive is designed based on the design power, which is the modified required power. The modification factor is called the service factor. The service factor depends on hours of running, type of shock load expected and nature of duty.

Proper service is determined based on intermittent, normal or continuous services, from standard table. The service factor, 1.2 is selected (Engineering data for v-belts and wedge belts) for normal service, i.e., daily service 6 to 16 hours.

b. Multiply the Absorbed Power by the service factor to get Design Power.

Required motor power = 1.5kw (by referring other related machines, E.g. Wood machines)

Service factor = 1.2

Design power = 1.2 x 1.5

= 1.8 kW but from standard table of V belt products 1.90 Kw is selected.

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Table.3.1: SPZ section – drives selections, drive speeds and kilowatts per belt (From power transmission products of hand book)

Speed ratio	Pulley datum diameters in mm		Driver 1440 rev/min		E in Kw
	Driver, R	Driven, N	Driven in rev/min	MC in	Kw
1.33	**75**	**100**	**1084**	**1.90**	**1.60**
2.06	60	125	698	1.27	0.95
2.07	63	132	694	1.41	1.09
2.07	67	140	696	1.58	1.27
2.08	56	118	691	1.10	0.77
2.08	170	355	692	5.83	5.57
2.09	71	150	688	1.76	1.45

IV. DESIGN OF SHAFT

Shaft is a basic, important and very common machine element. It is a rotating member used for the transmission of power. It is designed to perform a specific task in this machine. A pulley is mounted on it to receive motion from motor through belt and then the shaft rotates. This rotational movement of shaft performs grinding and polishing activities of bamboo.

4.1 Material Selection for the Shaft

Most shafts are made from steel, either low- or medium-carbon. However, high quality alloy steel, usually heat treated, may be chosen for critical applications. Other metals, e.g. brass, stainless steel or aluminium, may be used where corrosion is a problem or lightness is required.

4.2 Functional Requirements of the Shaft

The main function of shaft is to transmit power. Since the shaft is subjected to high torque, it may be bent. Therefore, the shaft must be strong, wear resistant, tough and ductile.

4.3 Material's Priorities Requirement of the Shaft

To satisfy the functional requirement of shaft, the material should be chosen require the following:

- ✓ The material should have better yield strength and tensile strength.
- ✓ The material to be selected requires higher young modules value.
- ✓ Should be tough enough, machine able and light in weight.

To select the material for the shaft, the following candidate materials are listed:

- ❖ Annealed SAE 1020
- ❖ SAE 1010
- ❖ W-100 of SAE 1045
- ❖ SAE 1040

Table.4.1: Application of digital logic method (Machine Design)

Property	Decision No.									
	1	2	3	4	5	6	7	8	9	10
Density	1	1	1	1						
Modules of elasticity	0				1	1	1			
Toughness		0			0			1		
Tensile strength			0			0			1	
Yield strength				0			0		0	1

Table.4.2: weight factor for the shaft (Machine Design)

Property	Positive decision	Weight factor
Density	4	0.4
Modules of elasticity	3	0.3
Toughness	1	0.1
Tensile strength	1	0.1
Total	10	1.0

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Table.4.3: Candidate material for shaft (A Text of Machine Design)

Material	Density kg/m^3	Modules of Elasticity (Mpa)	Toughness (Mpa)	Tensile strength (Mpa)	Yield strength (Mpa)
Annelid SAE 1020	7680	207	25	380	207
SAE 1010	7680	207	28	325	180
W-1000 of SAE 1045	7680	207	8	825	614
SAE 1040	7680	207	33	621	414

Table.4.4: Decision matrix for shaft (Machine Design)

Material	Density kg/m^3	Modules of Elasticity (MPa)	Toughness (MPa)	Ultimate Tensile strength (MPa)	Yield strength (MPa)
Annelid SAE 1020	7680	207	25	380	207
SAE 1010	7680	207	28	325	180
W-1000 of SAE 1045	7680	207	8	825	614
SAE 1040	7680	207	33	621	414

Table.4.5: Normalized outcome for shaft (Machine Design)

Material	Density kg/m^3	Modules of Elasticity (Mpa)	Toughness (Mpa)	Ultimate Tensile strength (Mpa)	Yield strength (Mpa)
Annelid SAE 1020	100	100	75.75	45.9	33.7
SAE 1010	100	100	84.85	39.25	29.3
W-1000 of SAE 1045	100	100	24	100	100

Table.4. 6: value outcome (Machine Design)

Material	Density X0.4	Modules of Elasticity X0.3	Toughness X0.1	Ultimate Tensile strength X0.1	Yield strength X0.1
Annelid SAE 1020	40	30	7.575	4.59	3.37
SAE 1010	40	30	8.485	3.925	2.93
W-1000 of SAE 1045	40	30	2.4	10	10
SAE 1040	40	30	10	7.5	6.74

Table.4.7: Overall satisfaction (Machine Design)

Annelid SAE 1020	85.535
SAE 1010	85.34
W-1000 of SAE 1045	92.4
SAE 1040	94.24

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The result should shows that on the bases of allocated weighting factor SAE 1040 gives the highest overall satisfaction among these materials. Therefore, this material is preferable for the production shaft (suitable material selected for the shaft is SAE 1040 for designing).

V. COST ANALYSIS

5.1Theory of Economic Consideration

It is important that the designer develops skills in estimating costs of designs in order to secure the most economic features. This entails being aware of the breakdown of products costs and the various cost stages that exists in an organization. These have to be broken down in to individual units to calculate the overall cost of the product. For most purposes of calculating costs however, it would be extremely difficult and time consuming to put together these individual costs which are:-

- Material cost
- Labor cost
- Overhead cost

Material costs plus labour costs in unit cost of manufacture; the overhead cost is the cost of preparation of the component.

5.2 Economics of Design

The following considerations high lights some of the methods by which thoughtful design may reduce the overall product least.

- Economic choice of production technique
- Economic choice of material
- Economic choice of design form
- Avoiding material wastage
- Avoiding excessive machining and close tolerance
- Consideration for size and product
- Efficient use of standard components and bought-items.
- Designing to aid packaging
- Using computer-aided techniques.

Design and manufacture a product according to a certain specification by minimizing total cost and maximizing efficiency of the product or machine to meet service requirements is only one aspect of production. Since economics is one of the most important aspects of any manufacturing operation, So that the product successfully marked and the cost must be competitive with similar products in the market place. Based on these the design and manufacture of certain bamboo processing machine analysis should be done in order to be competitive. The cost minimizing and maximizing efficiency of product or machine is the main objective of our project. In this project the total cost consists of material cost, tooling cost, labour cost, fixed cost and capital cost.

5.2.1 Labour Cost

According to the information obtained from different machine shops that are available at Adama city, a single beginner machinist is paid at least about 1400 birr per month. Assuming that developers each paid **5.8** birr/hr.

Table.5.1: Labor cost

Duties	No. of people engage	Total time	cost
Cutting aluminum ingot ϕ100mm, ϕ75mm using power hack saw	1	1/4 hr	1.45birr
machining Pulley ϕ100mm *60mm using lathe machine	1	3hrs	17.4birr
machining Pulley ϕ75mm *40mm using lathe machine	1	3hrs	17.4birr
Cutting round bar for shaft ϕ30 using power hack saw	1	¼ hr	1.45birr
Machining round bar for shaft ϕ30mm using lathe machine	1	5hrs	29 birr
Cutting angle iron for table	1	1.5 hrs	8.7 birr
welding angle iron for table	2	3hrs	34.8 birr
Thread making for end shaft	1	3hrs	17.4birr
Lay out & making hole for motor seating and bearing- house seating	2	1hr	11.6 birr
Cutting round road rollers using power hack aw	1	1hr	5.8 birr
Machining round road rollers	2	2hrs	23.2 birr
Making blades (splitters)	2	8hrs	92.8 birr
Tensioner for sand belt	4	2hrs	46.4 birr

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Total	**33 hrs**	**307.4birr**

5.2.2 Material cost

Material cost: - material cost consumes in order to produce each part is composed of different areas each component with these materials cost is listed as follows. Note that in this case it is roughly calculated value of each component. Since the detail is time taking and too much to show each calculation.

Table.5.2: Material cost (From current Adama town market price)

No	Item	Specification	Amount		Unit price (birr)	Total cost (birr)
			Unit	Quantity		
1	Sheet metal	1000 x 2000X1.5	Pcs	01	900	900
2	Aluminium ingot	Φ100mmx500mm	pcs	01	4000	4000
3	Aluminium ingot	Φ75mmx500mm	Pcs	01	3000	3000
4	Screws	Φ4mm	pkt	01	75	75
7	Paint brush	2 ½ inch	pcs	02	15	30
8	Wood Sand paper	Coarse	meter	04	20	80
9	Anti-rust	Grey	litter	01	68	68
10	Mild steel Round bar	Φ40x700mm	pcs	01	600	600
11	Chip wood	122*244*8mm	pcs	01	120	120
12	Electrode	E6013,Φ2.5	pkt	01	150	150
13	Drill bit	Φ4mm	pcs	06	08	48
14	Drill bit	Φ5mm	pcs	04	08	32
15	Drill bit	Φ6mm	pcs	02	08	16
16	Drill bit	Φ7mm	pcs	02	15	30
17	Drill bit	Φ8mm	pcs	02	15	30
20	grinding disc	180x22x6	pcs	02	32	64
21	Sheet metal	1700x620*4mm	pcs	01	2000	312
22	cutting disk	180x22x3	pcs	05	28	140
24	Glue	Tiger	Lit	01	80	80
25	hack saw blade	Sweden	pcs	04	25	100
27	Angle iron	40 x 40 x 3mm	pcs	01	300	300
28	Flat iron	40*4*6000	pcs	02	300	600
					Total cost	**10,175** ETB

5.2.3 Operation Cost

It is composed of handling, machining, and tool changing and tooling cost, handling time in minute to load and unload the work piece obtained from time table.

Start and stop ----------0.08min
Change speed----------0.04min
Engage speed----------0.05min
Inspect dimension with micrometre----------0.30min
Clean the machine----------0.50min
Load and unload----------0.40min

Total = 1.1 min

Let the cost for 60 min = 5 .8 birr, therefore,
Handling cost = 1.1*5.8/60 = **1.06** birr per min.

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5.2.4 Cost of Standard Materials

The cost of standard materials according to current market price, here are listed below in the following table.

Table.5.3: Cost of standard materials(From current market of price Adama town)

No.	Item	Specification	Unit	Quantity	Unit cost		Total cost	
					Birr	Cent	Birr	Cent
1	Bolt and nut	M6	Pc	6	3	50	21	00
2	Bolt and nut	M8	Pc	14	3	00	42	00
3	Bolt and nut	M10	Pc	4	4	00	16	00
4	Bolt and nut	M12	Pc	16	5	oo	80	00
5	Bolt and nut	M16	Pc	2	7	00	14	00
6	Bush Bearing	Dia. 30 mm	Pc	2	350	00	700	00
7	Ball Bearing	Dia. 25 mm	Pc	2	70	00	140	00
8	Electrode	Dia.2.5	Pack	1	120	00	120	00
9	Grinding disc	5 x 180	Pc	2	75	00	150	00
10	Cutting disc	3 x 180	Pc	1	75	00	75	00
11	Breaker	16A	PC	1	80	00	80	80
12	Cable	2.5 x 3	Meter	3	45	00	135	00
13	V belt	A 1425	PC	1	34	00	34	00
						Total	**1607.00**	

Standard material cost----------1607 birr
Total material cost----------10175 birr
Total operation cost----------1.06 birr
Total labor cost----------307.4 birr

Total = **12,090.46** birr

5.2.5 Fixed Cost

Fixed cost is the money that is paid for administration works.

Fixed cost is about ten percent of the sum of material costs and labour cost.

Material cost = 10175 birr and labour cost = 307.4 birr.

The sum of material cost and labour cost is 10482.4birr and fixed cost is 10% of these costs, i.e., Fixed cost = (10482.4*10) / 100 = **1048.24 birr**

5.2.6 Machine Depreciation

Many assets like machinery and equipment have a limited life span and even if that life span is many years, the asset will eventually reach the end of the life. Over the courses of machine's life span, it gradually decreases value and approaches its bottom end value as it becomes worn out or out dated. The percentage of the machine worn out each year is referred to as machine depreciation.

Machine depreciation cost is the cost of oil, grease and simple maintenance etc. This is estimated 20% of the fixed cost that is equal to **209.65** birr.

Total production cost (T_p)

T_p = material cost + Labour cost + Fixed cost + Cost of machine depreciation + standard material cost and tooling cost.

= 10,175 birr + 307.4 birr +**1048.24** birr + **104.824** birr +1607 birr

T_p =**13,242.46 birr**. This cost is good according to the current market price.

VI. CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The demand of this machine is higher and it is the time to response for the bamboo furniture workers' problem. It can solve the exhausting manual bamboo processing tasks and saves time, it can also facilitate products. This bamboo processing machine has three functions, namely, manual splitting, bamboo knot grinding and sanding the splitter bamboo. Since wood resources are declining, and their products are very expensive comparatively with bamboo, it is preferable to use bamboo furniture's.

Our country has good bamboo resources, but can't get economic advantages from the resources because there was no trend of usage of bamboo furniture's widely. So it

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is better to use bamboo for furniture's makings so as to reduce deforestation of wood plants. Since the main function of this machine is to process bamboo for bamboo furniture workers it can facilitate productivity and it increases quality as well. As it is well known one of the major problems in our country is forest declining but by nature bamboo is fast growing and renewable plant which belongs to grass which can substitute woods for furniture making. Because of the declining of forest and to solve the problems of bamboo workers, developers intended to design and manufacture bamboo processing machine.

The machine can perform the following activities:

- Grinding bamboo knots.
- Polishing bamboo surfaces into the required thickness.
- Split into the required divisions manually.

The machine can split up to the diameter of 100 mm in to the required divisions within one minute up to the length of 120 centimetres with average human push force 250N. The machine can reduce the time taking of bamboo processing for the operations of splitting, sanding of bamboo knot and polishing bamboo surfaces. This machine has the following advantages:

- Manufactured from local materials
- Easy to assemble and disassemble.
- It does not need highly skilled man.
- Convenient for transportation.
- Low in cost and easy to maintain.
- Having three functions leads not to buy three different machines, this helps to save time and money.
- It can create job opportunity.
- The machine has another advantage which is the bamboo grinding disc can be replaced by metal grinding disc or it can be replaced by cutter.

It can be easily manufactured and distributed to various areas of our country and easily adapted as technology transfer to SMEs.

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