Design and Manufacturing of Bamboo Processing Machine with Sanding Bamboo Surfaces, Grinding Knots & Splitting Functions

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Abstract:- *This paper presents about designing and manufacturing of bamboo processing machine having three functions, namely, splitting, grinding knots 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. The tail stock is designed having box in order to add weight which helps for splitting. This machine can also grind the external knot and the sand belt helps to sand or polish the bamboo surface in order to remove the outer and inner parts of bamboo to receive ink and varnish. Designing and fabricating such type of three functional machines is important so as to save money instead of buying a machine having single function. There are different kinds of bamboo processing machines previously made, but this machine is different than others; firstly, by having three functions, secondly, it is made from locally availably materials and thirdly it is cost effective. The demand of this machine was higher and it was 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. Since wood resources are declining, and their products are very expensive comparatively with bamboo, it is preferable to use bamboo furniture's. According to the manufactured bamboo processing machine, it was successful and able to perform manual splitting, grinding bamboo knots and sanding bamboo surfaces and also for the future it will create job opportunity for the society.*

Key Words: Designing, Manufacturing, bamboo processing, splitting and grinding knots.

1. INTRODUCTION

The International Network for Bamboo develops, provides and promotes 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. 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.

Machinery from various sources has become operational in recent years for the primary processing of bamboo by bamboo processing machine (BPM). The base requirement is for an optimal configuration of machinery with adequate performance and productivity in a cost-effective manner to process bamboo. At present individual machines are available for bamboo processing. However, operating of these machines for individual operations consumes time, materials and power requirement due to which cost of the operations carried out for the bamboo processing is very high.

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, Ethiopia has good bamboo substituting resources, so it is better to use bamboo, replacing wood forests. Bamboo is a renewable plant belonging to grass and its growing rate is faster than wood.

Now a day's Ethiopian government also focused on bamboo plants and initiating investors to invest in the area to process bamboo for different uses, this research will contribute significant role for the improvement of bamboo products since wood lumber is expensive and also forests are declining. Many Small and Micro Enterprises (SMEs) emerge to use bamboo for different furniture makings. Thus, this Bamboo Processing Machine will help them for facilitating and improving their productivity.

Bamboo is especially been integral part of the cultural, social and economic traditions of many societies. Main characteristic features, which make bamboo as a potential building material, are its high tensile strength and very good weight to strength ratio. It can withstand up to 3656 Kg/cm^2 of pressure. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Above all bamboo is renewable raw material resource from agro-forestry and if properly treated and industrially processed, components made by bamboo can have a reasonable life of 30 to 40 years. Construction techniques using bamboo as main material have been found very suitable for earthquake resistant housing.

Machinery from various sources has become operational in recent years for the primary processing of bamboo by Bamboo processing Machine (BPM). 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 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:

(i) 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 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. So most of wood working machinery and technologies can't be indiscriminately applied in bamboo processing. As a result, the technologies used in bamboo processing get largely behind wood industry.

(ii) 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.

(iii) 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.

(iv) 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.

(v) 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. The properties against insects and fungi of a product should be strengthened if it will be used in outdoor circumstance.

Because of above characteristics, bamboo processing couldn't imitate wood working methods. Some of products can be made of wood but can't be produced by bamboo because of the troubles caused by technique or economy. For example, wood can be sawed into block or board but bamboo can't because of its special structure. Moreover, wood can be easily manufactured into 3 layers or multi-layered plywood via peeling, but bamboo is difficult both in technology and economy. If bamboo and wood plywood are in the same use, the peeled bamboo plywood is not feasible on the economic opinion though it seems to be feasible in technology. Consequently, bamboo utilization should be based on understanding its structure, properties, and processing characteristics [5].

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, fuel and beehives in Benshangul-Gumuz Regional State 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 product's surface finish is poor and hence researchers are initiated to design and fabricate this bamboo processing machine in order to solve the existing problem.

2. LITERATURE REVIEW

There were very few technologies to add value to Bamboo, say for furniture. In Nagaland, bamboo based furniture is often made by local carpenters using inadequate hand tools. Lack of dedicated machines at affordable cost has stymied the efforts of the local woodworker. Even removing the hard green covering on the bamboo has remained a challenge for many users. Having worked extensively with bamboo, it was capable of processing bamboo, remove the outer knots, smoothen the surface, while enabling wood carving and final surface finishing of the job. While taking trials of his Arulepsa, Toshi noticed that there was a lot of bamboo dust/powder produced as waste material. Having an innovative temperament he made a composite material by mixing this powder with locally available resin and made a portable hydro generator combining the design of his earlier zero head water turbine and a Chinese made hydro generator [8].

The dedicated bamboo processing machine is an integrated unit that can remove knots, doing plain surface and polishing to facilitate inner and outer contouring of the job. Precision control is achieved with a soft touch, four-way joystick linked to a robust electro-mechanical control logic kernel. The machine has overall size of 4x2x12 ft and weighs 75 kg. It is electrically operated using a 1 HP motor running on 230 V AC supply to drive a spindle at the range of 40 to 90 RPM. It has been built with dedicated and independent sub-systems including the two stage planer, the bamboo feeder assembly, the self-adjusting gripper assembly and two sets of fixtures for inner and outer contouring (carving) [9].

The Planer assembly is the heart of machine and consists of a two-stage planer unit. The first stage achieves removal of the outer green covering and knots and the second stage makes the surface smooth. Prior art mentions machines for removing the outer green layer and knots of bamboo. Prior art has also disclosed individual machines for multipurpose and cross cutting, parallel splitting and sizing of bamboo.

Universally, complete woodworking on bamboo needs an assortment of machines such as Four Side Planer, Sanding machine, Finger jointing machine, Double End Cutting and Shaping Machine and Stick Sizing machine for making the stick in the desired size. Separate machines have also been used for internal and external knot removal, slicing the bamboo for making slivers, and making the square bamboo sticks and a tool post accessory fitment for polishing them.

The highlight of Imli Toshi's equipment lies in using a single versatile bamboo processing platform that facilitates seamless removal of knots, planning, polishing and carving of bamboo. The precision in work is achieved by deploying the dedicated control center and a user friendly four way joystick. For his hydro generator made out of the composite material, first, he developed a lightweight yet strong composite material using bamboo and resins [9].

Bamboo processing by hand is a time consuming and difficult process. Bharali has developed an assembly of machines that can perform operations like splitting long lengths of bamboo, sizing, surface finishing, polishing etc. These units have been installed with the help of a CFC (Common Facility Centre) of the NERCRMP (North Eastern Region Community Resource Management Project) at North Cachar hills [10].

Mechanical splitting and sliver making has been developed over the past few decades in a number of countries, but most particularly in China where it is very widely practiced, and from where a wide range of relevant machines and equipment are available. The technology has mostly been developed by private companies and research institutes. In India a unit for the primary processing of bamboo was established at Bangalore under a project sponsored by the International Development Research Centre (IDRC), Canada in 1997 using machinery imported bamboo processing machines from Taiwan. The experience gained in the operation of the unit has been made use of in the preparation of this technology transfer model [11].

The initial processes to be done on a bamboo to make it as a useful product is called as bamboo processing. The initial processes include Splitting, External and Internal Knot Removing, Slicing, Bamboo sticking making, Stick length setting, Stick Polishing [12, 13]. Bamboo and bamboo splits are used as the fencing material and for making various types of tool handles, ladders and scaffolding. In its natural form, bamboo as a construction material is traditionally associated with the cultures of South Asia, East Asia and the South Pacific, to some extent in Central and South America [14].

Traditionally the bamboo is processed in different steps and for each step a different machine is required, the main aim behind this development of experimental set up of improved bamboo processing machine is to reduce the number of steps and also to reduce the number of machines required to do the desired work. So an improved bamboo processing machine is fabricated which can perform splitting and slicing on a single machine. The design involves a new concept of making a special purpose of die for splitting and slicing, the concept behind this research is that, the machine is kept common for both the operations; only the die for splitting and slicing is different. This will eliminate the use of special machine for slicing which is to be done after splitting the bamboo [15].

In the year 2003, International Workshop on Bamboo Industrial Utilization titled "International Network for Bamboo and Rattan" [16, 17, 18] took place which was hosted by Hubei Provincial Government & Xianning Municipal Government which clearly shows although several types of bamboo processing devices have been developed, detailed in Production Process & Equipment for Bamboo Daily Products by Liu Kekun. The proceedings of 7th World Bamboo Congress which took place in New Delhi in Feb., 2004 shows that so far no attempt is taken in designing a machine for processing a bamboo which can perform multiple operations with a single unit.

3. MATERIALS AND METHODS

Here material represents about the raw materials used for experimental purpose. Some of the materials used by the researchers were from locally available materials like Aluminum, mild steel, belt, wood, sand paper, cotton cloth, glue, bearing, bolt and nut, electrical materials, antirust and paint. Necessary machines and equipment were also used for experimental practical work.

For the purpose of convenience, focusing on the need assessment, researchers used survey, exploratory and experimental research methods. The objective of using exploratory research is to identify key issues and their variables to identify the need assessment.

Researchers used different data gathering techniques like interviewing, direct observation, document analysis and questionnaires (closed and open types) to understand the timely need of bamboo processing machine by the bamboo furniture makers. The secondary data was obtained from documents, internet, reports and researches about bamboo processing machine.

After the quantitative and qualitative data were gathered from those sources, researchers designed and manufactured bamboo processing machine to solve the problem and to facilitate bamboo furniture products and to avoid the exhausting and time consuming of grinding or polishing activities.

The target group was, 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.

4. 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 (population).

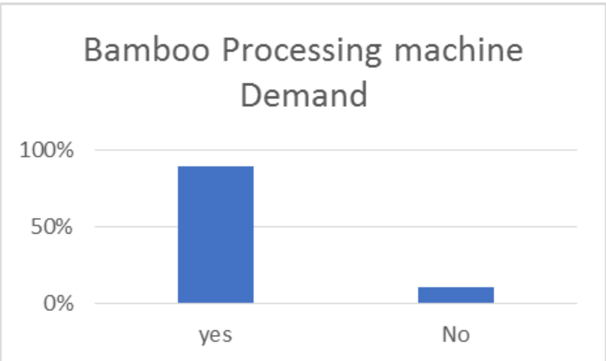
The sampling units are the defined target population elements available for selection during the sampling process. In this research, Adama Town bamboo furniture workers are selected purposely as the total population since the result can be considered for the whole bamboo workers in the country.

A total of 40 numbers of bamboo workers were selected from the population of 80 number of bamboo workers including SMEs at Adama Town that are currently working in the field of bamboo furniture makings.

The number of population being small indicates, Adama town is far from bamboo resources. According to the participants, they have got bamboo from Southern part of Ethiopia. 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.

5. DATA ANALYSIS

The collected data analyzed quantitatively in the form of tabulation and qualitatively with intuitive judgment. By considering the data analysis result will set conclusion of the need assessment that bamboo processing machine is currently having good demand. The needs of this study were presented in Figure1 below:



Research questionnaires results indicates that 95% respondents replied their feeling "Yes" and 5% respondents replied their feeling "No" about the need of Bamboo processing machines.

6. DESIGN CALCULATION

(i) Motor: Researchers selected AC single phase motor for bamboo processing machine because 220V is easily available and requires less energy.

The power is designed based on the required functions, for operating grinding and polishing of bamboo. Required motor power = 1.1kw (by referring other related machines, E.g. Wood machines).

By considering service factor 1.2 (design data hand book) design power =1.2 x 1.1 = 1.33 KW was selected.

(ii) Pulley: Researchers assumed 960 rev/min of driver (smaller pulley) and based on driver rpm, from design data hand book 723 rev/min for the driven (larger pulley) was selected. Based on speed ratio 1.33 the smaller pulley diameter is 75mm and larger pulley diameter is 100mm from same table.

(iii) V-Belt: Based upon pulley diameters, center distance (562.5mm) and arc length factor: 0.978, datum length (L_d) = 1410 mm and inside length (L_i) = 1390 mm was selected. Therefore, belt specification for this Bamboo processing machine is 54 ½ inch x 1390Li mm and 1410L_d mm is selected (Design data hand book).

(iv) Shaft: It is a rotating member used for the transmission of power. It is designed to perform a specific task for bamboo processing machine. Suitable material for the shaft was selected SAE 1040 for designing based on shaft design selection criterion.

The selected material is SAE 1040. The required factor of safety is 4. In this design the shaft rotates which is subjected to torsion so, the yield strength of SAE 1040 which is 414 Mpa. The factor of safety is based upon the yield point stress. In such cases,

$$\textit{The allowable shear stress}(\tau)$$

$$= \frac{\textit{Yeild strength of selected material}}{\textit{Factor of Safety}} \quad --(1)$$

$$= \frac{414}{4} = 103.5 \text{ N/mm}^2$$

Shear stress can be determined using one of the following criterions,

Ductile: Shear Strength ~ 0.5 Tensile Strength
Allowable stress (with key way) = 0.5*103.5

Therefore, τ = 51.75 N/mm^2

$$P = T\omega \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where ω = angular velocity

Torque (T) = P/ ω

$$T = \frac{60 * P}{2\,\pi N} = \frac{60 * 1.33 * 10^3}{2 * \pi * 960} = 13.23Nm$$

T=13230 N-mm (torque) since the Shaft is subjected to combine twisting and bending moment.

(a). Calculating belt tensions

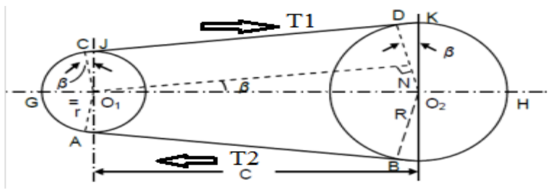


Fig. 2: Belt drive arrangement

From Engineering Data for v – belt.

Coefficient of friction between belt and pulley = 0.3
Density of rubber = 1140kg/m³
Allowable stress for belt = 2.1 Mpa
(dynamo efficiency) = 80% = 0.80
Pulley diameter (small) = 75mm
Pulley diameter (large) = 100mm
N = 1430 rpm (motor rpm)
P = 1.33 kw
Let T_1 = tension in the tight side of the belt, and

T_2 = tension in the slack side of the belt

Researchers know that the peripheral velocity of the belt on the driving pulley,

$$V = \frac{\pi dN}{60} = \frac{\pi * 0.075 * 1430}{2 * \pi * 960} = 5.6m/s \ldots (3)$$

Power transmitted,

$$P = (T_1 - T_2) * V * \eta d \text{ ---------------------- } (4)$$

Where T_1 and T_2 are belt tensions.

$1.33 \text{ X } 10^3 = (T_1\text{-}T_2)*5.6*0.8$

T1-T2 = 296.9N

It is known that,

$$2.3Log\left(\frac{T_1}{T_2}\right) = \frac{(0.3 * 2.6)}{2.3} = 0.3391 - - - (5)$$

$\frac{T_1}{T_2}$ = 2.183 (antilog of 0.3391)

$T_1\text{-}T_2$ = 296.9 N and $\frac{T_1}{T_2}$ = 2.183,

$T_1 = T_2$ (2.183)

$2.183T_2\text{-} T_2$ = 296.9 N

$$T_2 = \frac{296.9}{2.183} = 136\text{N}$$

T_1- 136N = 296.9 N

T_1 = 136N + 296.9 N = **433 N**

$T_1 + T_2$ = 433N + 296.9N = 729.9N

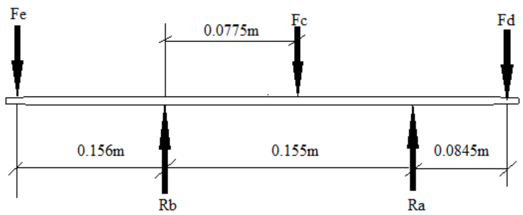


Fig. 3: Free body diagram of shaft

Where F_c = Force of belt tension

F_d = Force of disc

F_e = Force of grinding

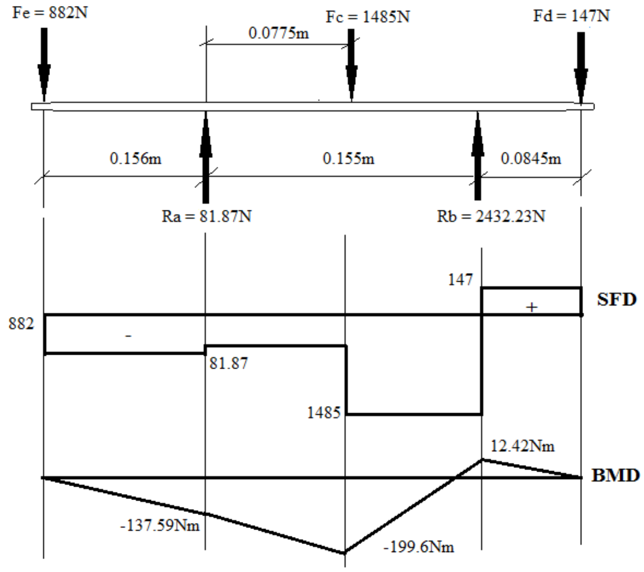


Fig. 4: Shear force and bending moment diagrams

R_a and R_b are bearing supports

Maximum bending moment is created at C

due to belt tensions, thus

M = 133.68Nm. Where,

$F_C = T_1 + T_2$ …………………… (6)

= 1018.4+ 466.5 = 1484.9 ~ **1485N**

The force applied on the grinding disc,

$F_d = \frac{T}{r}$ .... (7)

where T = torque and r = radius of disk,

13230N- mm / 90mm = 147N

F_b = Force on belt

The force applied on the sand belt,

$F_b = \frac{T}{r}$ .... (8)

where T = torque and r = radius of the shaft.

F_b = 13230/15 = 882N

Where F_c = 1485 N, F_d =147 N and

F_b = 882N

$$\sum Fy = 0,$$

$$F_b(0.156) + F_c(0.0775) - R_a(0.155) + F_d(0.2394) = 0$$

$$882(0.156) + 1485(0.0775) - R_a(0.155) + 147(0.2394) = 0$$

Ra = 81.86 N

Rb = total load – Ra

= 147 + 1485 + 882 - 81.86

R_b = 2432.14 N

(b). Bending moment

B.M at F_e = 0

B.M at Ra = -882*0.156 = -137.59 Nm

$$B.M. at\ F_c = -882(0.156 + 0.0775)) + 81.87(0.0775)$$

= -199.6 Nm

B.M at R_b = F_d*0.0845 = 147*0.0845

= 12.42 Nm

B.M at F_d = 0

From the above, M = 199.6*10^3N-mm, T=13230 N-mm (torque on the shaft) and τ = 51.75N/mm²

Using maximum shear stress criteria, diameter of shaft:

$$d = \sqrt[3]{\frac{16}{\pi\ \tau}\left(\sqrt{M^2 + T^2}\right)} \text{-------------------(9)}$$

$$d = \sqrt[3]{\frac{16}{\pi(51.75)}\left(\sqrt{(199.6 * 10^3)^2 + (13230)^2}\right)}$$

d= 27.00 mm

The shaft is affected by shock and fatigue load so considers fatigue and shock factor (k_m= 1.7) and k_t = 1.6 (suddenly applied load with minor shocks only)

Using maximum shear stress criteria, diameter of shaft can be calculated:

The allowable tensile stress (σ) = $\frac{Tensile\ strength\ od\ selected\ material}{Factor\ of\ safety}$ ..... (10)

$\sigma = \frac{621}{4}$ = 155.25 N/mm²

M_e = ½[K_m*M +$\sqrt{(Km * M)^2 + (Kt * T)^2}$]-(11)

= ½[1.7*199.6*10^3 + $\sqrt{(1.7 * 199.6 * 10^3\ )^2 + (1.6 * 13230)^2}$]

= ½[339320 + 339979.6]

M_e = 339649.8 N-mm

= 339.6498 * 10^3 N-mm

It is also known that equivalent bending moment

$(M_e) = \frac{\pi}{32} * M_b * d^3$ .... (12)

339.6498 * 10^3 N-mm = $\frac{\pi}{32} * M_b * d^3$

= $\frac{\pi}{32}$ * 155.25 d^3

d^3 = 339.6498 * 10^3 /15.24

d = 28.14 mm

Therefore, taking the larger of the two values, researchers selected d = 28.14mm, for more safe condition and standard size, 30 mm was selected.

Since the selected material is SAE 1040 having a modulus of rigidity, (G) equals 79.3Gpa. Therefore, Twist angle (θ)

$$\theta = \frac{TL}{GJ} \dots\dots\dots\dots (13)$$

$$\theta = \frac{13.230 * 10^3 N - mm * 443mm}{79.521 * 10^3 mm4 * 79.3 * 10^9 \frac{N}{m^2}}$$

$$\theta = \frac{13.230 * 10^3 N - mm * 443mm}{79.521 * 10^3 mm4 * 79.3 * 10^3 \frac{N}{mm^2}}$$

$$\theta = \frac{5860890}{6306015300} \ radian$$

$\theta = 0.05^0$, since the twist angle is less than one degree, the design of the shaft is safe from being twisted.

(v) Key: Mild steel square key was fabricated to transmit torque from the rating shaft to the pulleys. It is subjected to considerable crushing and shear stresses.

A longitudinal groove called a keyway was machined into the shaft and a corresponding groove into the bore of the pulleys to fit them together temporarily.

A square key has equal width (w) and thickness (t) i.e,

$w = t = \frac{d}{4}$ (From design data hand book)--(14)

Where d = diameter of shaft

Design specification of the key is selected as follows:

Diameter of the shaft = 30mm.
Width of the key, w = $\frac{d}{4} = \frac{30}{4} = 7.5$ mm
Thickness of key, t = $\frac{d}{4} = \frac{30}{4} = 7.5$mm
The shear stress of the material is = 40N/mm^2
The crushing stress of the key material = 70N/mm^2
The length of the key is obtained by considering the key in shearing and crushing.

$T = Lw\tau\frac{d}{2}$; ....(15)

Where T = torque, L = length, τ = shear stress,

d = diameter of the shaft.

= $L * 7.5 * 40\frac{30}{2}$

T = **4500 *L** N

The torsional shear strength (torque transmitted of the shaft),

$T = \pi * \tau * \frac{d^3}{16}$ .... (16)

$T = \pi * 40 * \frac{30^3}{16}$

= **211950 N- mm**

From equation (15) and (16),
211950 N- mm = 4500L N

L= $\frac{211905}{4500}$ = 47.1 mm

Now considering crushing of the key, researchers know that shearing strength (or torque transmitted) of the key.

$T = L * \frac{t}{2} * \sigma * \frac{d}{2}$; .... (17)

Where L= length of key, t = thickness of key $\sigma = stress$, d = diameter of shaft

T = L*t/2*σ*d/2 = L*7.5/2*70*30/2

= 3937.5Lmm

From equation (16) and (17)

211950 n- mm = 3937.5Lmm

L = 53.8 mm

Taking the larger of the two values, researchers selected 53.8 mm to be the length of key.

L = 53.8 mm ≈ **54 mm**.

(vi) Pulley: The function of pulley is to transmit motion to the shaft coming from motor through belt. The pulleys must withstand the forces imposed by both belt tensions.

Pure aluminum material was selected for pulley due to light in weight, less cost and ease of availability of material and ease of manufacturing among other alternative materials.

. A small drive pulley driving a bigger driven pulley by means of a belt is shown in Fig.5 bellow. The smaller pulley rotates faster than the larger pulley in the same direction.

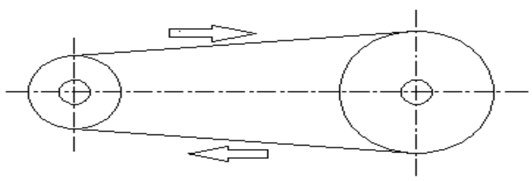


Fig. 5: Pulleys and belt arrangement.

When the pulley is rotating, it interacts with the tensions of belt T_1 and T_2. Due to frictional force between pulley and belt, the pulley is subjected compression forces exerted by the tight (T_1) and slack (T_2) sides of a pulley.

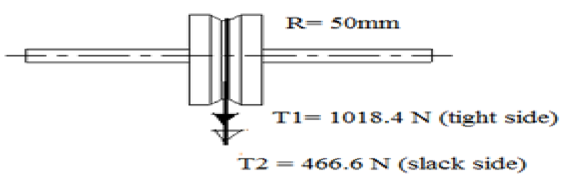


Fig. 6: Free body diagram of pulley

Pulley torque (T) = Difference in belt tensions in the tight (T_1) and slack (T_2) sides of a pulley times the radius (R), i.e.

$T = (T_1 - T_2) \times R$ ……………………. (18)

Where T = torque, T_1 and T_2 are belt tensions,

R = pulley radius

T = (1018.4N – 466.6N) x50mm

= **27590N-mm**

(vii)Pin: Taper pin was designed and fabricates from mild steel for the purpose of locking the shaft with pulleys. Mild steel 1040 gives the best overall satisfaction for the functional requirements of the pin.
The pin is subjected with torque and tangential force.

T= Fr ………………………………. (19)

Where T-torque, F-force on the pin and r- radius of shaft

$F = \frac{13230 \text{ N-mm}}{15\text{mm}} = 882\text{N}$

Using the maximum shear stress theory,

$$\tau_{max} \leq \frac{0.5\sigma_y}{n} \text{ ……………………. (20)}$$

Where n = 6 (factor of safety), σ_y = yield stress and the pin has a ductile property which is low carbon steel having a yield strength 530 Map.

$$\tau_{max} = \frac{0.5*530}{6}$$

$\tau_{max} = 44.17 \text{ N/mm}^2$

$F = \tau A_p$ ---------------------(21)

Where A_p = Area of the pin, F = Force

$$F = 44.17 \frac{N}{mm^2} * \pi \frac{d^2}{4}$$

$$882N = 44.17 * 3.14 * \frac{d^2}{4}$$

d = 5.04 mm ~ 6mm

(viii) Bearing: Bearing permits a relative motion between the contact surfaces of the members, while carrying the load. Bearing dimensions selection is generally based on the operating load and the bearing's life expectancy requirements, as well as the bearing's rated load capacity.

(a). Solid bearing: A cylindrical hole formed in a cast iron machine member to receive the shaft which makes a running fit is the simplest type of solid journal bearing. Its rectangular base plate has two holes drilled in it for bolting down the bearing in its position as shown in the figure bellow. Oil hole is provided at the top to lubricate the bearing.

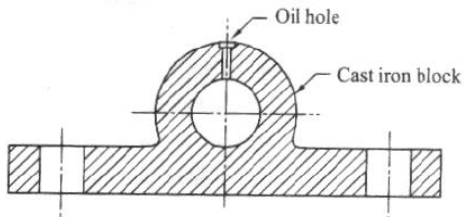


Fig. 7: Solid bearing

Therefore, for bamboo processing machine solid bearing is selected, because of advantage over the other bearing.

(ix) Splitter: It is designed to split a bamboo having length 1.5m. It has parts like roller way, slide, blades, and roller handle.

(x) Blade: The blade was designed and fabricated in to the required number of splitting bamboo divisions. It has cone shaped blades joined by arc welding.

(xii) Sanding: To improve the durability of the varnish attachment and to increase aesthetics, the products are sanded. Holding the splatted bamboo by two hands, and slightly pressing down on to the sand belt, it is possible to get the required thickness surface finishing of bamboo.

7. MANUFACTURING ASPECTS

Each part or component of a product was designed so that not only meets design requirements and specifications, but also can be manufactured economically with relative cost. This approach improves productivity and allows a manufacturer to remain competitive.

There are many methods of manufacturing processes to produce a part but cost effective method was targeted.

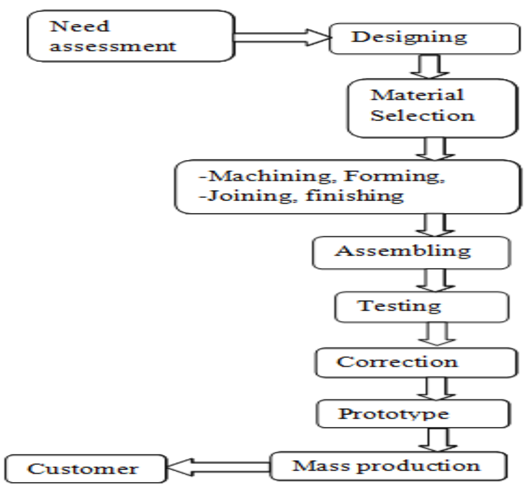


Fig. 8: Design and Manufacturing process of Bamboo machine

Selection of a particular manufacturing process depends not only on the shape to be produced but also on a large number of other factors.

8. CONCLUSIONS

After each and every machine element was designed and fabricated, the Bamboo machine was assembled. The machine was successful for its intended design. It has three functions, namely, manual splitting, grinding bamboo knots and sanding bamboo surfaces. The bamboo processing machine is as shown in figure 9.

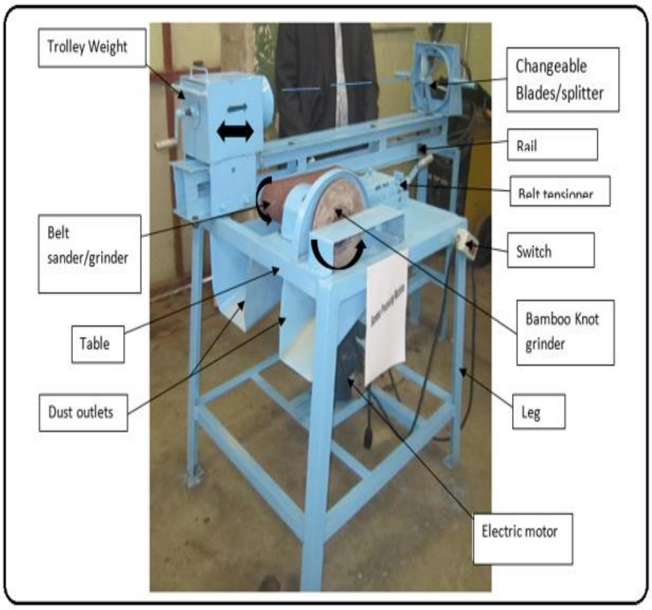


Fig. 9: Bamboo Processing Machine

The grinding of bamboo knot is as shown in figure10. It shows, how grinding of bamboo knots takes place.

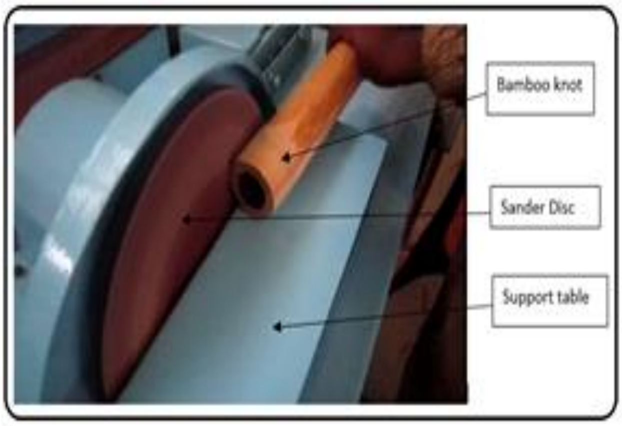


Fig.10: Grinding of Bamboo knot

The splitting function of bamboo processing machine is as shown in figure11.This indicates that how bamboo splitter of bamboo processing machine is working for splitting the bamboo.

Fig.11: Bamboo splitter

The sanding of bamboo surface/planning function of bamboo processing machine is as shown in figure12. It shows, how sanding of bamboo surface takes place on belt sander.

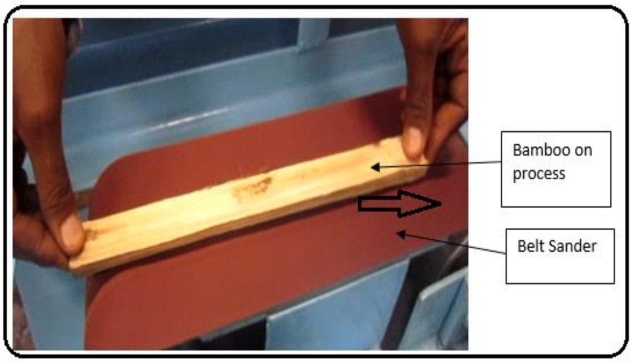


Fig. 12: Sanding of bamboo surface/planning

In Ethiopia, because of the declining of forest and limited productivity of bamboo workers, researchers designed and manufactured bamboo processing machine having three functions to overcome the existing problems.

The machine can split up to the diameter of 100 mm in to the required divisions within one minute up to the length of 1.5 meter with average human push force 250N. The machine reduces the time taking of bamboo processing operations.

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

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