Design Development And Manufacturing of Bamboo Cutting And Slicing Machine

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Abstract- *SPMs or Special Purpose Machines offer tremendous scope for high volume production at low investment and the low cost of production when compared to CNC machines. SPM, Special Purpose Machines is a high productivity machine, with specially designed tooling and fixture, dedicated to mass-producing the same component day in and day out. A judicious combination of limit switches, sensors, logic controls, automatic job clamping, etc is the essence of an SPM. A well-conceived Special Purpose Machine finds ways and means to utilize the man and machine to the optimum.*

Automation and technological advancements have drastically changed the manufacturing industry. One such aspect is Special Purpose Machine (SPM) design. Special Purpose Machine (SPM) are those machines that are not available off the shelf. These are not Covered in standard manufacturing programs. A well-conceived Special Purpose Machine finds ways and means to utilize the man and machine to the optimum. Our SPM is designed as per the specifications required by Vaishnavi Enterprises, Miraj. The machine can reduce production time by almost 90%.

I. INTRODUCTION

Bamboos are a diverse group of evergreen perennial flowering plants in the subfamily Bambusoideae of the grass family Poaceae. The origin of the word "bamboo" is uncertain, but it probably comes from the Dutch or Portuguese language, which originally borrowed it from Malay or Kannada.

In bamboo, as in other grasses, the internodal regions of the stem are usually hollow and the vascular bundles in the cross-section are scattered throughout the stem instead of in a cylindrical arrangement. The dicotyledonous woody xylem is also absent. The absence of secondary growth wood causes the stems of monocots, including the palms and large bamboos, to be columnar rather than tapering.

Bamboos are of notable economic and cultural significance in South Asia, Southeast Asia, and East Asia, being used for building materials, as a food source, and as a versatile raw product. Bamboo, like wood, is a natural composite material with a high strength-to-weight ratio useful for structures. Bamboo's strength-to-weight ratio is similar to timber, and its strength is generally similar to a strong softwood or hardwood timber.

As the modern trend is approaching mdcrafted art and natural artifacts more, the demand for such hand-crafted arts has increased tremendously. To meet this increasing market demand there is always a need for advancement in the conventional production techniques to counterbalance the ever-increasing market demand for such handcrafted arts. India is known for many cottage industries and handicraft designs but still, continuous efforts are required to design and produce unique handicrafts to satisfy customer demands. In most of the large-scale industries, production is achieved with the help of machines but whereas in small-scale production, the man force is a must to carry out the entire production manually which results in the increased workload on workers which ultimately affects the production rate as well as quality. To overcome this and to minimize the stress on the worker, an attempt has been made to design a bamboo stick-making machine, which is simple in design and even can be handled by unskilled labor.

II. BAMBOO TYPES

1. Bambusa Balcooa:-

It is also known as Bhaluka in Assam, Balku bans in West Bengal, and Wamnah in Meghalaya. The Bambusa balcooa occurs at a height of 600m. It prefers a heavily textured soil. This bamboo can be found mostly in West Bengal and the north east region of India. It has a 30m tall, dark green culm.

2. Bambusa Nutans

The bambusa nutans grows at an altitude of 500 to 1500m. It grows best on moist hill slopes. It prefers a well drained loamy soil. It is also known as Mallo, Malla, Mukia and Badia bansa. It can be commonly found in north eastern regions, Orissa and even Bengal. The culm of this bamboo is smooth, loosely clumped and has a height upto 20m.

3. Bambusa Polymorpha

Also known as Jama betwa, Narangi bans and Bari, this bamboo can be found the North East and other regions like Arunachal Pradesh, Meghalaya and Tripura. The bambusa polymorpha likes a deep, fertile and well-drained soil or a riverine alluvial soil. The culm can be either light green or greyish green. Some are even white grey. The culm is also 25m tall.

4. **Bambusa Vulgaris**

This bamboo can be found in the natural forests in Central India and the North East. It generally prefers moist soil and is an open clump type species. The culms are generally lemon yellow or bright green stripes. It has a smooth and shiny texture and is 20m tall. The bambusa vulgaris is also known as basini bans and bakal.

5. **Bambusa Arundinacea**

The bambusa arundinacea is also known as bambusa bambos. It grows at an altitude of 2100m and can be found in moist parts of India. They can grow up to a height of 40 metres and have linear leaves. The culms are dense and purplish green when young but later turn golden yellow.

6. Bambusa Multiplex

The bambusa multiplex is an evergreen bamboo. The flowers of this bamboo are hermaphrodite. It is grown in a well drained and moist soil. The stem of the bambusa multiplex can be used as an edible item.

7. Bambusa Nana

The bambusa nana is a very beautiful screening bamboo. It has a soft and fern like foliage. The bambusa nana is popularly used as an ornamental plant due to its attractive foliage. The average height attained by the bambusa nana is 8 metres

8. Bambusa Tulda

Bambusa tulda is also known as the Indian timber bamboo and the Bengal bamboo. It is considered to be one of the most species of bamboo. It is generally found at altitudes of 1500m.

9. Dendrocalamus Hamiltonii

The dendrocalamus hamiltonii is known by several names in different regions of India. it is known as Kako in Assam, Pecha in West Bengal, Unep in Manipur, Pao in Sikkim and Phulrua inMizoram. It can be found in semi evergreen forests and prefers a fine textured soil. It is found in large numbers in the north eastern part of the country and the Himalayan region. It has a dark green, 30m tall culm.

10. Dendrocalamus Giganteus

This bamboo is also popularly known as the giant bamboo or the dragon bamboo. The dendrocalamus giganteus is known to be the tallest bamboo species in the world. The culms of this bamboo are about 25-35m tall. It is generally found at an altitude of 1200m. This bamboo has one large dominant branch and other clustered branches.

2.2 Bamboo Processes –

The right kind of Bamboo that is needed to make furniture is harvested. The gathered bamboo is treated to remove all the moisture content. The bamboo is dried well to make it durable. Depending on the orders of the clients the products are made mostly, the sizes of bamboo as required for to accomplish the product is cut and soaked in water and boiled with natural medicines. This makes the bamboo unaffected from the contamination from pests, termite and the external triggers. The bamboo is completely dried before use. The bamboo is segregated initially according to the products that are going to be made. They are cut to the required sizes with the help of bamboo sawing machine. The cut bamboo sticks are arranged to the products that have to be made. The products are always made depending on the clients' orders.

Raw Materials.

Bamboo has been an easy and versatile material for all societies that have practiced a self-reliant, ergonomically and environmentally sustainable way of living. Bamboo is considered sacred in such societies as it is invaluable for many tasks in their daily lives. For rural people who do not depend on industrial goods for their daily practices learn to fashion bamboo to their requirements from an early age. A majestic bamboo grove creates an atmosphere of delicate shade

Weaving Bamboo into Products.

Sons and daughters first observe and then assist their fathers and mothers in creating much of their utility objects, especially if the raw material is easily at hand. Farmers for centuries have cultivated their lands and then relied heavily on artisans to offer them articles for the next step in their work. Bamboo articles are made first by cutting the bamboo to the sizes, widths, and lengths required. Different bamboo species are best for performing separate functions. Not much is needed to fashion them further except for the indigenous cutting knives called dao and takal. Any kind of fine lacy pattern or tough open weaves depends simply on the process and technique of cutting the bamboo.

Making Panels.

Besides making baskets, craft persons also produce panels for screens, and room dividers combining fine matting, sticks, and shaped chips of bamboo. Fine framing with strips of bamboo is pasted onto bamboo matting. Small designs are sometimes made on the surface of strips that form part of a screen. Finely woven matting made of thin bamboo strips is laid on a flat plyboard and decorated with miscellaneous fittings over it.

Bamboo as a Sustainable Construction Material.

In 2004, the International Organization for Standardization (ISO), in partnership with the International Network for Bamboo and Rattan (INBAR), a Beijing-based agency whose aim is to promote bamboo and rattan for poverty alleviation in developing countries, published a standard on structural design using bamboo (ISO 2004a) and a series of methods for determining the mechanical properties of bamboo (ISO 2004b and ISO 2004c). If the use of bamboo is limited to rural areas, the standard recognizes established “experience from previous generations” as being an adequate basis for design..And export and import all require some degree of standardization (Janssen 2005). The ISO standard aims at prescribing a modern limit states design approach to traditional designs and practice. Precisely because of this dichotomy, however, the standard approach is simultaneously inadequate on both counts in the context of developing regions. A limit states approach requires specialized knowledge and engineering which may not be readily available. The traditional approach, while often adequate for service conditions, is unable to address ultimate limit states, particularly those associated with extreme events such as earthquakes.

Ready Bamboo Products.

Another simple process of dyeing thin strips of bamboo for a more decorative or festive look adds to their popularity as gifting baskets amongst a population that loves distributing sweets at every festival. Tripura bamboo products, including basketry, are so widely used in daily life that the local population is its largest customer and consumer. From homes to bridges, fishing rods, and multiple types of basketry, to souvenirs, the craftsman caters to a variety of clientele.

Bamboo and its Physical Properties.

Bamboo is being given an increasing amount of attention by developed and developing countries alike, and for good reason. Bamboo grows at a much more rapid rate than the hardwood and soft wood species that are currently utilized for construction purposes. This rapid growth rate translates into an equally rapid harvesting rate – usually a two- or three-year cycle - thus reducing the amount of land and resources necessary for timber production.

This reduced development cost means that it is easier to manage bamboo production at a sustainable rate. Additionally, bamboo species may be grown throughout the temperate, subtropical and tropical world; and as long as the bamboo is grown locally, it will reduce the cost and harmful byproducts of transportation. Bamboo has been put to extensive use in both the developed and the developing world. In the developed world it tends to be used in value-added applications such as cutting boards, utensils, and flooring. In the developing world it is used in a more utilitarian manner, as either structural members or as strips used for weaving mats (used for walls and flooring).

Bamboo is a member of the grass family, but is unusual in the fact that it is mostly comprised of a rapidly growing woody stem and grows to a very tall height (see Figure 1.1). The stem is the hollow cylinder that most people associate with bamboo, and it is commonly referred to as a “culm”. Bamboo culms also possess a unique physical characteristic known as a “node” 8 (see Figure 1.2a-b). Nodes serve the purpose of allowing a location for leaves to grow, and as a result, the longitudinal fibers of the bamboo are forced to change directions in those areas. This leads to reduced structural properties at the nodes (Arce 1993). In addition to node spacing, culms vary widely in length, diameter, wall thickness, and material properties depending on the species and height along the culm (Janssen 1981).

Additionally, bamboo has a higher concentration of fibers towards the outer edge of the culm (Amada 2001). For this reason, bamboo may be considered a “functionally graded material” as shown in Figure 1.3. Despite its many theoretical advantages, the widespread ‘engineered’ use of bamboo is still hindered by many problems. The three most important ones being: a) the way societies view bamboo; b) its inadequate durability; and c) the lack of sufficient engineering knowledge. Throughout most of the world, bamboo is regarded as “the poor man’s timber”; where available, various types of wood are generally preferred. For bamboo to be broadly adopted, this negative mentality will have to change.

. Untreated bamboo that is in direct contact with the ground tends to last about 2 years, and about 4-7 years when not in direct contact with the ground. Treated bamboos may last for more than 30 years (Kumar 1994). While testing has been done on a broad range of bamboo preservatives and preservation methods, no single method has been exhaustively studied or agreed upon. Treatment choice tends to be regional and based on convenience. This has led to confusion regarding the effectiveness of individual treatments as well as uncertainty about the effects that the treatment 9 methods have on the bamboo’s mechanical properties. For bamboo to realize its full potential, an effective method that will enable bamboo to last as long as common woods will have to be developed and broadly accepted.

III. LITERATURE REVIEW

General Properties of Bamboo The history of engineering knowledge with regards to bamboo is surprisingly recent. The first major work was completed by Janssen (1981) of the University of Eindhoven, The Netherlands. In his 1981 thesis, Janssen first explored the composition of a bamboo culm. He developed a mathematical model of the culm by considering it to be a structure composed of a number of substructures cells. Janssen then explored different mechanical properties of bamboo including bending, shear, tension and compression. Finally, he explored different truss systems and various ways to connect bamboo elements. From his work on the composition of bamboo, Janssen drew several conclusions:

18 1. Although bamboo has more than double the number of layers of cell walls as softwood, this does not have an influence on the stresses and displacements of bamboo (Janssen 1981). 2. The angle that the microfibrils of bamboo make with the cell axis has a large impact on the stresses and displacements (Janssen 1981). 3. A numerical of a single substructure cell may be used to predict the Poisson ratio and tensile strength, but cannot be used to predict the compressive strength as pectin prevents the buckling of individual fibers; a more expansive model is required to accurately predict compressive strength (Janssen 1981).

In addition to simple mechanical tests of bamboo, Janssen applied statistics and linear models in an attempt to discover which parameters are related to bamboo’s material properties. Some of his conclusions are as follows: 4. An increase in moisture content decreases compressive strength, and the compressive strength increases with height along culm where sample was taken. 5. Shear stress is the cause of failure for smaller spans, and the limiting shear stress is much lower than a typical shear test would indicate (Janssen 1981).

6. In bending, dry bamboo behaves better; strength decreases with the height the sample is taken from the culm (i.e.: strength decreases from bottom to top); and there is a possible relationship between ultimate bending stress and density (Janssen 1981). 7. A new shear test was needed to determine the correct shear strength of bamboo (which he then designed). The new shear test “ISO 22157-1” (ISO 2004) is shown in Figure 1.9 (Janssen 1981).

19 Figure 1.9 Shear test developed by Janssen shown without a bamboo specimen. 8. Shear strength and density are related. 9. A new test method is needed to determine bamboo’s tensile strength. Arce’s (1993) work is essentially an extension of Janssen’s thesis. He begins with a more indepth examination of the tensile properties of bamboo. This examination included tensile strength both the parallel (along culm) and perpendicular (transverse) to the primary orientation of the fibers. Arce also attempted to relate different mechanical properties throughout his dissertation. His most important conclusions are as follows: 1. Transverse tension capacity and density are not correlated whereas longitudinal tension capacity and density are.

Tension modulus, E, in the transverse direction is about 1/8 that measured in the longitudinal direction. 3. There may be a universal maximum transverse strain that bamboo may experience before failure. Three different species exhibited similar values during testing, approximately 0.0012. 4. Variation in cross-section and modulus of elasticity produce a reduction of no more than 15% in the bending strength and axial stiffness compared to the values a theoretical uniform member would yield. 20 5. Variation in cross-section and the presence of nodes can reduce bending stiffness by 50%, and axial stiffness by 80%. 6.

The slenderness ratios of compression elements should be kept below 50 to avoid global buckling or splitting resulting from flexural behavior. The present understanding of the material properties of bamboo expressed in the ISO Standards (2004a) and the Indian Code (2005) stem largely from the work done in the Netherlands by Janssen and Arce. While these standards are a start, there are many areas that still require further exploration. For example, while Janssen (1981) quotes several researchers in the past who claimed that “the collapse of the bamboo was always sudden and the material was split into pieces parallel to the longitudinal axis”, the splitting behavior of bamboo has not been adequately addressed in present standards due to both a misunderstanding of the physical nature of bamboo and inconsistent data.

IV. CURRENT SYSTEM

In the artifact industry, all of the tasks related to bamboo processing are completed by hand. There is no automation in the whole process. Right from the selection of bamboo sticks, to the final cutting and finishing of the product, is done by hand. This needs an enormous amount of skilled labour. And in today's day modern age, it is becoming increasingly difficult to find and employ skilled labour for bamboo processing. The current step by step process is as follows: -

1. Bamboo selection.

When the raw material arrives, one of the workers' jobs is to select the perfect quality of bamboo stick for the current product that is being processed. This is done by physical examination and observation. As this step is very crucial in making the artifacts, it is always done by an experienced person. A person who is well aware of the quality of bamboo and knows which qualities are required for the specific type of artifact is only allowed to do this work.

2. Cutting of bamboo stick into segments.

After the selection of suitable bamboo sticks for the specific artifact, the next step is to cut the bamboo stick into smaller segments. As the average length of one bamboo stick is around 4.5-12m, it is very important to split the stick into smaller segments of approximately 0.3-0.5m. This makes working on bamboo easier. For completion of this process, a semi-skilled worker is required, because the person needs to know where and how the segments are to be made.

3. Axial cutting of bamboo segments into small sticks.

After the cutting of bamboo sticks into smaller segments, the next step is to cut the bamboo segments axially into smaller sticks of 12-14mm thickness. The thickness of the stick depends on the overall diameter of the bamboo stick. This process also needs skilled labour.

4. Final Axial cutting of sticks as per requirement.

Various bamboo artifacts require sticks of varying thickness. So, depending on the current production requirement the sticks are reduced to the required thickness. This cutting task also needs a skilled person because the cutting of stick into small thickness is a difficult task and cannot be done by an unskilled or semi-skilled person.

V. IDENTIFICATION OF PROBLEMS IN CURRENT PRACTICE

In day-to-day manufacturing, the process carried out for making bamboo sticks requires manual force to a greater extent, and the accuracy achieved is also very less. Considering the ever-increasing demand for bamboo artifacts in the market, the production quality and speed are of utmost importance. Following are some of the problems in current practices

1. Skilled labour requirement: -

In the bamboo artifact manufacturing industry, all the processes are complicated which always requires a skilled person. Also, as the demand increases, the production rate needs to be increased which in turn requires more skilled labour. And in the current state of affairs, it is becoming increasingly difficult to find and employ skilled labour for this job.

2. Time-consuming operation: -

The time required for the existing process is very high. This results in overall less productivity and lower production rates. Considering the ever-increasing demand for bamboo artifacts, it is difficult to cope up with the demand with such low production rates.

3. High labour cost: -

As all the processes require skilled labour, the cost to fulfill this requirement is also very high. Also, it is getting increasingly difficult to find skilled labour and even if you find them they demand very high wages which reduce the profitability of the business.

4. Cost per product: -

As there is full use of skilled labour, the cost per product keeps increasing with ever increasing wages.

5. Safety: -

In the current process, the biggest concern was safety. Even though the processing was done by skilled labour, there is always a risk of getting injured by the sharp blades that are used for cutting.

6. Product quality: -

Being made totally by hand, the finished product always lacked uniformity and precision. As multiple people work with any aid of machines, it is very difficult to keep uniformity in the products. This might affect the brand image in the market.

VI. ADVANTAGES

Efficiently Malleable

One of the most beneficial properties of mild steel is it can be bent, cut and twisted to create the desired shape easier than other metal. It is one of the reasons why carbon steel (mild steel) is popular in many industries from the manufacture of household items to structural applications to the DIY and home improvement project. The high level of demand makes mild steel a widely produced material and therefore a very affordable material.

Weight

Compared to high carbon steel mild carbon steel is lighter. The proportion of carbon is the main influencing factor for the weight. Working with mild steel is, therefore, easier and is used for manufacturing auto parts, pipelines and i.e. fences and ornaments for homes and businesses.

Greatly Affordable

While working on a low budget, mild carbon steel proves to be the best. It is an ideal material that keeps project cost as low as possible. While mild steel is relatively cheaper than other metals you will have to consider the fact that you may have to treat it to prevent it from corrosion.

VII. CYCLE TIME COMPARISON

With manual operation, the rate of output was 320 sticks per hourAfter the development of this machine and using it, we were able to improve the rate of output to 1358 sticks per hour.

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