A thesis submitted to the faculty of the College of Imaging Arts and Sciences in application for the degree of Master of Fine Arts in Industrial Design.

TOPIC: Human powered production tool for the renewable material, Bamboo.

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July 12, 2010

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ABSTRACT

Sustainable design in a simple manner usually involves the impact of the things we design – their manufacturing process, time of use, and final disposal – on the earth's environment. In India, I was exposed to a different definition and concept of "sustainable design," some similar to the West, and some rather different. When a particular object is related to its context, it becomes a part of the living system, making it human-centered and deeply rooted in the culture. It has to do more by defining a relationship between the object and the user environment. In order to attain sustainability in design, renewable materials and product systems play major roles in the entire process.

In India, bamboo is available in abundance. As bamboo has many ecological and economic benefits, it is considered as one of the most versatile and sustainable materials. Many of the hand-made products from bamboo involve different weaving patterns that define structural strength and at the same time look aesthetically pleasant. People prefer hand tools to manufacture handmade products, as the tools require less maintenance, not need of power and are inexpensive to maintain.

My objective in this research process was to improve the manufacturing systems by designing a hand tool, which can hold and split the bamboo efficiently. My design development process involved; to study impact of renewable materials on the environment, data collection of existing manufacturing systems for bamboo, to interview the locals regarding their needs of simple affordable manufacturing tool to

split bamboo, to study and implement simple interface to use the tool. The tool, which I designed; is portable, has no power requirement, and is cost effective with less maintenance - very important features of the tool that could be used by the locals in rural areas. The tool has very few parts to assembly avoiding the difficulty for the users to go through the instructions, as most of the users are not literate and cannot read the instructions.

This thesis paper encourages designers and more over the manufacturing industry to consider renewable resources, design for the environment, improved manufacturing systems and at the same time involves socio-cultural tradition, economic factors, which are equally significant for material and product development.

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TABLE OF CONTENT

1. Introduction

1.1 Sustainability and environmental degradation

In this rapidly growing technology all over the world, manufacturing is becoming an irretrievable process. The population growth and industrialization has caused more demand on the world's infrastructure and also enormous consumption of natural resources. It is our responsibility to pay better awareness to the importance of environmental sustainability.

Sustainability is being looked upon in different ways by people. For some it is all about manufacturing methods, living methods or resources which we use throughout our lives. Sustainability in design is a process, rather than a simple achieved defined goal. It is a process to balance the needs of humans for socio-ecological development with the need to protect natural resources in the environment not only in the present but also for future generations. The term was used by the Brundtland Commission which coined what has become the most often-quoted definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations 1999). People should always be careful when using natural resources and how that will affect the socio-economic culture of the region's environment. In order to achieve sustainability, we need to work towards the way we use our resources, and a better way to generate and dispose of waste.

When considering development of a country, a conflict between development and environment has been observed. Every country has different priorities for its development. The environmental issues should be confronted by analyzing the different priorities of developing countries and developed countries. The approach to these developments must be strategic towards the betterment of our lives and the environment. Sustainability is not all about environmental issues but as explained in The United Nations Summit, it refers to the "interdependent and mutually reinforcing pillars" of sustainability as socio- economic and environmental factors (World Summit Outcome 2005).

As we all know the path towards sustainable development is not a defined one. The use of the word, Sustainable, has been very common and often in contexts today, and especially sustainable environment is the term, which baffle many people. “Everything is sustainable” (Temple 1992). One hears about sustainable progress, sustainable development, sustainable economy, sustainable culture, and sustainable farming.

Every individual has his/her own perspective towards an issue. In the very same way, the developed countries and the developing countries have their own economic demands for local and global growth; environmental demands for natural resource conservations; in turn firmly linked to the social factors that have a collision on environmental sustainability. So from the above description, it can be inferred that sustainable development could be conceptually divided into three sections: environmental sustainability, socio-economic sustainability and socio-political

sustainability. Sustainable development most of the times have been measured in terms of ‘better’ rather than ‘more’ and also understood as to improve quality rather than material standards of living. “Poverty eradication, changing unsustainable patterns of production and consumption and protecting and managing the natural resource base of economic and social development are overarching objectives of and essential requirements for sustainable development” (World Summit Outcome 2005).

Sustainability in design is achieved in various ways, such as, renewable energy sources, improved manufacturing techniques, biodegradable plastics, bio-fuels, Recycling, Permaculture, Low-carbon economy materials. By choosing environmentally friendly materials, it helps us to understand the environmental performance of a product, the energy flow over its life cycle, and the processes of manufacturing the material undergoes. Every technology, material and manufacturing process, which we adapt to use in our lives, has an impact on the environment and our lives. This shows there is a methodology involved to identify the stages throughout the life cycle of a product. The methodology involved is Life Cycle Assessment, which explains a process of checking the facts about the environmental burden of a product throughout the life cycle; acquiring raw material, manufacturing and production processes, usability period, disposal, reusability, recycling. “It examines the energy used in the extraction of raw materials, and the pollution that results from manufacturing the product. It also accounts for environmental harm that might occur during the distribution and use of the product”

(IISD 2007).

1.2 Life Cycle Assessment

Life Cycle Assessment helps to create a better sustainable design oriented product and manufacturing systems, helps to avoid use of scarce resources and by substituting a sustainable material for the product, identifies information of a product that helps to provide a basis for environmental improvement of a system and provides life cycle stages involved in a system. Additionally, it also helps "to identify those stages in production processes and in use which cause or have the potential to cause pollution and those which have a heavy material or energy demand" (Urban Environmental Management 2007). Therefore, it is very necessary to brainstorm efficient product systems, cradle to cradle cycle of a product, and material life cycle thinking to save this planet.

Life Cycle Assessment (LCA) applications has also helped producers, designers in various ways to brand the product. As explained above, we understand that LCA scrutinize the stages which could be harmful to the environment. It helps in the design development phase, where redesign of a product is involved. Before a manufacturer or designer starts with the conceptual development of a product, strategic planning and material selection is considered one of the most important steps. This helps to foresee the life cycle management process involved throughout the cradle to cradle stages. According to ISO 14040, there are four interconnected phases in Life Cycle Assessment. As shown in figure 1, that the end result gathered may help us to modify one or more phases that occurred earlier in the entire

procedure.

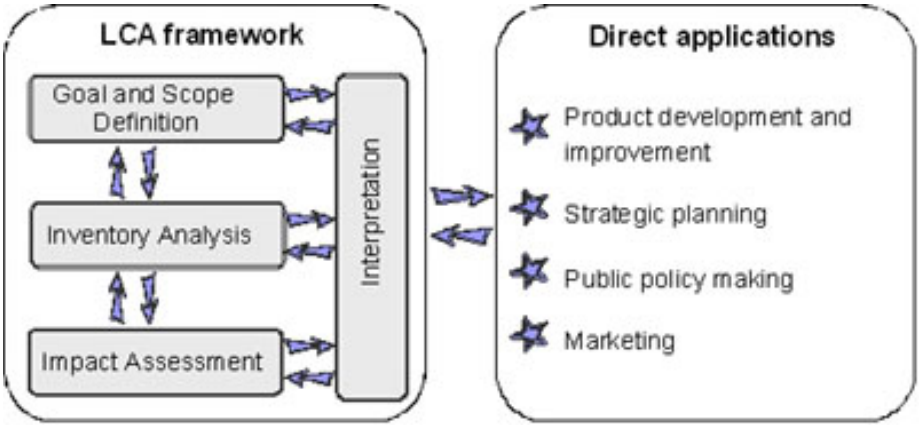


Figure 1: LCA Framework and applications

Life Cycle Assessment applications should not only be used in the designing and manufacturing phase, but also in selling the product by proper branding and marketing. Creating awareness among the consumers regarding the benefits of buying the product for the user and the environment is crucial. Environmental labeling, following the guidelines to introduce the product to the public is very important to procure environmental benefits.

Life cycle Assessment has its own limitations of the applications, such as, improbabilities in the inventory and the methodology involved in the impact of the data; involvement of technical assumptions and value choices. But still LCA is considered the “core topic in the field of environmental management” Cradle to Gate, Cradle to Grave and Cradle to Cradle, which is an evolving LCA. So in these process LCA research is helpful “in a whole range of different decision makings situations ranging from mere internal use to public comparative use” (Guin’ee 2007).

Therefore an analytical basis in life cycle assessment (LCA) provides a rigorous assessment of environmental sustainability. In order to make LCA useful for sustainability, measures should be taken from individual organization to the global level, social and economic aspects, research directions and areas where LCA could be used for sustainability assessment. Talking about the research areas, an “established understanding of the problems of environment and development, stressing the inadequacy of a narrow view of environmental impacts and a limited response based on traditional conservation measures” (IFAD n.d.) should be questioned. The study must be focused on which “bridges the gap between environmentalism and development studies and argues that the central focus of "green development" should be on the needs of the poor, and their capacity for control, power, and self-determination” (IFAD n.d.).

1.3 Encouraging application of sustainable design

Sustainable design can be achieved by using efficient technologies, which use less energy, fewer limited resources, do not deplete natural resources, do not pollute the environment and can be reused or recycled at the grave stage. These technologies maintain natural resources and environmental integrity, add to the well being of the three important components of earth; air, water, and soil, integrate design and construction that reproduce natural ecological conditions of the region, and reduce the impacts of human use.

The designers play one of the most fundamental parts in shaping the way we live and interact with the surrounding environment. Appending sustainable design at

schools of architecture is an important method of encouraging sustainable architectural design in practice. In recent years, universities have been introducing sustainable design, as a concentration in the graduate degree courses that is resulting an increase in the number of students enroll every year. The degrees in sustainable design are related to architecture, ecology, construction and many others, helping individuals to increase their knowledge in this field.

In India, many organizations, design institutions, industries, research center are working out different ways to advance sustainability in design. In any country, to adopt sustainability in design in terms of improved awareness, significance, and function depends deeply on the economic, environmental, and social dimensions. These three dimensions affect the way people perceive and use sustainability in their environment as shown in figure 2. Human well-being is dependent upon the relationships of Environmental Sustainability, Economic Sustainability, and Social Sustainability (Sustainable architecture and building design 1996).

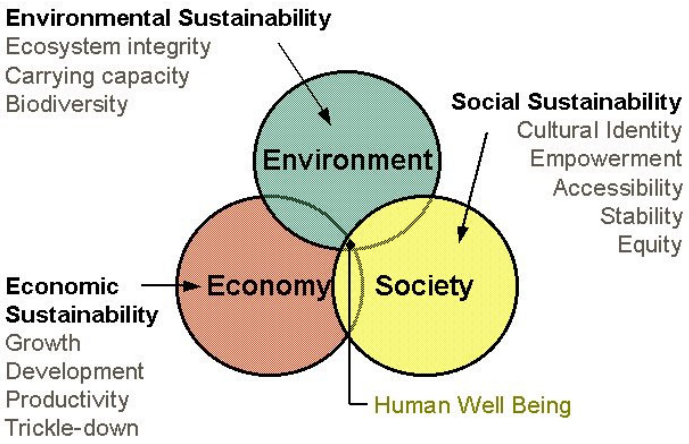


Figure 2. Model of Human Well-being

Sustainability requires “global interdependence, environmental stewardship, social responsibility, and economic viability” (Guiding Principles of Sustainable Design 1994). This changes the design approach and has made designers to be acquainted with the impacts of every design on the bioregional and cultural resources of the local, regional, and universal environments. The benefits of sustainable design are varied approaches and manufacturing techniques and are also flexible in terms of applications of design. As there are a number of tools available in sustainable design, setting up design priorities and material information would be very useful. “Lack of knowledge is part of the problem, but many tools are too quantitative and dry to appeal to designers” (Otto n.d.).

2. Research

2.1 Impact of Sustainability

Design is a vital element leading towards an enhanced sustainable future - by rethinking how the new products and their benefits could be delivered without devastating the world around us, or negotiating the well-being of future generations. Most of the time, emphasis is placed on new generation ideas but these ideas benefit very little to the society.

A well sustainable designed object can improve performance and competitiveness in the real world. The production, life cycle and final disposal of the products we design has some impact on the earth's environment. The demand and supply of products goes hand in hand. In design world, there is always this natural human character to transform innovative ideas into good design and on the other hand, there is also continuing demand for new products, which has negative environmental impact. A thoughtful production method will have less harmful impact on the environment, which makes consumption, an unsustainable practice.

The concept of sustainable design in India has been defined in different way. It has more to do in relation to the culture, tradition and how the product blends with the living standards of the common man. When designing a product, factors, such as, adaptation, customization and culture are considered.

As explained in the previous chapter about Life cycle Assessment, the calculations will help the research analysts to understand the environmental impact of design

decisions for sustainability of a design.

Designers should be encouraged to commit themselves to the principles of sustainable design to produce designs that reduce use of non-renewable resources, minimize environmental impact, and helps people communicate to the environment. This involves considering processes of selecting raw materials, manufacturing systems and final disposal.

2.2 Improved manufacturing systems for sustainability in design

The immense mass production of products and waste development in societies has had an intense effect on the socio-economic cultural patterns on this planet, including its vital natural resources. Currently, the thoughtless way of consuming resources has emphasized the urgency of more sustainable development to sustain natural resources in the future. In this context, design with the help of science and technology has the potential to preserve the natural environment when enhancing the socio-economic lives of people and improving the value of the products. When it comes to meeting scientific dimensions and technology juxtaposed with the concept of sustainability, innovations in design methods and tools are required. In order to achieve sustainability in design, simple and efficient product systems in all aspects should be adopted. In rural sectors in India, lack of improved manufacturing systems for materials is observed. There are tools available in the market, but they are not efficient and most importantly not affordable by everyone.

Manufacturers should use a sustainable approach, which is a key challenge for them during production of design. “Good design can help integrate environmental sustainability into the creation of attractive products and services. It can help shift customers’ consumption and lifestyle aspirations as well as stimulate the market for sustainable offerings” (Sustainability and Sustainable Design n.d.).

The responsibilities of manufacturing industries should involve a sustainable manufacturing system towards a design, having less impact on the environment, less consumption of natural resources. The entire material selection plays a very important role in sustainable manufacturing systems for the manufacturers. “One of the key results is that the technology capability and economic risk are the two main factors which prevent a company to adopt sustainable manufacturing” (Jayachandran, Singh, Goodyer and Popplewell n.d.).

The issues listed below need to be considered when working with the manufacturing systems to approach sustainability.

2.2.1 Material life cycle thinking: is very important when we work with materials.

Both consumers and producers should have good information about the process involved towards the production of an object until the final disposal. This will explain the entire system of materials and manufacturing systems used in the product life cycle.

Presently, most of the products make use of harmful toxic chemicals and high

consumption of natural resources during the production process causing hazardous generation of waste. These issues should be tackled through cleaner production processes, which has less impact on the earth's environment and resources are used in a smart way.

Traditionally designers have first the thought of product materials for meeting user's needs.

- Where the materials come from?
- What are the manufacturing processes and alternatives?
- Does it consume energy?
- What happens to the product when the consumer is ready to get rid of it?

2.2.2 Simplified & Efficient product systems: The idea behind simplified product systems is to find a combination of products and services that meet consumer needs. The production systems should use sustainable technologies, which use less energy, less natural resource consumption, and can be reused or recycled at the stage of final disposal. The technologies should also consider the people's needs and should be compatible with the local and regional available resources.

Some of the points listed below change as per the needs of people and would make the manufacturing system compatible with the society.

- Less number of components in the local manufacturing system would create a quick assembly of the system
- Components should require less maintenance
- An efficient product system with its simple mechanics makes the product easy to operate by any individual.
- The local manufacturing methods and materials make easy to design and help keep the initial cost much cheaper than goods transported.

2.2.3 Design for Environment (DFE): In order to design for environment, it is important to understand the characteristics and design requirements of the material.

In this competitive global market sector, it is a challenge to maintain high quality goods and meet consumer demands by producing products that are environmentally safe. The principles of DFE help businesses redesign products to make it more cost effective and eco-friendly. The process involved in DFE performs these functions systematically:

- "Identifies the array of technologies, products, and processes that can be used to perform a particular function within an industry and related pollution prevention opportunities.
- Evaluates and compares the risk, performance, and cost tradeoffs of the

alternatives.

- Disseminates this information to the entire industry community.
- Encourages and enables use of this information by providing mechanisms and incentives to institutionalize continuous environmental improvement" (About DFE by EPA 2007).

Design for Environment provides many benefits, such as, reduced ecological risks, includes socio- cultural for product development, promotes marketing opportunities, economic factors, improved productivity of the product and also acceptance of the same by the customers and most importantly; provides indigenous ideas and solutions, which address the problems and needs of the region.

Without understanding appropriate and thoughtful manufacturing systems to build a product, the entire manufacturing process could be cumbersome and time consuming. Manufacturing systems should be understood so that material can be used in a better and efficient way.

- Damage to the productivity of the material
- Undesired material finish could be experienced.
- Waste of the material when making a product

2.3 Sustainable Materials

The concept of green design, as explained in previous chapters involves a variety of strategies in the design process, which includes selection of materials, production, and marketing. Selection of the raw material is one of the crucial factors, as further application of the design depends all on the base material.

Overall Material selection criteria:

- Material Selection- A lightweight material and at the same time a sturdy one, which contains less toxic substances and also less various type of materials in the design making it easy to recycle or reuse. The materials should be durable, free from chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and halons with an efficient disposal or recyclability.

- Design for Disassembly- This factor is helpful when it comes to maintenance, mass production, recycling or reusing, packaging or in modular design.

- Energy- Less consumption of energy which goes into the manufacturing process. Inclination towards renewable energy or extraction of energy from the waste would be possible in some cases.

- Accessibility to the material- Selection of raw material should be based on locally available materials that consume less energy to transport. By using

local materials, recycled content materials and salvaged materials, it will help to reduce the initial material cost.

Materials should be composed of renewable resources and environmentally responsible, considering its impact over the life of the product. Depending upon project-requirements, material consideration may require an estimate of one or more of the selection criteria. “Product selection can begin after the establishment of project-specific environmental goals. The environmental assessment process for building products involves three basic steps” (Froeschle 1999).

- Research – This involves collecting all information which would be helpful to evaluate the raw material during the production process, warranties, content of recycled material, environmental and durability information.

- Evaluation – There is always a confirmation of technical information required to sort out the environmental claims. The Life Cycle Assessment calculates the impact of a product through the entire life span and helps to balance the environmental performance of the product.

- Selection- After scrutinizing the evaluation of the material, the highest environmental values can be considered to accommodate in the design process of the product.

There are alternative materials available as compared to the petroleum and clear cutting materials, such as, natural linoleum, cork, bamboo. Bamboo has been used

over wood for many construction purposes.

2.4 Bamboo: tomorrow's timber

Worldwide there are more than “1,250 species under 75 genera of bamboo, which are unevenly distributed in the various parts of the humid tropical, sub-tropical and temperate regions of the earth” (Subramaniam 1998). The demand for wood for construction and manufacture of paper and pulp, resins and many other uses increases throughout the world daily. Cutting trees down has become uncontrollable way to meet the demand of wood, resulting in depletion of the natural resources.

A renewable material, substitute for wood must be found that could be used extensively with no harm to the ecological system. This substitute material does exist and is know as Bamboo. It has been used in local, region and globally by human race for many years back already. A renewable resource when compared to “hardwood trees that require 40 or more years to mature, bamboo is a grass that matures in less than six years and is harvested over and over again from the same plant” (Revelle 2007). From its appearance and size, one thinks it is a tree but it is a fast growing woody grass that has a very short growing cycle.

Bamboo has been used in applications in Asia, for over thousands of years. Accessibility to this woody grass was convenient and also the cultivation conditions were suitable for it to grow in abundance. Due to this reason, the locals started experimenting with bamboo in many applications. Bamboo has its major role in the livelihood of rural people and in rural industry. The structural and chemical

properties of Bamboo are very favorable for versatile uses, such as, construction, food, clothing, jewelry, weaving materials and many others. For example: It is “used as a substitute for steel, bamboo plywood formwork has a number of advantages which can improve the quality and cost-effectiveness of cast-in-place concrete” (Yan 1995).

Bamboo has advantages of strength, good rigidity, wear and corrosion resistance and low cost.

2.5 Processing and Utilization

Bamboo could be used either as a whole section by itself or could be split into strips. Either ways is strong in its own form but the process of making the products from bamboo is different. The weavers sliver the bamboo strips to create different weaving patterns. The weaving pattern of bamboo strips makes the structure of the product very durable and at the same time decorative. Bamboo strips are woven in mat form, processed to make woven mat look uniform, which are then developed as the bamboo ply for construction purposes. Bamboo has flourished in its use in the handicraft industry in all rural areas, creating a making livelihood for traditional workers. Bamboo is used in various ways as follows:

Handicrafts: Many of the cottage industry manufacturers of baskets, trays, and tablemats use bamboo as a raw material. The range of bamboo handicrafts is always being updated as one delves into the wonderful world of bamboo crafts and art. Manufacturers experiment different weaving patterns to make the product

sturdy and at the same time doing justice to aesthetics. Some of the decorative patterns as shown in figure 3 are weaved from bamboo slivers by the handicraft manufacturers.

Figure 3: Weaving pattern from bamboo slivers.

Splitting is one of the most popular ways to use bamboo. As after splitting, the slivers could be used in making weaving patterns. At times artisans use different width bamboo slivers to achieve a desired strength and form for the product.

Figure 4a

Figure 4b

Figure 4: Bamboo Weaving

Bamboo nesting baskets as shown in figure 4a and 4d has unique, versatile designs

which are ideal for fresh herbs, produce, fruit and baked goods.

Pulp and Paper: Bamboo has been an alternate material for wood in the paper industry. The Industry found bamboo fibers much better than any other fiber also of wood. “A fiber's utility is calculated on the basis of its length thickness ratio. The longer and thinner the fiber, the better the paper produced” (Enviro n.d.).

House Construction: Bamboo due to its structural properties has been used for the house construction purposes as shown in figure 5. It is used for roofing, bamboo reinforced walls, flooring, doors, and windows. Also bamboo has been used in scaffolding purposes for high rise buildings.

Figure 5a

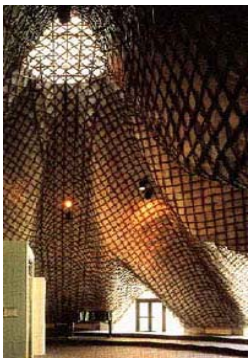


Figure 5c

Figure 5b

Figure 5d

Figure 5: Bamboo Architecture

Below are some of bamboo uses:

- Building and Construction Material
- Small Scale and Cottage Industries
- Medicinal Use
- Wood substitutes
- Industrial Products like activated carbon
- Transportation Industry
- Furniture
- Paper and Pulp Industry
- Long-time source of biomass for industry

Not only bamboo has many applications but also it has its identity in human culture. In Asia, each and every country, bamboo plays a major role in common man's life. In Chinese culture, it symbolizes longevity, and in India it signifies friendship.

Due to the following reasons bamboo's applications in design is increasing day by day. Bamboo has many properties which can be considered and used in many ways.

Versatile: Bamboo truly is a remarkable renewable resource. Having a tensile strength greater to steel, bamboo is one of the most versatile and robust natural resources in the world.

Sustainable: Bamboo plays a significant role in the reduction of timber consumption and also releases 35% more oxygen than same number of timber plantation. Bamboo stands also help towards ecological and forest protection, improvements in the livelihood of poor and sustainable development of rural economies.

Renewable: It is one of the earth's fastest growing plants with no need of replanting. Bamboo has an amazingly short growth cycle of three to five years with no need of fertilizers or pesticides. People worldwide have introduced bamboo in their lives by means to provide food, shelter, furniture, handicraft products, and earth and water conservation.

2.6 Bamboo availability in India and across the Globe

Due to Globalization, designers are made to evaluate their designs with respect to the context of socio- cultural needs, especially in Asia. “India's economic potential has long been attracting major international corporations” (IDSA 2007). Developments have always been focused on the urban sector of India, but mostly people forget that almost 70% of India’s land comes under the rural category.

But, recently, the rural sector has been receiving greater attention in terms of development.

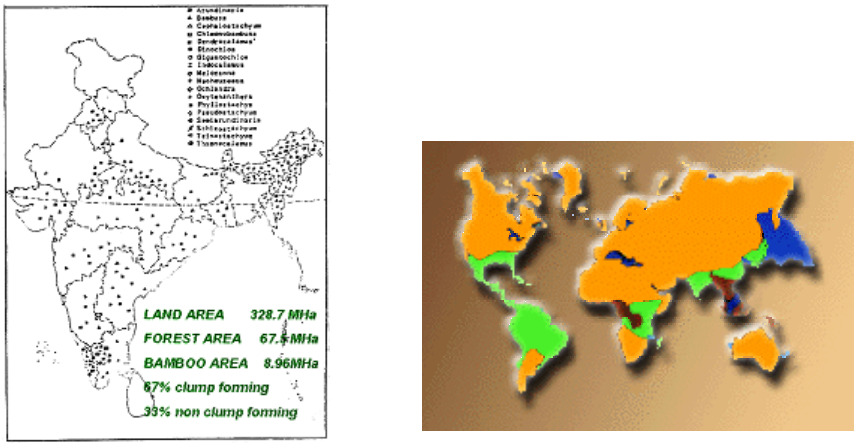


Figure 6: Distribution of Bamboo in India and over the world.

Bamboo is found in abundance in Asia as shown in figure 6 and due to that reason; the locals experiment with bamboo for various purposes. “India is the second richest country in bamboo genetic resources after China” (Katwal, Srivastva, Kumar and Jeeva 2003).

India has a rich inheritance of flora and fauna with bamboo and rattan representing widely occurring species in the India forests. Because bamboo is readily available in India, the locals, mostly in rural areas, make use of bamboo in their daily routine. The demand for this renewable resource has made its annual production," about 4.5 m tons out of which about 1.9 m tons is supplied to the paper." (Katwal, Srivastva, Kumar and Jeeva 2003).

Design has always been the driving force, when it comes to innovation. Designers always look for context that affects design, which are unique to every country. So it is in India too. Designers "look to India to understand design innovation from a deeper, more resource driven perspective" (IDSA 2007). Bamboo is available in abundance and also has been used by locals for their livelihood. It is a material that signifies India's identity. Design has always been encouraged when it reflects identity of its origins and traditions, in order to cherish its cultural diversity. "Product/service innovation is the result of bringing to life a new way to solve the customer's problem – through a new product or service development – that benefits both the customer and the sponsoring company" (Tucker 2002).

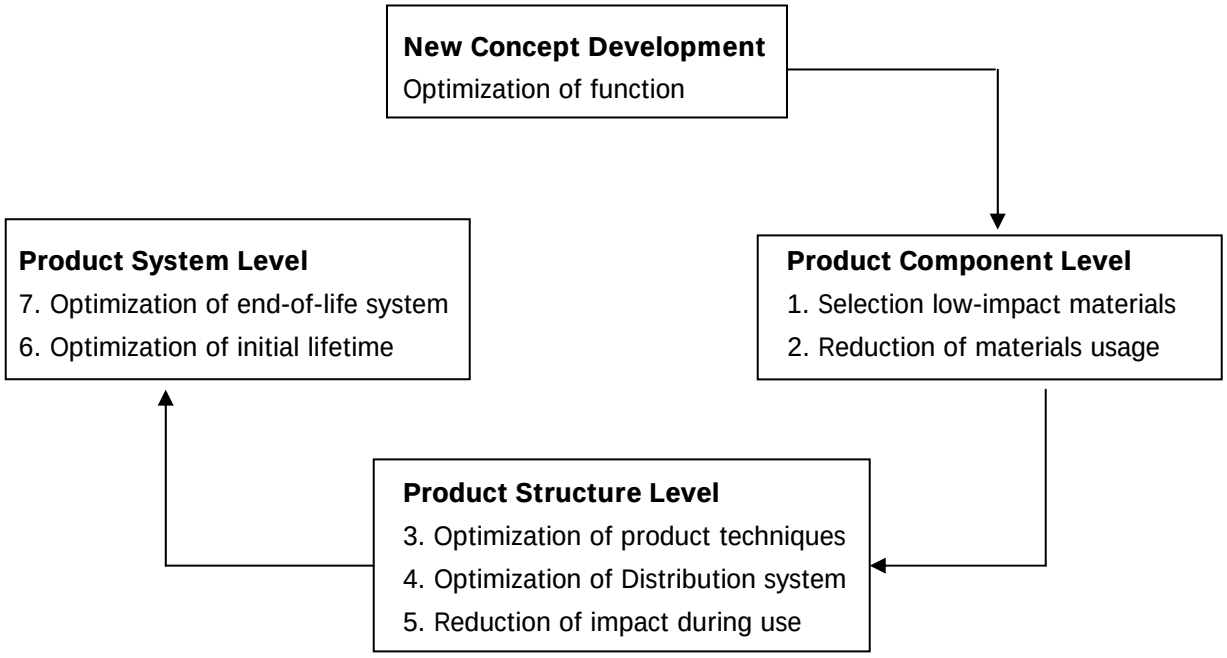


Figure: 7 Development of a design from concept to product system level

The above diagram shown in figure 7 is a very good example when a production or service innovation takes place. Product innovation is compare to vision of the company. It is very crucial that the company foresees the entire production cycle of the product including customer satisfaction.

The New concept Development is explained in different phases starting with selection of low impact materials, production techniques and end of life system. The diagram helps to decide the materials, systems and techniques involved for the new product design.

3. Ideation + Design Development

3.1 Manufacturing Tools

Though there are mechanical tools available to manufacture products from bamboo, hand tools have always been accessible by locals. From the previous chapters, we can see that, splitting the bamboo into slivers is the most common approachable way to make products from bamboo. The artisans design a wide good range of products from the bamboo slivers, such as, lamp shades, plant holders, fencing, weaving baskets, handbags and many other accessories. There is no limit to the designs just from the slivers. People prefer to use tools which are powered by them, which give flexibility for them to design. “Due to shortage of electricity/diesel for energy apart from costs and scale of operations”, (National Metallurgical Limited n.d.) it developed constraints to adopt the mechanical powered machines. Moreover, the maintenance cost of the machines is far more than the hand tools and during the breakdown of the same, there is no source for them to continue their work. Usually in rural areas, as an individual cannot afford the cost of the electric powered mechanical tool, they have workshops where they go and get their desired amount of work done.

As shown in figure 8, the mechanical workshop has machines that take care of knot removal and splitting of bamboo.

Figure 8a:
Traditional or Non-Chemical Treatment

Figure 8b:
Bamboo Knot Removal

Figure 8c:
Splitting of Bamboo

Figure 8d:
Manual Silver Making

Figure 8: Primary processing of Bamboo.

For some it is not convenient to reach the workshops and for some tasks they might not find it to be cost- effective. So they prefer having a hand tool, which the family could also use to make the product at an affordable price. There are human powered hand tools, but it is very cumbersome to work with them. So I decided to analyze the existing hand tools and then design a hand tool, which serves the purpose of splitting bamboo efficiently.

3.1.1 Available human powered tools to work with bamboo:

Bamboo knives are used to split bamboo into larger widths. It has different blade widths, with which fine splits of bamboo can be made. The hand tools as shown in figure 9 do split bamboo but it is not safe to use these tools. It is cumbersome to split bamboo with knives and saw.

Figure 9a:

Bamboo Saw

Figure 9b:

Bamboo Hatchets

Figure 9c:

Bamboo knives

Figure 9d:

Bamboo Gimmets:

Figure 9: Hand tools in form of saws, hatchets, knives and Gimmets

There is no such feature to these existing tools which can split the bamboo in equal parts and hold the bamboo at the base during the splitting procedure. As these are single blade tools, it is more likely for the blade to get trapped in the knots when splitting the bamboo. When the blade gets fix in between the knots, then one has to use a hammer to push the blade down.

3.1.2 Traditional ways to Split Bamboo:

After analyzing some of the traditional ways to split bamboo as shown in figure 10, many disadvantages could be noticed.

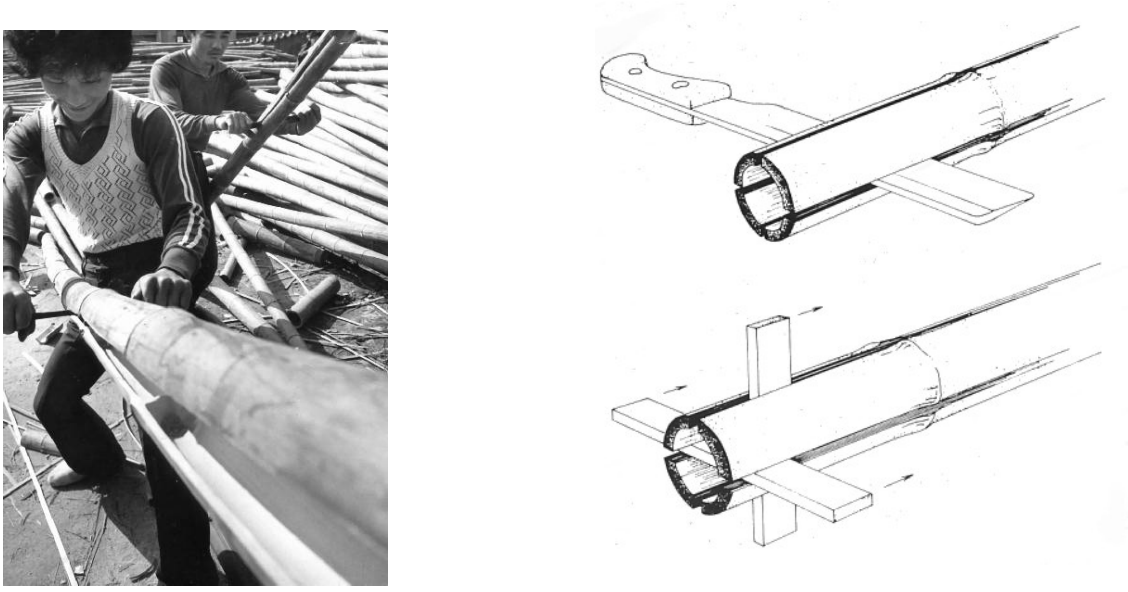


Figure 10: Traditional ways of splitting bamboo

Some of them are as follows:

- Splitting of bamboo in equal parts gets very difficult.
- It is not an easy and safe method to use this tool.
- This technique needs of more than one person to split the bamboo.
- There is more consumption of time and human power when spitting the bamboo.

3.2 Initial brainstorming

The structural and sectional properties of bamboo indicates that splitting is the most common way to manufacture products from the sliver. I started brainstorming random ideas, of how bamboo could be split efficiently. During my process of initial brainstorming, my strategy was based upon the needs of people and the environment, as the aim was to design within the design parameters of the socio-economic culture of the environment.

How bamboo could be split?

At the time of splitting, the tool should also perform the function of holding the bamboo, which is not seen in many of the bamboo splitting hand tools. The structure of bamboo is well designed to split, as the fibers are along the longitudinal axes of the bamboo. At the time of splitting, just a hard strike with

help of a well-designed tool that goes half way of its length, the rest of the split happens at ease.

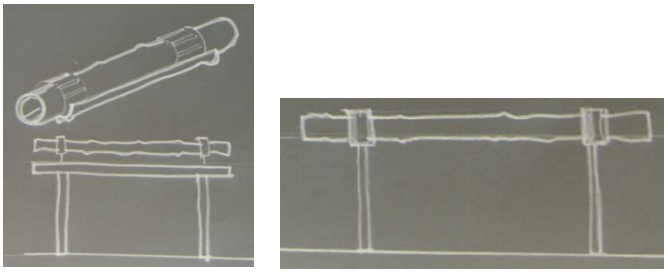


Figure 11: Initial brainstorming of splitting bamboo horizontally.

Holding bamboo horizontally as shown in figure 11 is not a good way to perform the function of splitting, if the operation is going to be human powered. It won't be appropriate to design the tool which is placed in a horizontal position, as vertical pressure applied is more effective than the force applied horizontally in a human powered tool.

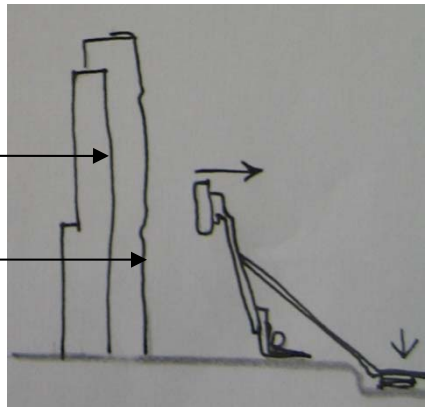
The main objective of the splitting tool is that it should consist of less components, so that it is easy to assemble, maintain and also portable. The target audience for whom I have aimed to design the tool is not literate, so I want the design of the tool to be self explanatory. As we have seen before in the traditional splitting of bamboo, the methods used are not at all safe or convenient.

3.3 Understanding various mechanisms

In order to design a tool, which can hold/ release the bamboo and at the same time split the bamboo in equal parts in one strike by one person, mechanisms should be analyzed thoroughly. I decided to study the mechanisms that are listed below because they are good at holding an object and in what manner I can apply a specific mechanism. The splitting tool will be a totally different component. So either the holding mechanism could be introduced to the splitting tool or each tool will be independent portable tools; one as splitting tool and other as holding tool. Here are couple of holding options of the bamboo.

3.3.1 Concept of mechanical spring

In mechanical spring, I wanted to study the press and release action applied by the user. Refer figure 12. For a quick mock- up, I took a flat platform base and placed a fixed vertical member at one end. The movable member is attached to the spring through a pulley, which helps to distribute the flow passed by the spring gradually. By arranging couple of springs together, they were pretty robust to take the force applied on them. During the splitting process, I applied the press action on the spring and then placed the bamboo along the fixed member. In order to hold the bamboo, I released my foot over the spring, which leads the member hit the bamboo.



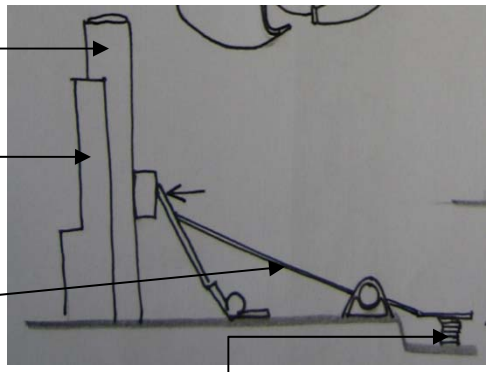


Figure 12: Exploring the concept of mechanical spring to hold bamboo.

Observations during the mock- up:

- As one releases pressure applied by foot on the spring, the member attached to the spring holds the bamboo.
- As one compresses the spring, the member releases the bamboo.
- During the entire process of press and release, there was lot of wear and tear of the spring.

3.3.2 Concept of Clamping

Clamping or holding the bamboo when splitting is an important action performed by the tool.

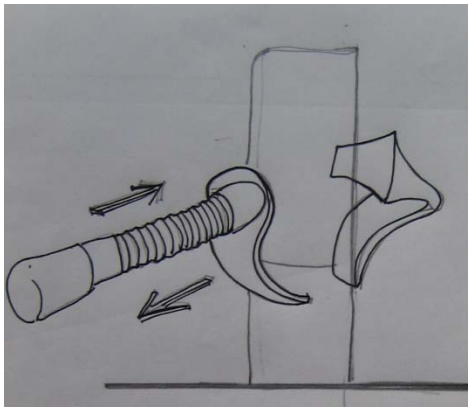


Figure 13a

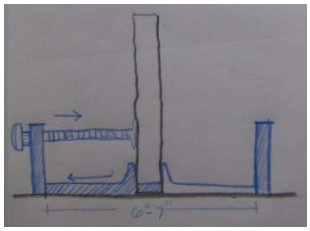


Figure 13b

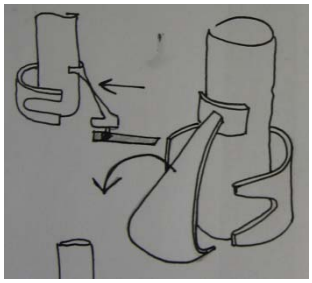


Figure 13c

Figure 13: Concept sketches showing holding options

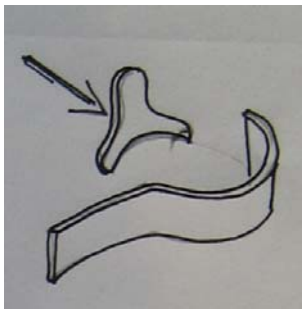
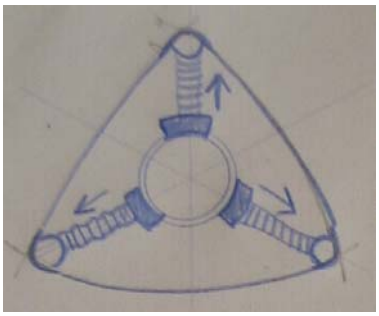


Figure 13d

But manual clamping of bamboo as shown in figure 13 has the following disadvantages:

- It takes time to fix the bamboo
- It is hard to align the bamboo at the center, as there is no reference to follow.
- The clamp gets very heavy, making it not portable.



In this concept, a quick mock- up of clamping the bamboo was experimented with help of springs, which are placed at three vertices of the tool as shown in figure 14a and 14b.

Figure 14a

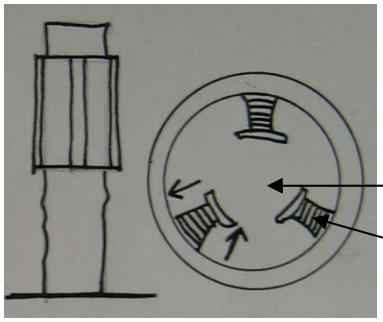


Figure 14b

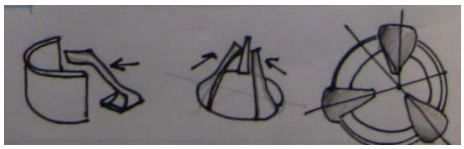


Figure 14c

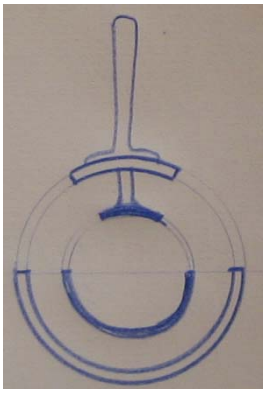


Figure 14d

Figure 14: Options of holding the bamboo by introducing, clamping and spring mechanism.

Observations when making a prototype of this concept:

- Well designed compression springs are required so that it is easy to slide in bamboo after every split.
- Springs should be designed in such a fashion, which would involve less maintenance.
- As the springs were exposed and didn't have any robust surface area over it, they were less capable to hold bamboo of any greater diameter than it does.

3.3.3 Applying the mechanism of a Bar clamp and horizontal toggle clamp:

Bar clamp was a good example for me to analyze the example of sliding, clamping and a fixed head at one end.

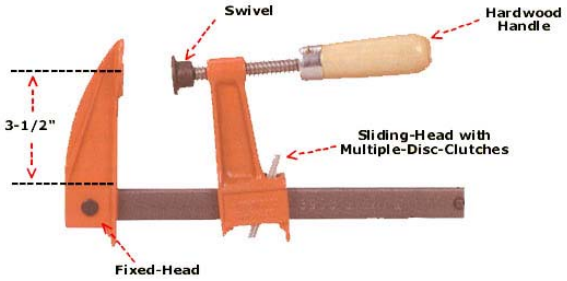


Figure15: Bar clamp

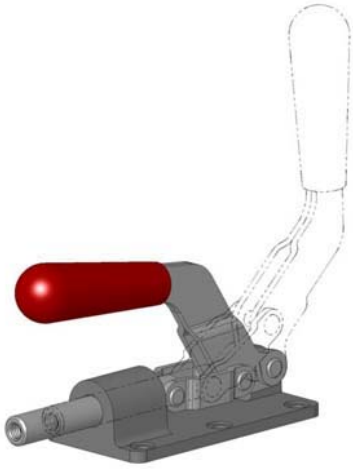


Figure 16a

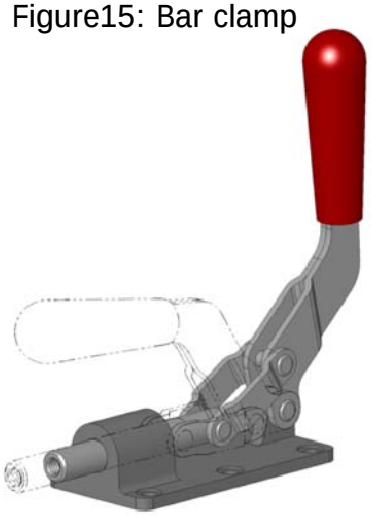


Figure 16b

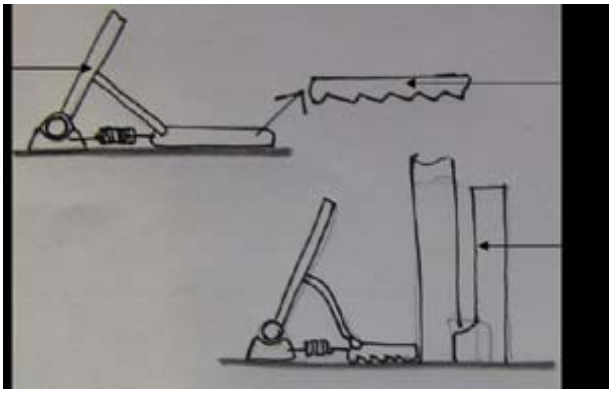
Figure 16: Toggle Clamp

I studied concepts of bar clamp shown in figure 15 and push/ pull type toggle clamp shown in figure 16a and 16b simultaneously. Combining the concepts of both the mechanism helped me during the design process.

I implemented the mechanism of toggle clamp to the bamboo holding tool in the following way and as shown in figure 17:

- An elevated flat base that allows the clamp, placed on one side to slide and hold the bamboo.
- On the same flat base, to the opposite side of the clamp, I made arrangement for a fixed vertical member.
- The horizontal member has a knurled edge allowing getting lock within the locking arrangement on the flat base. The horizontal member of the clamp can be locked to a particular locking slot within the flat base depending upon the diameter size of the bamboo being used for splitting.

clamp



Horizontal member,

the knurled

the fixed vertical member.

Figure 17: Sketch showing implementation of toggle clamp concept to the hand tool

When working with this mechanism, I realized there were many components of the tool, which didn't make the tool portable and also it would have been time consuming to assemble the components.

3.3.4 Concept of the Lockable castor:

As I have been working on mechanisms, which has one movable end and the other end to be a fixed one, I came across the lockable castor mechanism. My aim was to experiment with different techniques to make this tool function single- handed and also increase the efficiency of the tool to split the bamboo faster than the current tool splits.

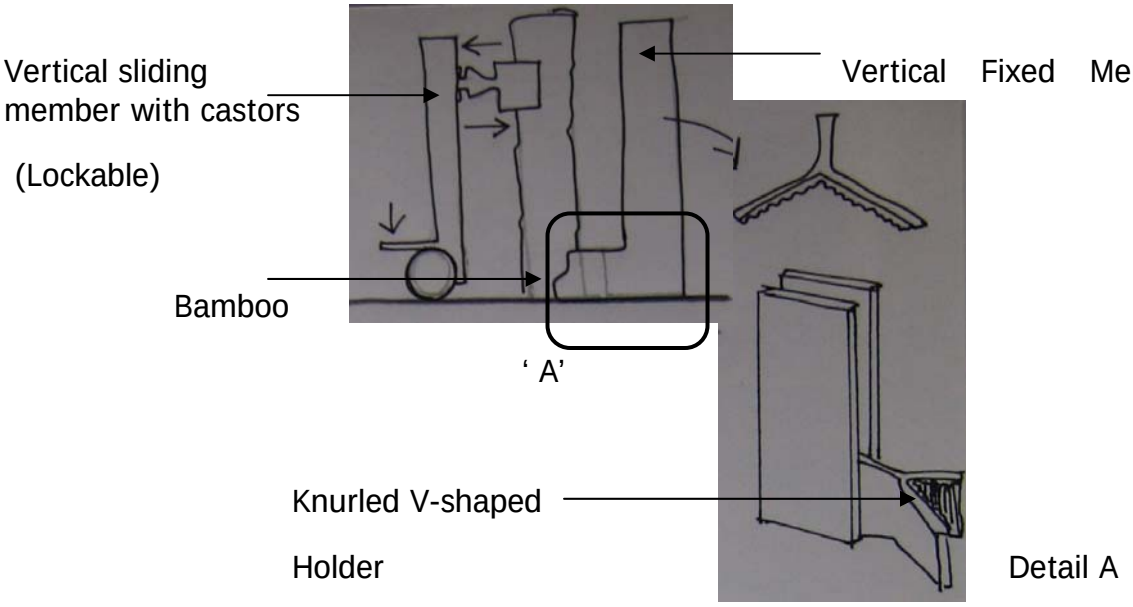


Figure 18: Sketch showing implementation of castor wheel concept to the hand tool

In this concept, the bamboo is placed within the knurled ‘V’- shaped holder fixed to a base and when the castor wheel member slides, the bamboo is held and locked at that position with the castor locks.

The locking system built with the castors is simple and quick method to lock the

bamboo in the position. But the lock does not have a very good hold on the bamboo. The bamboo shifts away from its locked position, making the splitting of the bamboo difficult to perform.

3.3.5 Mechanism of Bike Brakes:

Figure 19: Concept of bike brakes

- This concept of bike brakes mechanism as shown in figure 19 could be applied in the lever below the handle of the splitting tool, which would be easily accessible by hand.
- But the press and release mechanism of the brakes involved many parts for assembly.
-

3.3.6 Applying the concept of a mechanical pencil:

The mechanical pencil has an interesting mechanism of having a very good grip over the pencil lead. I analyzed the mechanism and applied some concepts of the device to my tool as shown in figure 20.

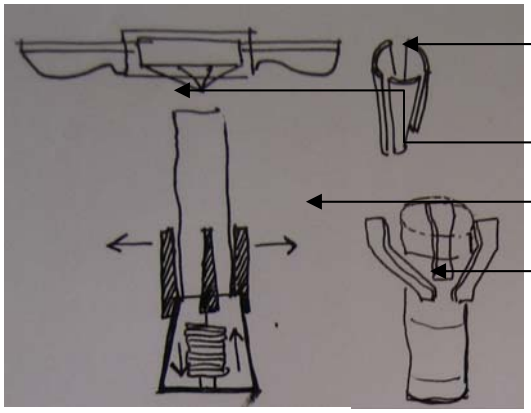


Figure 20a

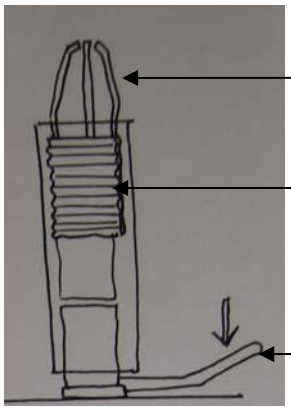


Figure 20b

Figure 20: The cylindrical tool, consisting three flanges, spring mechanism and the foot pedestal.

A vertical pedestal body comprises of a foot lever, where pressure is applied by foot. The pressure could be manipulated depending upon the varying diameter sizes of bamboo. When a downward force is applied to the lever, the spring that is linked to the lever and also to the three flanges, spreads the three flanges and allows holding the bamboo.

- The flanges can hold the bamboo and the spread of the flanges could be adjusted depending upon the pressure applied by foot.
- After couple of mock ups of splitting bamboo, I noticed that the flanges were not much capable to hold the bamboo firmly and also this mechanism would demand integration of many small parts.

It has been very helpful for me to analyze all the above mechanics involved in these human powered tools. After going back and forth when studying various mechanisms for my tool, I developed some concept sketches/ mock ups of the tool in the following sections.

3.4 Concept development

The main concept of this tool is that it should be designed for people in relation to the socio-economic and cultural context.

- My objective is to design this tool for the rural population, as the target audience. The facilities available in rural area are not sufficient and convenient for the locals to use electric powered tool. As a human powered tool doesn't involve many prior and after maintenance expenses, it is well adopted by the locals.
- The tool should perform the task of splitting bamboo single – handed.
- The function of holding and splitting bamboo could be performed by different parts of the tool. The main tool is defined as the splitting tool and an attachment will be used for holding the bamboo.

Considering the above concepts and then integrating them with the help of mechanics, I developed couple of design developments for hand-tool design.

3.4.1 Concept-1

I developed the concept of locking castor and clamping mechanism by incorporating rollers in this design development process. The main tool consists of circular ring with intersecting blades at the center of the ring,

allowing equal bamboo splits. The rollers should be attached at the other end of the vertical flange, which will be fixed below the handle of the circular ring. The lever, which is fixed underside of each handle on either side by a spring mechanism, when pressed in upward and then released, helps the flanges to hold varying diameters of bamboo.

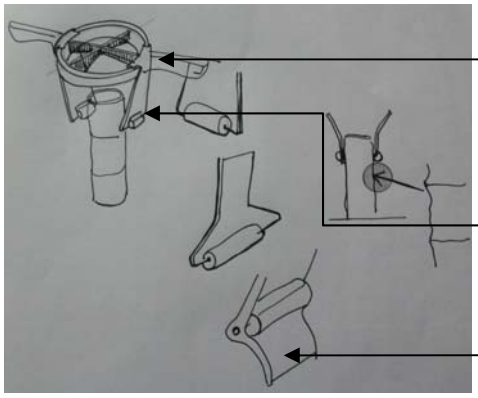


Figure 21a

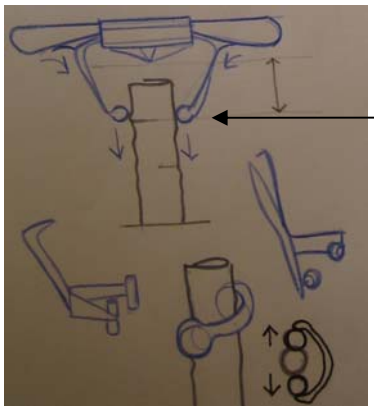


Figure 21b

Figure 21: Design Development sketches – Concept 1.

When making a mock up of this concept as shown in figure 21, I noticed that the rollers were not a great help of holding the bamboo. Bamboos have these knots at certain interval of its length. The rollers failed to run at ease over the bamboo knots that came when splitting the bamboo.

There was an issue with springs that attach the lever to each handle on either sides of the main tool. Springs help function the lever to hold the bamboo of varying sizes, which has lot of wear and tear during this action. A better design of springs was needed.

3.4.2 Concept -2

Understanding the requirement of quick hold and clamp for the bamboo when splitting, I included some elements which will hold the bamboo as soon as the tool strikes the bamboo. I introduced a second member to the main tool, a ring attached to the main tool by three vertical members, as shown in figure 22.

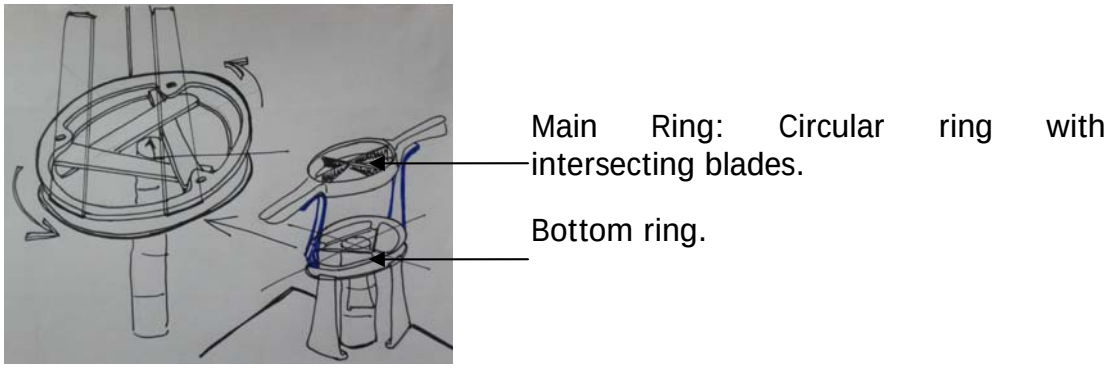


Figure 22: Connecting the main Ring to the Bottom ring.

The bottom ring has three horizontal intersection linkages as shown in figure 23a that hold the bamboo when the tool follows downward direction when splitting the bamboo.

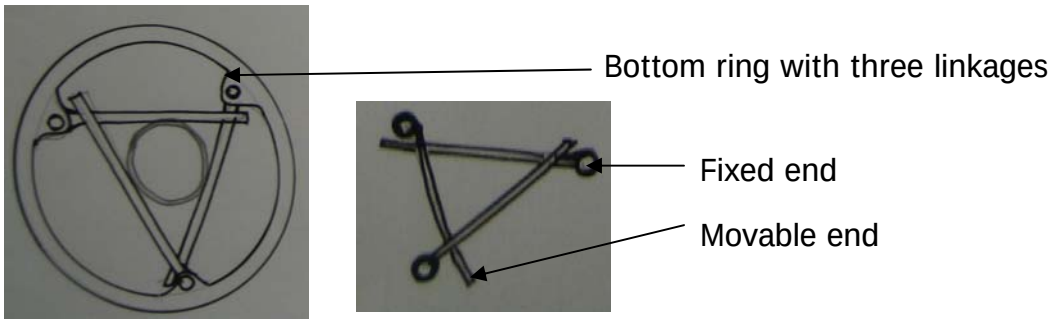


Figure 23a Figure 23b

Figure 23: Three linkages fixed to the bottom ring.

The linkages have one movable end and the other fixed one as shown in figure 23b. The linkages that are fixed to the bottom ring are attached to the upper ring by three tapered extended members as shown in figure 24. When the upper ring's handle is swiveled, the movable end of all the three linkages move along the lower ring circumference. The locking arrangement was based upon in which direction the handle is swiveled. The rotation of the handle adjusts the linkages to hold varying bamboo sizes and just by turning in opposite direction will lock the linkages to that particular size of bamboo.

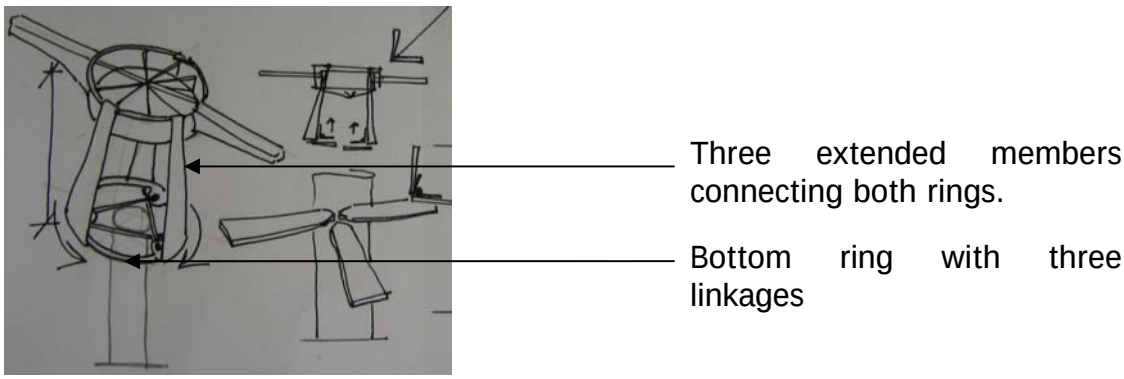


Figure 24: Locking mechanism in the bottom ring

This tool was well-developed with the mechanism. But it included many parts, that means, more parts to manufacture, more time to assemble and mainly, not a portable tool. The handling of the tool by a rural man would be doubtful, as it involved some operations which were not simple enough for them to use.

3.4.3 Concept -3

When I was developing the concepts, I preferred to have hands- on experience with the tool. I made couple of quick mock up models, which helped me to understand the mechanism as shown from figure 25a to 25d.

Making certain that the newly designed hand tool should be efficient in all means, such as; cost, time and usability were couple of my design principles when designing this hand tool.

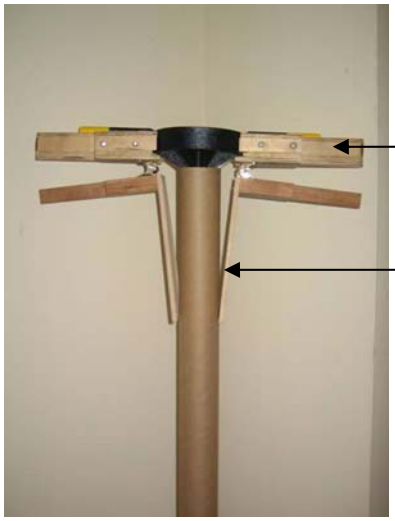
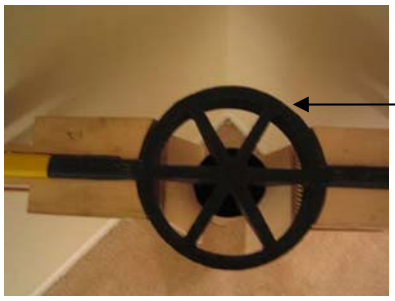


Figure 25a



Main Ring: Circular ring with intersecting blades.

Figure 25b

Figure 25c

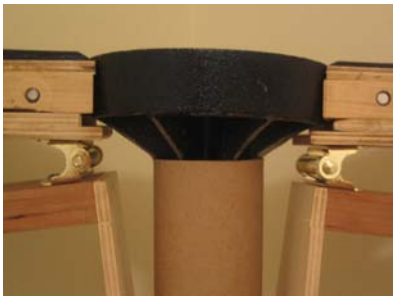
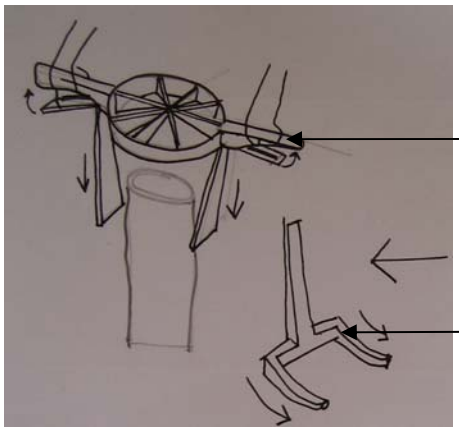


Figure 25d

Figure 25: Mock-up models

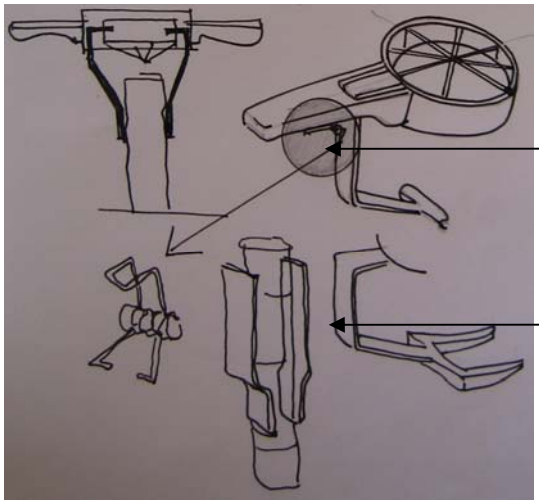
I further developed the first concept, of using the vertical flanges that were fixed to the handle and lever with spring. But instead of using the rollers at the end of the flanges to hold the bamboo, I used a v-shaped member. I observed that during splitting bamboo, a V-shaped profile had a good hold of bamboo as shown in figure 26.



Lever is attached on either side of the handle

Vertical flange fixed to the lever by spring mechanism

Figure 26a



Spring fixed underside of both handles on either side of the tool.

Both flanges on either side with a V- shaped end that hold the varying size of bamboo

Figure 26b

Figure 26: Sketch of working mechanism of concept-3.

The operation of this tool was very simple, making the use of this tool easy for the locals. Due to its compact size, the tool was portable. The tool didn't have many parts to manufacture, making the tool less expensive and quick to assemble.

A well- designed spring mechanism was very crucial in this concept. The function of holding the bamboo is controlled by springs attached on either sides of the handle. In order to avoid the following factors, I wanted to scrutinize the design development process of spring mechanism as shown from figure 27a to 27d:

- As the springs are placed just below the handle, I wanted to make sure that they do no harm to the user when splitting the bamboo.
- There is a good percentage of wear and tear involved by the spring when splitting, so an additional element is required to support the springs.

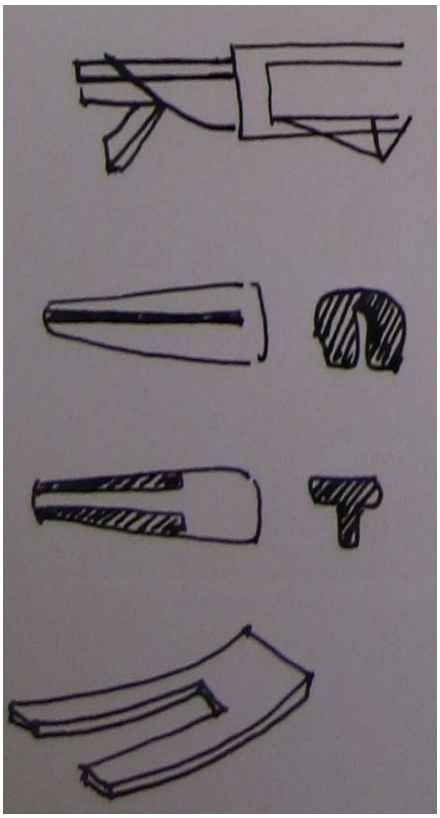


Figure27a

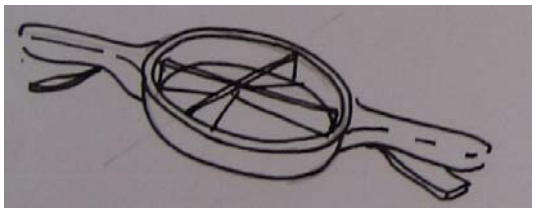


Figure27b

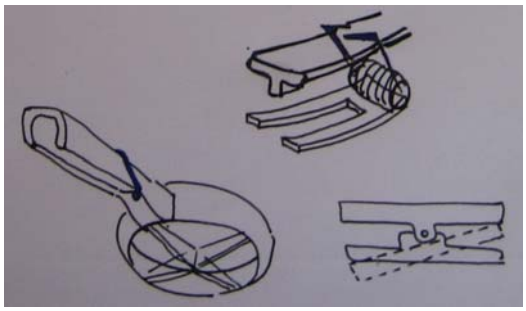


Figure 27c

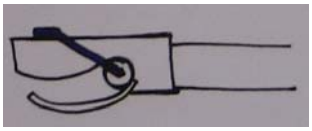


Figure 27d

Figure 27: Working out options to place the spring below the handle

4. Final Design

The development of the concept ideas helped me decide the significant factors required for the final tool design. By having a continuous back and forth process when analyzing mechanisms and ideas in the entire concept developments, I decided that the hand tool should have the below listed features to meet the design requirements.

- Easy to carry/ Portable
- Simple and efficient design to use
- The holding tool should hold the bamboo at the base to get a robust hold also at the same time clamp bamboo of varying diameter starting from 2” diameter to 7” diameter.
- The splitting tool should split the bamboo in equal number of desired parts.
- As it is human powered, it should have less parts and less maintenance.
- It should be affordable by the people to use.

The final design has a very simple concept which makes it easy for the target audience to use the product. The design of the tool makes it self explanatory for the function of the same. The tool consists of two main elements, the upper main ring and the base.

4.1 Upper Ring

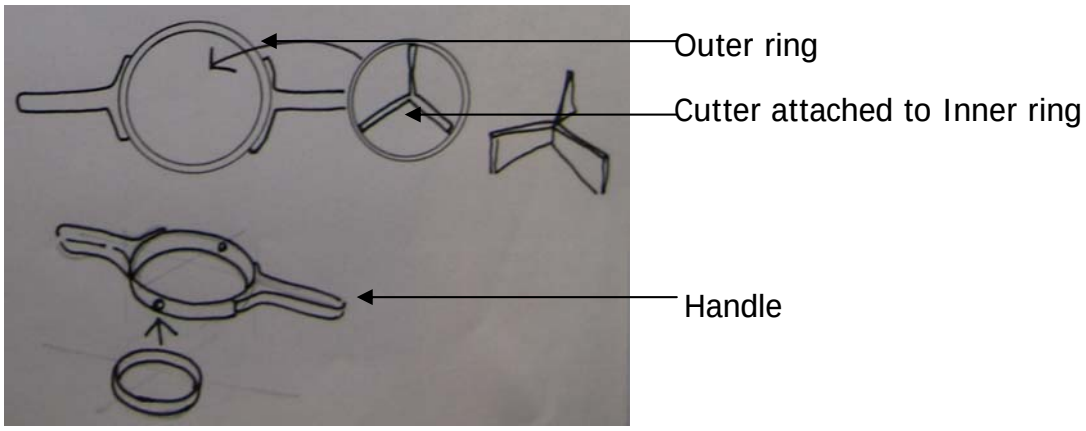


Figure 28: Components of Upper ring

- Outer Ring
- Cutter which has Inner Ring with arrangements of different number of blades and center rod.
- Handle; as shown in figure 28.

Components of Upper Ring are described as follows:

4.1.1 Outer Ring:

The simple concept of Taps & Dies as shown in figure 29 was carried further to outer and inner ring. The Inner ring is machined to the outer ring. The blades are welded to the inner Ring.

Figure 29: Taps and Dies

4.1.2 Cutter:

The Blades has arrangement to split bamboo in different number of splits. It includes 3- way, 4- way and also 6- way cutters as shown in figure 30. The cutter is assembled to outer ring by fitting of grub screws. Blades of high speed steel is hardened and tech welded to ring and center rod. The center rod aligns the bamboo at the center and helps to split equally. The number of blades like 3, 4, 5, 6 and 8 are welded to the inner ring for different division of bamboo. The advantage of having cutters of various numbers of blades allows splitting the bamboo in equal number of parts. It is also very quick process to change these different cutters and attach them to the outer ring.

Figure 30: Blades of high speed steel

4.1.3 Handle:

The Handle is made of Mild Steel Ring machined to suit the seating of cutter with a step. In order to make the tool light weight and at the same sturdy, appropriate materials were used accordingly.

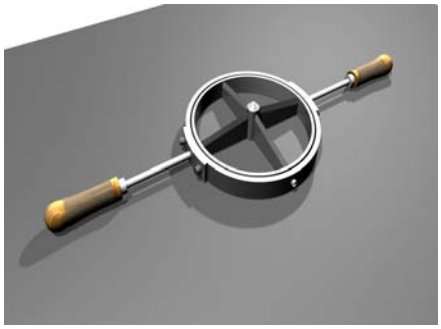


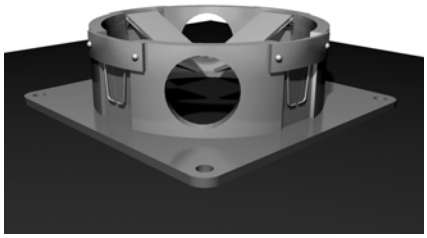
Figure 31a

The grub screws are used for tightening the handle to the outer ring, which can be detached by unscrewing at ease. This also makes the tool portable and consumes less space during packaging of the tool. The handle is made up of two hollow pipes on either sides of the outer ring. A wooden attachment with rubber grip is used to gain good grip over the tool when using the tool.

Figure 31b

Figure 31: Attachment of Handle to the outer ring.

4.2 Base Plate



- Square plate
- Four plates with custom spring attachment; as shown in figure 32.

Figure 32: Base Plate of the tool.

Components of Base Plate are described as follows:

4.2.1 Square Plate:

The base has a function to hold the bamboo, that doesn't make the bamboo quiver. In order to have a good seize over the bamboo, four MS plates are fixed to the ring with spring attachment as shown in figure 33. The four clamp plates with the spring attachments are placed equally along the ring, which balances the function of holding the bamboo at the base.

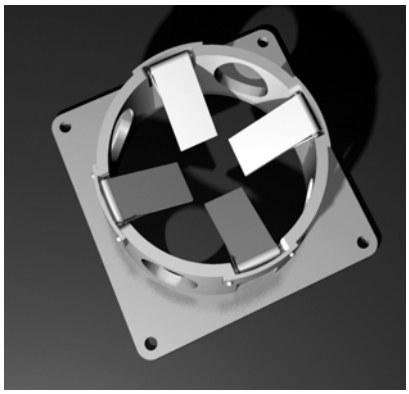


Figure 33: Square Plate and four plates with custom spring attachment.

The reason the holding function is introduced at the base, because if the member at the splitting tool holds the bamboo at the top and runs till the base when splitting the bamboo, there is a high possibility the action won't be performed at ease and it might get stuck in between the slivers of bamboo.

4.2.2 Four plates with custom spring attachment

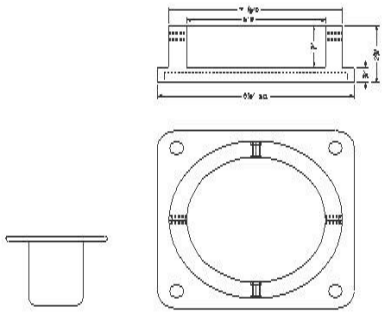


Figure 34a

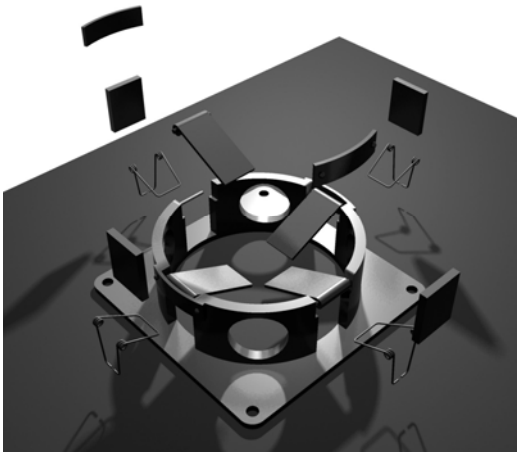


Figure 34b

Figure 34: Production drawings of Base plate.

The springs used in the base with the four clamp plates were designed after working out several options as shown in figure 35, as the springs will go through lot of wear and tear in the act of releasing and holding the bamboo.

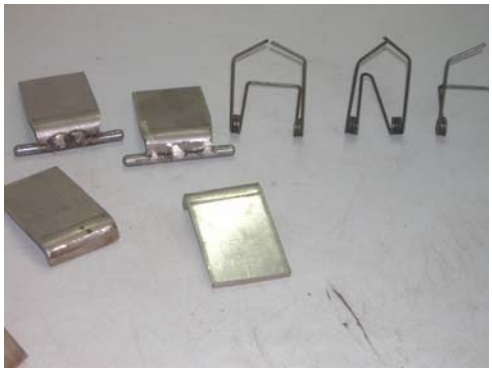


Figure 35a

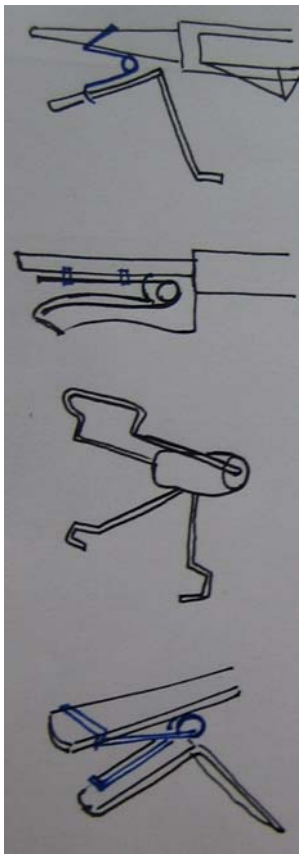


Figure 35b

Figure 35: Different assemblies of springs with MS plate

4.3 Working Mechanism of the tool

The working of this hand tool that includes holding and splitting of bamboo requires only one person. A user places the Base plate on the flat ground surface. As soon the user places the bamboo vertically at the center of the base plate, the four base plates with an attachment of spring mechanism seizes bamboo of varying diameters. During splitting the bamboo, place the splitting tool over the fixed bamboo as shown in figure 36a. The center rod at the center of each cutter is a simple way to align the center of the bamboo with the cutter of the splitting tool.

After aligning the center rod with the bamboo, a hard strike splits the bamboo in equal number of parts as shown in figure 36b. If one requires different number of bamboo splits, one has to change the cutter and then attach that to the outer ring of the splitting tool.

This entire splitting process for one bamboo takes 15 seconds.

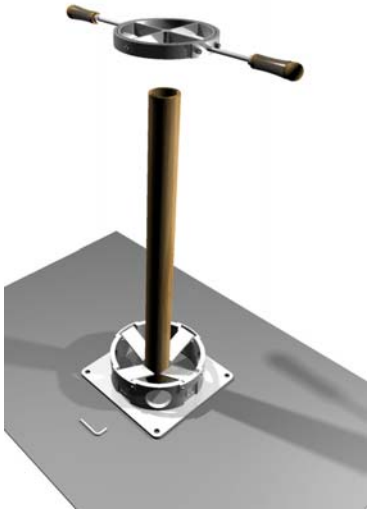


Figure 36a

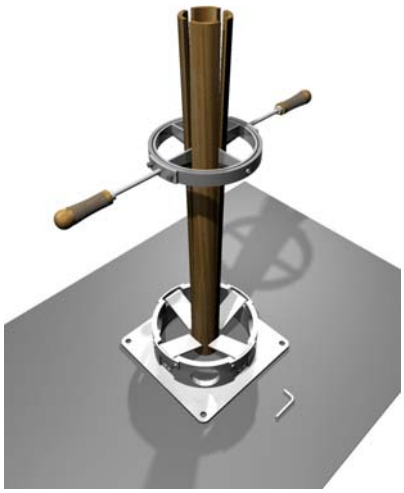


Figure 36b

Figure 36: Rendering of final design

4.4 Production Process

Total Mechanical process involved in the production of the tool is as follows:

As the tool was designed by keeping the mass production factor in mind, the production of the same was not time consuming.

The Splitting and the holding tool are made in 3 parts. The material of construction is Mild Steel with cutter of high speed steel. All the items are Chrome plated to give better resistance to corrosion.

- Handle - Size of MS ring OD 8.55" X ID 6" X 1.5" thick. Ring of above size is taken and machined to size with a step to have a seat for cutter. Grub screws are used to tighten the cutter in this ring which can be detached by unscrewing it. Two pipes of 1" Round is fitted on both side with wooden grip for holding.

- Cutter -Size of ring OD 7" X ID 6" X 1" thick is machined as per the requirement. 4" long and 1" diameter center rod is machined and fitted in centre with blade to give guide to Bamboo.

Cutters are of high speed steel of size 2.75" X 3" X 1/8" thick. It is then welded to ring and rod. The number of cutters is welded to give different segment of cutting of 3,4,5,6 & 8.

- Base - Size of the Square plate is 8.5" X 8.5" X 3/4" thick It is machined as per size. 7.5" OD X 6" ID X 2" High ring is then welded on square plate. Four lever fitted with ring are equally spaced to hold the different size of Bamboo.

The above mechanism is free from any maintenance hazards and can be easily portable. The manufacturing cost is app. Rs.5000/- i.e. approximately $102.00. It can be reduced in bulk manufacturing. Special care has been taken for the hardening of cutter so that the sharpness should last for longer time. All the items are hard chrome plated to give more resistance for corrosion.

It involved some basic processes, such as,

4.4.1 Machining on Lathe Machine

The lathe machine uses stationary cutting tools to shape a rotating part. The cutting tools are applied to the part to obtain a generally cylindrical shape as shown in figure37a.

Figure 37a

4.4.2 Welding

The parts were welded as shown in figure 37b, so that the production process gets quick, cost effective and also there is less work involved during the assembly of the tool. Also when it comes to recycling it is convenient to do so.

Figure 37b

4.4.3 Grinding

After welding, the metal undergoes a grinding process as shown in figure 37c, which removes, if there are any imperfections on the surface of the metal.

Figure 37c

4.4.4 Drilling

After the metal goes through the grinding process, the surface gets a good finish that allows adding if any drilling is needed as shown in figure 37d.

Figure 37d

4.4.5 Assembling

As the manufacturing process involved welding, the assembly process did not take much time. In this process, all parts of the tool, such as, cutter, handle, rings are assembled as shown in figure 37e, which will help to know the time taken for the same.

Figure 37e

4.4.6 Finishing

If any changes to be made during the assembly process, those are fixed in this step. This process also takes care of finishing the details of the springs as shown in figure 37f per the tool requirement.

Figure 37f

Figure 37: Production Process

4.4.7 Final fabricated tool

- Robust
- Portable
- Light weight
- No maintenance
- No power required
- Cost – effective
- User friendly
- Chrome plated.

Figure 38: Fabricated tool

4.5 Conclusion

Efficiency of the tool:

The designed hand tool is much more efficient than the existing tool used to split bamboo. At present, with the existing tool the splitting task requires two people to split bamboo because it is difficult to split and hold the bamboo single handed. The entire splitting time for one bamboo is 3 minute as compared with the new deigned splitting and holding is just 15 seconds. At present, the splitting function is performed by traditional knives and saws, so the bamboo splits are scattered. But with this new tool the bamboo splits fall in the same radius making easy to gather those split bamboos.

Less waste of material:

The fibers in bamboo are composed longitudinally. The easiest and the quickest way to split bamboo require simply running the tool parallel to the fibers. One of my objectives when designing the tool was to design the hand tool that will leave less waste during the splitting of bamboo. The equally spaced blades in the designed splitter tool help to split the bamboo in equal parts, resulting in lesser wastage of the material than the traditional method of splitting.

Presently, the locals have to manipulate the number of splits, resulting to unequal splits from a bamboo. Many applications of bamboo split require equal width size of each splits, as it is visually and at the same time structural necessary.

Improved production techniques have been one of the ways to support sustainability in design leading less harmful impact on earth's environment. Having appropriate material in the raw material selection process makes less consumption of natural resources. It is an entire process of selection of raw material, manufacturing and final disposal. Manufacturers have started realizing their responsibility to design the system in such-a- way that has fewer burdens on the environment.

Design has its impact on the living standards of the local community and also reflects the culture and social factors of the region. It is all about subtle technology which is designed as human centered, helping the locals to gain their needs by available resources.