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Modelling of a Banana Fiber Extraction Machine

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Abstract: **The paper details the modelling and analysis of natural fiber extraction machine to extract high quality natural fibers from the banana pseudo stems. Manual extraction of banana fiber produces good quality fiber, but it is a time-consuming process. Labor expenses are quite high, and output is low. Hence efficient extraction of banana fiber can only be possible through a machine. Machines existing in present scenario for extracting banana fiber are manually operated and cannot be referred for mass production. The impurities are present in rolled fiber. The efficiency of existing machines is average. It consumes time and the process is not safe. This paper describes the model of machine to be designed for extracting banana fiber from the banana stem. The machine is to be designed in a very simple way such that it can be used by everyone, as the mechanism is very simple.**

Index Terms: **Pseudo stem, extraction, mass production, efficiency.**

I. INTRODUCTION

Natural fibers such as jute, coconut, banana, and sugarcane extracts are the upcoming promising fibers within the area of composites as well as handcrafted products. Most developing countries like India are in the verge to grow these natural fiber plants due to the favorable climatic conditions. There are several methods of extracting natural fibers from its source, but the mechanical way of extracting fibers is commonly used for reducing the amount of time and efforts put for it. The mechanisms and therefore the design features for extracting fibers should be developed in such a way that the natural properties of the fibers are not lost and comprising the value factor suitable for this system. Natural fibers offer several advantages in comparison to synthetic fibers in terms of low production cost, tenuity, renewability, ecofriendly, availability, budget friendly, nonhazardous and simply available [1] [3] [10]. For a better understanding of the properties of natural fiber materials, it is essential to know the physical, mechanical and chemical properties. The strength characteristics of fiber depends on the properties, fibrillary structure, lamellae matrix, method of processing and chemical modifications [9]. Due to these factors they're well-known to the composites field. The disadvantage of natural fibers is that the moisture absorption and the poor compatibility between fiber and the matrix .in the composites. But the importance of these fibers is highlighted by various government schemes to provide employment in this domain [10].

Banana tree is a symbol of prosperity and fertility and thus it is frequently used in all the Indian festivals for serving food or as a cooked dish. Almost every part of banana tree is employed for some economical or medicinal purposes. Banana fiber is extracted by crushing its pseudo stem for obtaining the pulp. Pseudo stem [2] is the part of the tree which is disposed after it bears fruits only once. It is produced above the ground by the true stem which lies underground. It looks like a trunk and is formed by the leaf sheaths which are tightly packed. The fiber is extracted by splitting the stem into strips, crushing it under rollers, washing it for the residual removal and later drying it for the production. The design of this fiber extracting machine considers the factors such as the detangling and pulp cleaning for its direct usage in the applications like textiles or paper making [6] [7].

Banana fiber is used as a raw material in the following industries:

- Paper Industries
- Cardboard Industries
- Plywood Industries
- Handicraft Items- Cap –Purse-Bag
- Rope Making
- Handloom Industries
- Banana Yarn – Textile Use

Banana fiber has its own physical and chemical characteristics [3] [8] and many other properties that make it a fine quality fiber.

- Banana fiber is finer than any other naturally produced fibers.
- The chemical composition of banana fiber is cellulose, hemicellulose, and lignin, which makes it a highly strong fiber.
- It has smaller elongation.
- It appears shiny depending upon the extraction & spinning process.
- It is lighter in weight.
- Also, it has strong moisture absorption quality. It absorbs as well as releases moisture very fast.
- It is bio- degradable and has no negative effect on environment and thus can be categorized as eco-friendly fiber.
- It can be spun through almost all the methods of spinning including ring spinning, open-end spinning, bast fiber spinning, and semi-worsted spinning among other.

Figure 1. Pseudo stem of banana tree

II. Problem Statement

The pseudo stem is chopped off from the original stem once the fruits on it are harvested. It can bear the fruits only once and hence disposed after single harvest. The disposal of these stems creates a lot of biogas which goes waste. To avoid this and the rising interest in natural fibers gives a way to extract the fiber from these stems [3] [10] [11]. These fibers possessing good mechanical properties and being economical are widely used in many applications including fiber composites. These fibers can be thick and thin. Thick fibers are mainly used for handicrafts whereas the latter is used in textile industry. Table I shows the composition of fiber highlighting the properties that are very useful for various applications [12].

TABLE I.
Chemical Composition of Banana Fiber

Property	Value
Tenacity	29.98 g/denier
Fitness	17.15 denier
Moisture regain	13%
Elongation	6.54
Total cellulose	81.8%
Alpha cellulose	61.5%
Residual gum	41.9%
Lignin	15%

III. Extraction of fiber

There are two methods used for the extraction of the fiber [7].

A. Manual way of extraction

Fiber is extracted from the leaf sheath or pseudo stem of banana plant by decortication of the sheath. The pseudo stem is the aerial stem that is seen above the core part of banana stem. It is created by closely packed leaf sheaths embedded within the growing tip. Each leaf incorporates a banana leaf sheath forming a part of pseudo stem petiole and lamina [2]. It is hectic to extract the fiber by segregating the fiber from the pulp manually or by machines. It is often extracted chemically, as an example boiling in NaOH solution. Though Manual extraction of the banana fiber produces a better quality of fiber but it is much time consuming.

B. Mechanical way of extraction

By employing a finest fiber extractor machine, an oversized amount of fiber is obtained which can produce an additional income. The Banana Fiber Extractor Machine is the exclusive form invented [4] for the extraction of fiber from waste portions of Banana like stems, leaf stalks and peduncle. The manual (or) semi mechanical extraction of Banana Fiber is tedious, time consuming, and damages the fiber. It's an economical portable device developed for the good cause about the farming community and self-employed women group. Cost of the Machine varies basing on the iron and steel rates [4]. 100% safety in machine operation with less maintenance cost. Many schemes were introduced by government for encouraging the practical usage of these machines.

IV. Modelling of Parts in CATIA

The 3D model of the machine is designed in CATIA. The major components designed are as follows:

A. Frame

All the parts of the machine are mounted on this frame structure with the suitable arrangement. According to the bearing size bore holes are drilled for their proper alignment during the assembly and proper lubrication provisions are also provided. Figure 2 shows the frame modelled. The frame is designed with a height of 750mm and length of 750mm. Width of the machine is taken as 400mm.

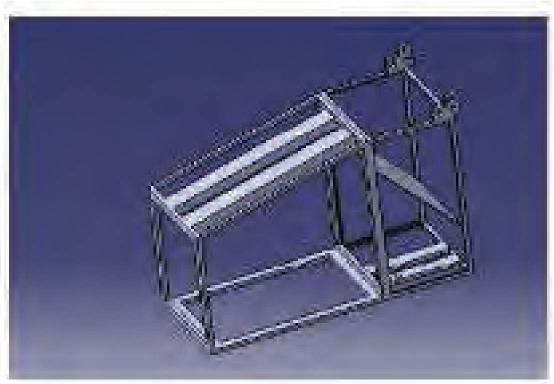

Figure 2. Frame

B. Bearing

Bearings are used to reduce the friction between parts which have relative motion between them [6]. Ball bearings as in figure 3 are used in this machine to reduce the motor friction. These can also be easily replaced when they deform or squish under heavy loads. Bearing 6202 type is used for this [8].

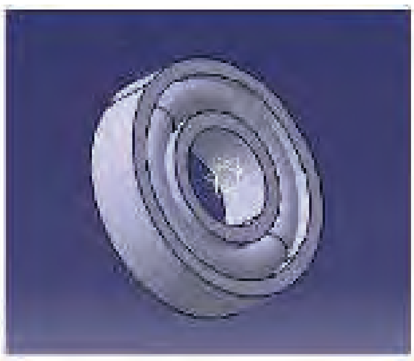

Figure 3. Bearing

C. Belt

Belts provide mechanical link between two rotating shafts. The shaft on the motor and the other on the roller drum are connected by this and slippage of belt over these shafts is taken care of. A32 power loom belt is used in the mechanism.

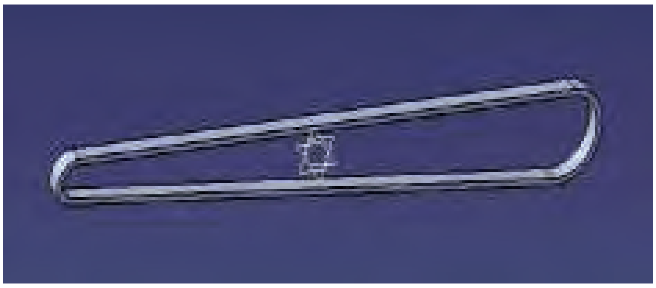

Figure 4. Belt

D. Motor

This part provides the initial motion of the machine. An AC type motor used for the speeds and driving force to the roller [5]. A motor of capacity 1hp with single phase is used for the running of the machine.

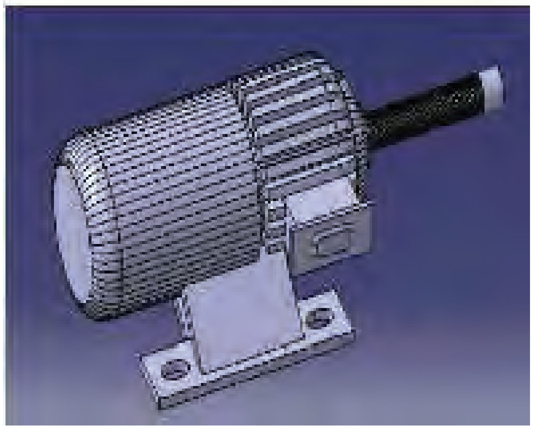

Figure 5. Motor

E. Pulley

Pulley transmits the power from motor to the roller drum with belt attached to it. Two pulleys are used for this purpose. One of them is fixed which provides deviation for the force on the rope or belt moving on its circumference. The second pulley is a movable pulley which offers a greater mechanical advantage when the rope or belt is passed over its circumference. Both the pulleys are designed with a diameter of 300mm.

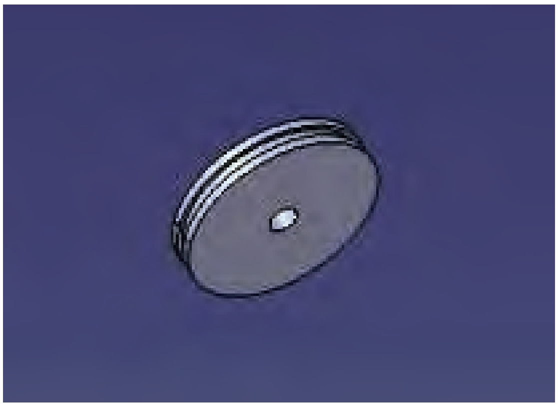

Figure 6. Pulley

F. Feeding roller

The feeding roller is used to insert the banana pseudo stem, which is placed in between operator and in front of roller drum. This roller ensures the stem is inserted fully and safety to the operator during the stem insertion in to the roller. The dimensions of roller design are 400mm in length and 50mm in width.

Figure 7. Feeding roller

G. Supporter

It is used for holding the motor on the frame. The motor is held fixed on the machine with the help of this supporter shown in figure 8. This is designed in such a manner that the vibrations occurring at larger speeds of motor does not interrupt the working of the machine and the roller drum functions smoothly during the crushing process.

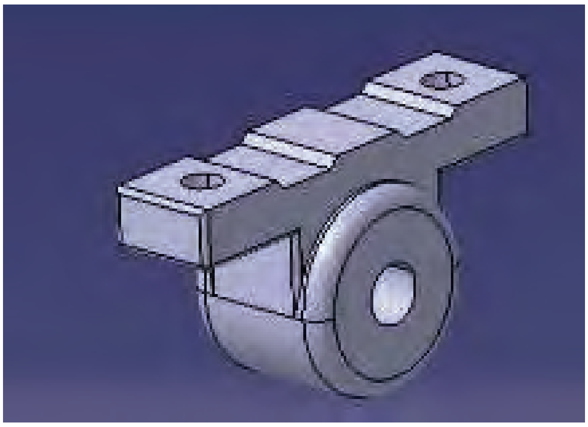

Figure 8. Supporter

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H. Roller drum

Roller or crusher is the most important elements in this machine. It provides necessary crushing load on the pseudo stem such that the pulp is separated from the stem leaving only the fiber. Type of the roller used mainly affect the quality of fiber. The standard of fiber depends on the design of the roller. When compared with square tooth roller, the crushing line saw roller separates a finer quality of banana leaf sheath. So dual saw rollers are used in this machine and one square tooth roller or rasp bar roller. The diameter, length and number of cutting blades on the roller are 300mm, 350mm and 12 blades respectively.

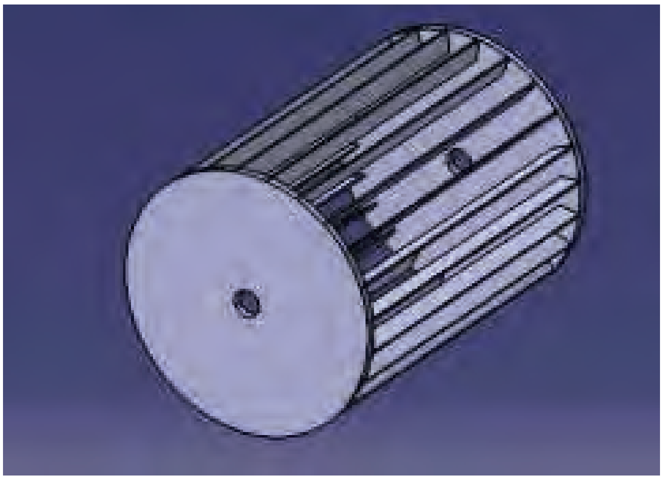

Figure 9. Roller drum

V. Assembly of Parts

Assembly of these parts to form the machine can be carried out in two formats. One of the models has the motor and roller drum placed on the frame and the length of the belt connecting these is small [3][6]. After the crushing process, the pulp must be taken away from the machine by the operator and not letting it fall on the motor. The other version of this machine has the motor placed at the bottom while the roller is placed on the top. This model offers an advantage of the pulp falling away from the motor without any human intervention. The length of the belt connection the shafts is large and hence slacking or sagging must be taken care of. Any one of these formats can be used for the construction of machine. Both give the same output with respect to the fiber extraction.

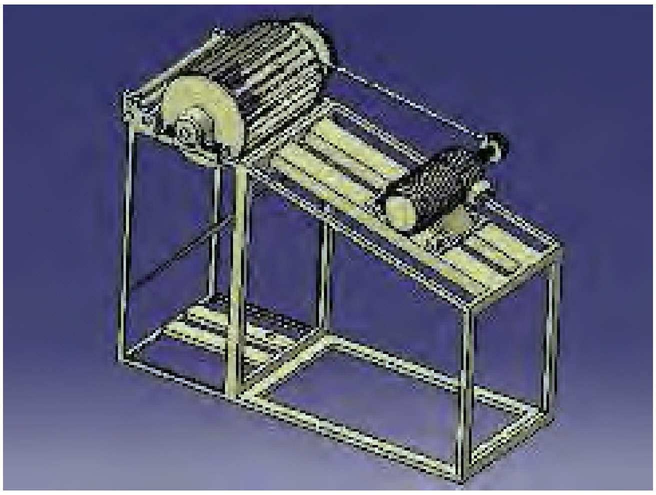

Figure 10. Assembly 1

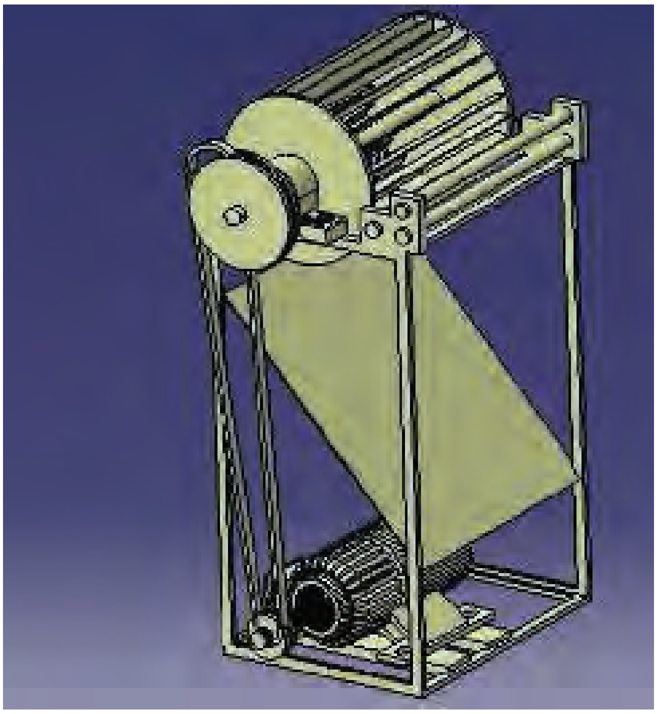

Figure 11. Assembly 2

VI. Analysis on Roller Drum

Structural analysis is carried out on roller drum as it is the part that bears maximum load during the fiber extraction process. Loads are applied on the roller at different speeds and the deformation and von misses stress are analyzed.

EN 8 carbon steel [6] with improved strength over mild steel, through-hardening medium carbon steel is used for the roller. It is also machinable in any condition. The analysis was carried out in ANSYS workbench. Figures show the deformation and von misses' effects at 1000 rpm. The analysis was also carried out at 2000 rpm and 3000 rpm.

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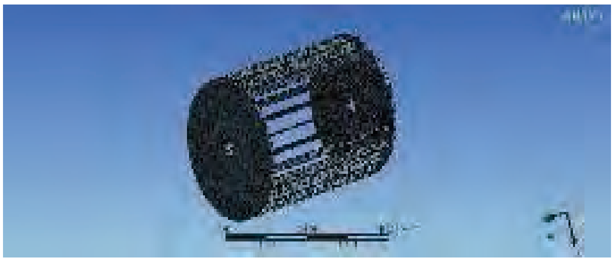

Figure 12. Meshing of roller drum

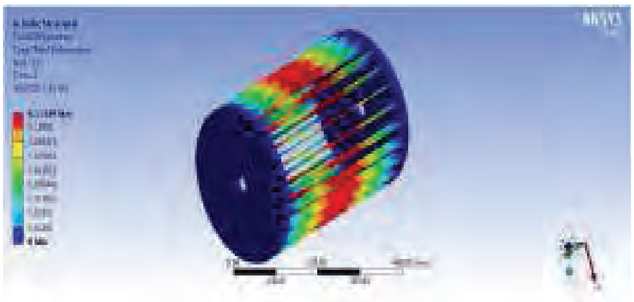

Figure 13. Total deformation

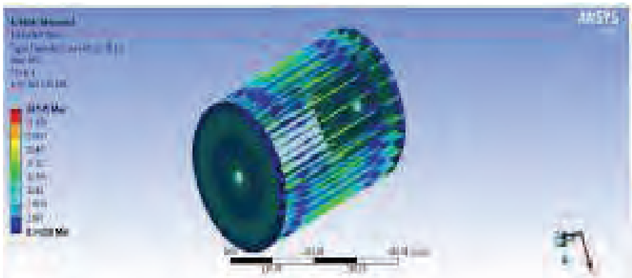

Figure 14. Von misses stress

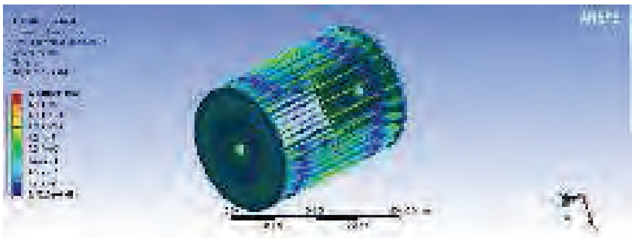

Figure 15. Von misses strain

VII. Conclusions

Table II shows the deformation and von misses stress & strain values of roller drum at 1000rpm, 2000rpm and 3000rpm. Even at high speed conditions the deformation and von misses' values are optimal, thus resulting in a good working condition of machine at heavy loads.

TABLE II.
RESULTS OF STRUCTURAL ANALYSIS OF ROLLER DRUM

Material	Speed (RPM)	Deformation (mm)	Stress (N/ mm^2)	Strain
EN 8 Steel	1000	0.11349	30.545	0.001546
	2000	0.45397	122.18	0.000618
	3000	0.66523	179.04	0.000906

The fabrication can be carried out with the same steel as it is economical and of higher efficiency. The fabrication cost is also less with the parts chosen for the machine, hence reducing the process cost. Purified form of fiber is obtained by this design and enzyme treatment can be done on the fiber for its usage directly in the production of various products. The design offers advantage in terms of compactness and easy dissembling.

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