# UNIVERSITY OF NAIROBI

COLLEGE OF ARCHITECTURE AND ENGINEERING

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

*FINAL YEAR ROJECT*

**DEVELOPMENT OF A SISAL DECORTICATOR FOR SMALL HOLDER FARMERS/TRADERS: REDESIGN, FABRICATION AND FIELD TESTING**

PROJECT CODE NO: MFO 01/2011

DONE AND PRESENTED BY:

| | |
|---|---|
| MATIRU HUMPHREY KANOGU | F18/1812/2006 |
| OSORE VIDEL ANTONY | F18/1816/2006 |
| KAMANDE JOHN KIGURU | F18/1819/2006 |

SUPERVISOR:

PROF. MOSES FRANK ODUORI

DATE: JUNE 10th 2011

## DECLARATION

We declare that this is our own original work and has not been presented in this university or any other university for examination or other purposes.

**MATIRU HUMPHREY KANOGU**
**F18/1812/2006**

Signature…………………… Date………………………

**OSORE VIDEL ANTONY**
**F18/1812/2006**

Signature…………………… Date………………………

**KAMANDE JOHN KIGURU**
**F18/1819/2006**

Signature…………………… Date………………………

**SUPERVISOR**
This design project has been submitted for examination with my approval as university supervisor.

**PROF. MOSES FRANK ODOURI**
Signature…………………… Date………………………

## DEDICATION

We dedicate our project to our Parents and the Mechanical Engineering fraternity for their sincere support in our project work.

## ACKNOWLEDGEMENT

Our gratitude and appreciation goes to our supervisor Prof.Odouri for his time and continuous guide and support.

We also express our sincere gratitude to engineers and staff of numerical machines complex for their continued support especially Mr. Musuko .

We also appreciate staffs of University of Nairobi especially technical staff of mechanical department, Yana tyres staffs and car and general staff.

Last and not least our appreciation goes to our fellow colleagues of Nairobi University for their moral support and encouragement during difficult times.

Above all our appreciation and gratitude to God almighty who enabled to do this project.

## ABTSRACT

The main purpose of the project is to analyze and modify the existing decortication prototype to meet the demands of Kenyan small scale sisal farmers i.e. to finish the design, by refining the small scale decorticator designs of previous years to the extent that they can be manufactured and tested.

The machine should be transportable and allow sufficient yields such that the sisal farmers will be better able to compete in the world sisal fibre market.

Throughout the design process, affordability, energy consumption, transportability, reliability, on-site material and assembly constraints were taken into account.

The designs chosen accomplished the project requirements by minimizing cost through material selection and ease of manufacture, and provided adjustable parameters in order to facilitate decortication quality testing.

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# CHAPTER ONE

## 1.1 INTRODUCTION

Sisal is scientifically known as *Agave sisalana*. It is a native of the Yucatan peninsula, Mexico and grows best in a hot climate and may be grown throughout the humid and sub-humid

lowland tropics.

*Figure 1.1 Sisal plantation*

It is a perennial succulent which forms an inflorescence after 6-9 years after having produced 200-500 leaves in it lifespan. The leaves are arranged spirally around the stem and on average are 120 cm in length at maturity.

It is suitable for the manufacture of several products such as ropes, sacks, bags, carpets and mats, pulp for papermaking and handicrafts. The demand for sisal worldwide is currently on the increase because it is environment friendly in comparison with synthetic fibres.

The most valuable part of the sisal plant is the fibre and therefore fibre extraction is one of the most important aspects of sisal production. A process of decortication is used to extract the fibres from the leaf tissues. Leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibres remain. For the case of large plantation decorticators, all other parts of the leaf are washed away by water. Decorticated fibres are washed before drying in the sun or by hot air. Smallholders just decorticate their sisal leaves and sell when they are still wet. This contributes to the poor quality of sisal fibre produced by smallholders. Kenya Sisal Board is now putting in efforts to encourage small-scale farmers to wash and dry their fibres to improve on their quality

Artificial drying has been found to result in generally better grades of fibre than sun drying.

The sisal industry has potential for a great future; in general the demand for sisal outstrips the supply. However sisal production is faced with a lot of problems including transportation of sisal leaves from the fields to the decorticating plants. In some areas, sisal has been planted both in large scale and small scale , but there is no adequate decortication capacity. In other areas, manual decortication is employed which is laborious, hazardous, and low in productivity producing fibre of lower quality.

## 1.2 THE PROBLEM STATEMENT

Small scale sisal farming in Kenya has experienced stunted growth due to inefficient sisal fibre processing. A majority of the small scale farmers process their sisal manually. Hand processing is a tedious, laborious and slow exercise resulting in low productivity and low quality of the fibre. Moreover, the acidic sap released during manual decortication causes skin irritation and discomfort.

*Figure 1.2 Manual decortication*

So far, attempts made to address this problem have not been successful. There is therefore the need to develop appropriate technology for decorticating sisal. The technology should be efficient and affordable. This will serve to support the revival of the industry and provide sustainable livelihood for the small scale farmers and traders.

This project design undertakes to redesign the previously made decorticator by seeking:

- To refine the small scale decorticator designs to the extent that it can be manufactured and tested.
- To evaluate the commercial viability of the resulting small scale sisal decorticator.

We endeavour to design a sisal prototype decorticator for small-scale farmers, which can be locally manufactured. The decorticator should be mobile and portable so that it can be transported from one place to another. It should also be cheaper than the available decorticators, because it is meant for small holder farmers, who cannot afford the available large automatic decorticators.

The machine should provide fibre of acceptable quality that can fetch good price in the market just as automatic decortication do.

## 1.3 THE PROJECT OBJECTIVES

- To refine the small scale decorticator designs to the extent that it can be manufactured and tested.
- To evaluate the commercial viability of the resulting small scale sisal decorticator

The scope of this project lies on the redesign of the initial prototype's designs, which involved research on the best pair of wheels for the decorticator's transportability, modifications on the prototypes frame to ensure neat merger to the wheels, design of a central pulley network connection to the engine of the machine, building a prototype and thereafter field testing the prototype to achieve the most commercially viable product.

In order to be financially practical for the Kenyan farmers, the price should be below Kenya shillings 250,000 (inclusive of tax).

# CHAPTER TWO

## 2. LITERATURE REVIEW

### 2.1 Sisal production in Kenya

The sisal industry in Kenya begun in 1907 with the establishment of the first sisal plantation at Pundamilia .From then it grew steadily ;this was witnessed by the first export to Europe in 1914 establishing sisal as a cash crop. This led to ambitious expansion in production of sisal fibres and by 1950s the number of sisal plantations had increased to fifty four, which occupied almost 120,000 hectares with exports reaching all time highs of approximately 60,000 metric tonnes per annum in 1960.This culminated in the opening of a spinning factory in 1954 to process twine, ropes, gunny bags and mats for both domestic and export markets.

The rapid growth witnessed a further culmination in the opening of a high level sisal research station at Thika in 1937 which ensured development of superior varieties, improved agronomic, management and processing practices.

Kenya Sisal Board is mandated to inspect, certify and facilitate the marketing of sisal both in the domestic and external markets. It also licenses and registers agents in the industry who may want to market their sisal.

The Sisal Board of Kenya under the Ministry of Agriculture regulates the sisal sub-sector in Kenya. The sisal industry in Kenya has largely remained an export commodity industry. The industry is mainly composed of producers, marketing agents and spinners. Currently there are about 7 sisal fibre producers involved in production and processing of sisal,as shown in the table below.

**Table 2.1: Sisal fibre producers & their locations**

| COMPANY | LOCATION |
|---|---|
| REA VIPINGO PLANTATIONS | VIPINGO – MOMBASA |
| DWA ESTATE LTD | KIBWEZI |
| TEITA ESTATE | MWATATE |
| MOGOTIYO PLANTATIONS LTD | MOGOTIO |
| KILIFI PLANTATIONS LTD | KILIFI |
| TABU ESTATE LTD | MOMBASA |
| VOI SISAL ESTATE | VOI |

Source: Kenya Sisal Board, August 2010

***Small scale sisal production***

Small scale sisal farming is a very important activity as it economically improves the living standards of small scale farmers. Initially sisal was planted along the boundaries of farms as 'hedge sisal' for fencing the homesteads, crops and as fire breakers.

In Kenya, small scale farmers are concentrated in Machakos and Kitui areas in Eastern province. Areas where some research has been carried out to establish suitability of small scale sisal growing include Machakos, Kitui, Embu, Nyanza,and Siaya and the coastal belts. According to KSB Unwashed Hand Decorticated Sisal (UHDS) production by small holders accounted for almost 25% of the total sisal production.

## 2.2 The Sisal Leaf

The plant is characterized by its leaves which grow to a length of over one metre and yield a long, creamy-white and very strong fibre. Leaves average 120cm in length and are arranged spirally around the thick stem. The leaves are 75% schlerenchyma bundles. Physical properties of sisal leaves according to the analysis by American Society of Agricultural Engineers are as follows;

**Table 2.3 Average leaf parameters:**

| | |
|---|---|
| Mass | 0.545 kg |
| Length (with spine) | 1.220 m |
| Length (without spine) | 1.196 m |
| Width (at base) | 0.07 m |
| Width (maximum) | 0.109 m |
| Thickness (maximum) | 0.022 m |
| Cross-sectional area (70 mm from butt end) | 748 $mm^2$ |

The average center of mass is 35.3% of the width-spine leaf length from the butt. The moisture content of the leaves increases more or less linearly from about 80% at the tip end to about 86% at the butt end, while the average moisture content of the whole leaf is about 83.6%. The dry fiber content averages 2.9% of wet leaf mass. Fiber strength measured using the ASTM D 3822-82 procedure gives an average values of Young's modulus as 113 $N/mm^2$ when a load is applied 150 mm from the butt end, and 213 $N/mm^2$ when a load was applied 260 mm from the butt end.

**Source:** American Society of Agricultural Engineers.

### *2.2.1 Frictional Characteristics.*

The coefficient of friction of sisal leaves is measured in two ways. One method involves placing the leaf on a panel of the test surface and tilting the panel upward until the leaf begins to slide. The second method involves measuring the force to pull a leaf across a horizontal test surface. Different levels of normal load are added to the leaves. The leaves are pulled both manually and with a mechanical drive.

The coefficient of friction results are presented in **table 2.4.**

**Table 2.4 Coefficients of static and sliding friction for sisal leaves on three different surfaces**

| Method | Galvanized Steel | Stainless Steel | Mild Steel |
|---|---|---|---|
| Tilting pane | 0.384 | 0.388 | 0.396 |
| Static coefficient (manual) | 0.489 | 0.434 | 0.426 |
| Static coefficient (mechanical) | 0.491 | 0.453 | 0.442 |
| Sliding coefficient (manual) | 0.387 | 0.385 | 0.357 |
| Sliding coefficient (mechanical) | 0.354 | 0.376 | 0.336 |

### *2.2.2 Sisal harvesting*

There has been decline in sisal production in Kenya and now there are plans to increase production. The major constraint to this increase is the labour-intensiveness of traditional sisal harvesting methods. A first "cut" or harvest is taken 24 to 36 months after field planting and harvesting then continues every six to nine months thereafter throughout the plants' remaining life. This is terminated by the plants' single flowering which sees the emergence, from the centre or "bole" of each plant, of a stalk, known as a "pole'.

Harvesting is carried out by hand. All lower leaves, standing at an angle of more than 45 degrees to the vertical, are cut away from the bole of the plant with a sharp flexible knife. Not only is the harvest labour requirement of 100 worker-hours per tonne of fibre high, but also the working requires much stooping, lifting and carrying of sizable weights, and avoidance of the sharp spines on the end of the sisal leaves.

As a result there is a shortage of harvest labour as workers prefer less strenuous and less hazardous jobs. Thus, there appears to be some potential for mechanizing part or all of the harvest operations.

### *2.2.3 Current cutting practices*

Harvesting is usually conducted twice per year with the lower, mature leaves (those inclined at greater than 45° below the vertical). First cutting of the plants can occur when the plants are 40-48 months old depending on climate and soil conditions, and a total of 50-60 leaves are removed per year. The leaf harvesting continues until the plants are 9-12 years old.

The two major areas in which mechanization may contribute to improvements in sisal harvest are those of cutting of the leaves and of collection and transport of leaves. Current practice is for each individual field worker to carry out both activities, alternating between the two every several minutes. Collection and transport of sisal leaves in the field is not unlike some already mechanized operations with other crops. Cutting and removal of leaves from the plant however, are unique and selective-type operations that have never been mechanized.

If cutting were to be mechanized it would most likely be integrated with mechanized collection and transport. However, the possibility exists for manual cutting to be combined with mechanized collection and transport. An economic model was formulated (Majaja, 1990) which linked labour wage, machine cost, annual machine use levels and various levels of partial and full mechanization. For the case of 200 days per year of machine use partial mechanization requiring 50% of the current field work force would break-even with the traditional method at a labor wage of $0.62/h if the machine cost $100,000, $0.48/h if the machine cost $50,000, and $0.24/h if the machine cost was $25,000.

### *2.2.4 Characteristics Of Sisal Fibre*

#### i. Physical properties of sisal fiber

Analysis done by Dr. Bashira A. Majaja (1990) Senior Lecturer in Mechanical Engineering University of Dar es Salaam reviewed literature relative to the physical properties of sisal fiber. Reports of the ultimate tensile strength ($\sigma_{uts}$) of the untreated fiber ranges from 169 to 640 MN/m. Fibers soaked in an alkali solution for 80 to 90 hours were reported to approximately double in tensile strength. Modulus of elasticity (E) values ranges from 2.7 to 32.9 $GN/m^2$. The elongation at the point of tensile failure ranges from 2.8 to 29.3%. Since the apparent density (ρ) of the fiber ranges from 1.125 to 1.208 $g/cm^3$ [true pore-free material density 1.369 to 1.452 $g/cm^3$], the length of a fiber of uniform cross-sectional area that can be supported against gravity (g) (breaking length) is in the range of 14 to 106km. Comparable lengths for copper and mild steel wire are 3 and 5 km, respectively.

#### ii. Morphology of sisal fibre

A single sisal filament or fibre is constructed of numerous elongated polygon shaped fusiform cells that taper at each end. These cells are referred to as ultimates, and in a fibre they are closely bonded together so that there are no intercellular spaces. The ultimate of sisal fibre range from 1.5-4mm in length and are mostly 3mm long. In breath they vary from 20 to 30 micrometers (µm)and thus each ultimate is many times longer than its width.

**iii. Number and types of fibre in sisal leaves.**

Ribbon fibres; crescent shaped and protect the vascular bundles or conducting vessels. Those in the median line extend through the entire leaf and finally coalesce to form the tip spine. Mechanical fibres; horse shoe-shaped, or near circular and reinforce the structure of the leaf. As a general rule a sisal leaf contains from 1000-1200 fibres of which a quarter are ribbon and three-quarter are mechanical fibres.

The number of ribbon fibres in the median line is remarkably constant irrespective of the size of the leaf and vary from 45-50 per leaf.

**iv. Distribution of fibre within a sisal leaf**

The number of fibres diminishes from the butt end to the tip of the leaf. Decortication of the butt end gives rise to higher losses of fibre than scotching the blade of the leaf, more so if the blade is decorticated first because the fibres are still imbedded and held firmly at one end of the thick butt end tissues. Thus the suggestion that fibre losses during decortication may be reduced considerably if scotching was confined to laminar portion of the leaf only and a short length of the thick butt end was cut off afterwards.

### *2.2.5 Fibre Grading*

In East Africa, sisal fibre is sorted and sold under certain grades which have been defined by the East African Sisal Grower's Association and the London Sisal Association with effect from 1st December, 1995 as follows:-

**Grades**

***NO. 1*** Length from 3ft. upwards with an average of 3ft. 6in.Free of defective decortications. Properly brushed, free of tow, tousled and bunchy ends, knots and harshness. Colour: creamy-white to cream.

***NO. 2*** Length from 2ft. 6in. upwards. Free of defective decortication. Properly brushed, free of tow, tousled and bunchy ends, knots and harshness.
Colour: Creamy- white to cream.

***NO. 3*** Length from 2ft. upwards. Brushed fibre with minor defects in cleaning permissible, but it must be free of tow, knots, barky or undecorticated fibre. Colour may vary from creamy-white to yellowish but a higher proportion of spotted or discoloured fibre is permissible than for Grade A.

***3L*** (3 Long). Length from 3ft. upwards. Brushed fibre with minor defects in cleaning permissible, but must be free of tow, knots barky or undecorticated fibre. Colour may vary from creamy-white to yellowish but a higher proportion of spotted or discoloured fibre than for Grade A.

***UG*** (Under Grade). Fibre that does not conform to the above mentioned grades as regards colour, cleaning and length. Although defects in cleaning are allowable and some imperfectly decorticated fiber or barky runners are permissible, it must be free from undecorticated leaf and knots. Length must not be less than 2ft.

***S.C.W.F*** (Short Clean White Fibre). Length ranges from 18inch to 24inch free of defective decortication. Properly brushed, free of tow, tousled and bunchy ends, knots and harshness. Colour: creamy-white to cream.

### *2.2.6 Uses Of Sisal Fibre*

Traditionally sisal was the leading material for agricultural twine ('binder' and' baler' twine) but the importance of this is now tending to diminish (with competition from propylene and other techniques) although there is still a major business between Brazil and the United States.

Apart from ropes, twines and general cordage sisal is used in both low cost and specialty paper, dartboards, buffing cloth, filters, geo-textiles, mattresses, carpets, wall coverings, handicrafts and macramé.

In recent years sisal has been utilized as a strengthening agent to replace asbestos and fiberglass and is increasingly a component used in the automobile industry, where its strength, "naturalness" and environmentally friendly characteristics are greatly appreciated.

### *2.2.7 Overview Of The Various Alternative Uses Of Sisal Fibre*

Development of new uses and markets in recent years has reversed the trend. The new uses include the manufacture of composite, particularly for manufacture of interior motor vehicle panels to replace glass fibre, manufacture of gypsum blocks for building and specialty paper.

With entry of these new products in to the market in the early 1990s, the trend changed with demand and prices for Sisal fiber rising gradually. In the late 1990s, introduction of new uses (products), markets and application of improved production and processing techniques further accelerated the rise in demand. Research is now at an advanced stage to introduce Sisal fibre in manufacture of geo-textiles

Research in improved production and processing systems including propagation of sisal using meristematic tissue culture, and harmer mill extraction technology in addition to the conventional decortication has greatly enhanced production and quality of sisal fibre as well as improved soil and environmental conservation.

Research is also at advanced stage to use Sisal extraction waste in bio-energy generation, livestock feed as well as organic fertilizer. This enhanced interest and investment in Research and Development (R&D) will enhance production, efficiency, and quality of Kenya's Sisal fibre.

# CHAPTER THREE

## 3. DESIGN OF THE SISAL DECORTICATOR

### 3.1 HISTORY OF DECORTICATORS

When sisal fibre was found to be useful, methods of extraction of fibre from the leaf started to be developed. First, fibres from leaves of Agave were extracted by hand. However, these methods originally practiced in Mexico were primitive, slow, inefficient and laborious.

The raspador principle is attributed to a Franciscan Monk named Ceron. It is said that Padre Ceron took pity of the peasant farmers in 1939 by removing a wheel from his buggy to which he attached some rough knives and placed it on an iron bar so that it could be turned by hand for scraping the leaves.

This had been preceded by the invention of German engineer Hubert J.Boeken of the earliest wholly automatic sisal decorticator in 1906 in Europe. His model was called "Viktor" and employed a cross feed principle, with the raspador drums on opposite sides of the machine in contradiction to the American design. The introduction of automatic decorticators led to great increase of quality and volumes of sisal produced. The modern automatic decorticator has been brought to a high pitch of efficiency by Swiss sisal engineers who made many useful modifications after gaining experience working with the machines in East Africa.

However, automatic machines are very expensive and can only be afforded by the large sisal estates. They also require electricity to operate which is not available in many rural areas where sisal is grown and cannot be powered by other available energy sources.

### *3.1.1 Types of decorticators.*

Decorticators can be divided into two major groups:

- Automatic decorticators
- Raspador.

Automatic sisal decorticators are usually used for the production of sisal fibres on large sisal plantations. The following figures describe the difference between the raspador and automatic decorticator leaf feeding mechanism.

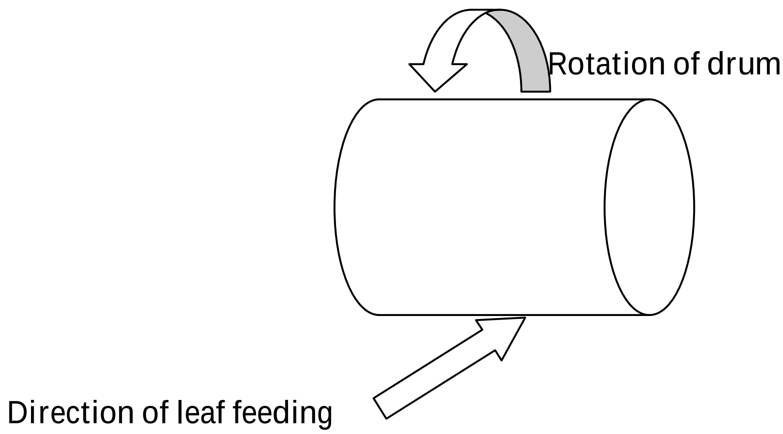



**Fig 3.1 Sidewise or Lateral leaf feeding in a sisal raspador.**

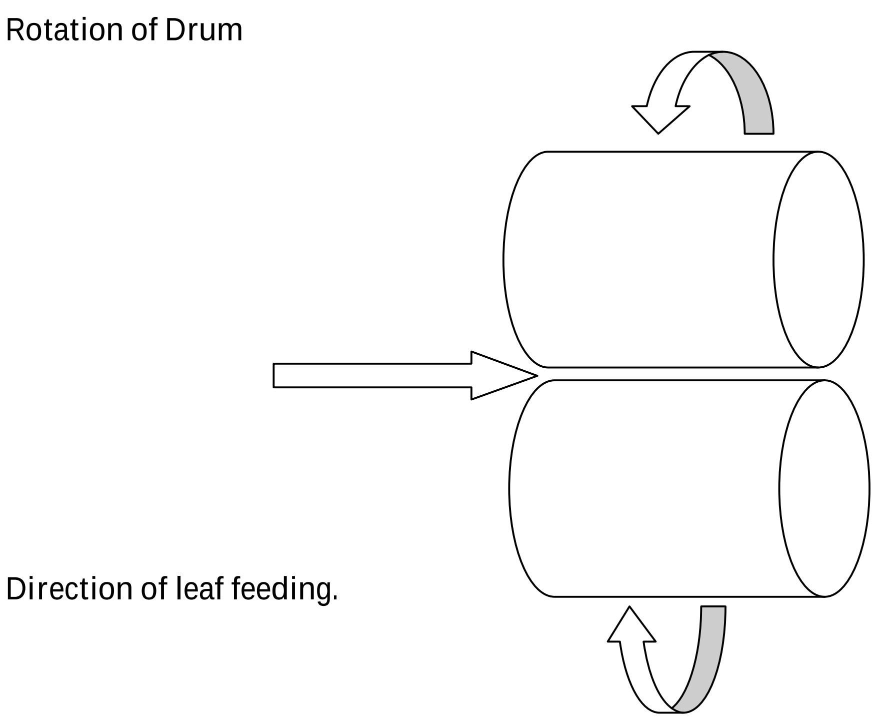



**Fig 3.2 Longitudinal leaf feeding in an automatic sisal decorticator.**

### 3.1.2 Raspador

Sisal leaves are fed end wise and fibres are produced through the nibbling action of raspador. This is then followed by scrapping upon withdrawal of the leaf or fibre in the reverse direction.

The leaves are fed into the machine by hand, butt end being presented first because of the need to thrush the thick end through the narrow gap between the breast plate and downward revolving knives .After the leaf has been pushed for haft of its length, it is then withdrawn and exposed fibres are grasped so that the tip-end of the leaf can be decorticated in a similar manner. As a leaf is introduced, the knives progressively smash and chip off the leaf tissue at closely spaced intervals against the breast plate and only a few centimeters or even millimeters of the leaf is decorticated at any one moment.

The crushed portion continues to be beaten for as long as the leaf is inside the raspador and when the leaf is withdrawn, knives commence to act as scrapers, removing the leaf pulp down the length of the bundle. Many of short fibres are whisked away out during the first stage before the leaf is reversed for the tip half to be treated. In addition, a few of the long fibres may be lost owing to grip on the slippery fibres being more tenuous than that on the leaf itself. Frequently a whole leaf may be lost as it may be pulled out of the operator's hand, particularly during the second stage. Fibres may be washed either in the raspador or in a tank soon after decortication.

### 3.1.3 Description of the raspador.

One design of raspador has been described mainly as a strong cast -iron wheel, of 1 metre in diameter having a broad flat rim that is 28 mm in width to which are bolted sixteen iron angle bars or beater knives equally spaced on the periphery of the wheel. The wheel is fastened onto a horizontal shaft which is mounted on the bearings that are in turn fixed onto a firm base. An adjustable concave breast plate of about 83 mm long and 28 mm width is attached to the framework about 800 mm from the ground so that its top is level with the main shaft and it covers the lower quadrant of the circumference of the wheel. The distance between the breast plate and the knives is regulated so as to give clean decortication without undue strain on the leaves and the fibres.

***Kinematical Considerations***

In the actual raspador working head, the beater drum rotates uniformly about a fixed axis of rotation while the sisal leaf is fed to the beater drum. If it is assumed that the leaf is fed to the beater drum at a uniform rate then the relevant kinematics of the working head may be successfully modeled by considering the leaf to be stationary and the beater drum to be rotating uniformly about an axis that advances uniformly towards the leaf. This is illustrated in **Fig. 3.3**, in which O is the origin of a fixed Cartesian frame of reference.

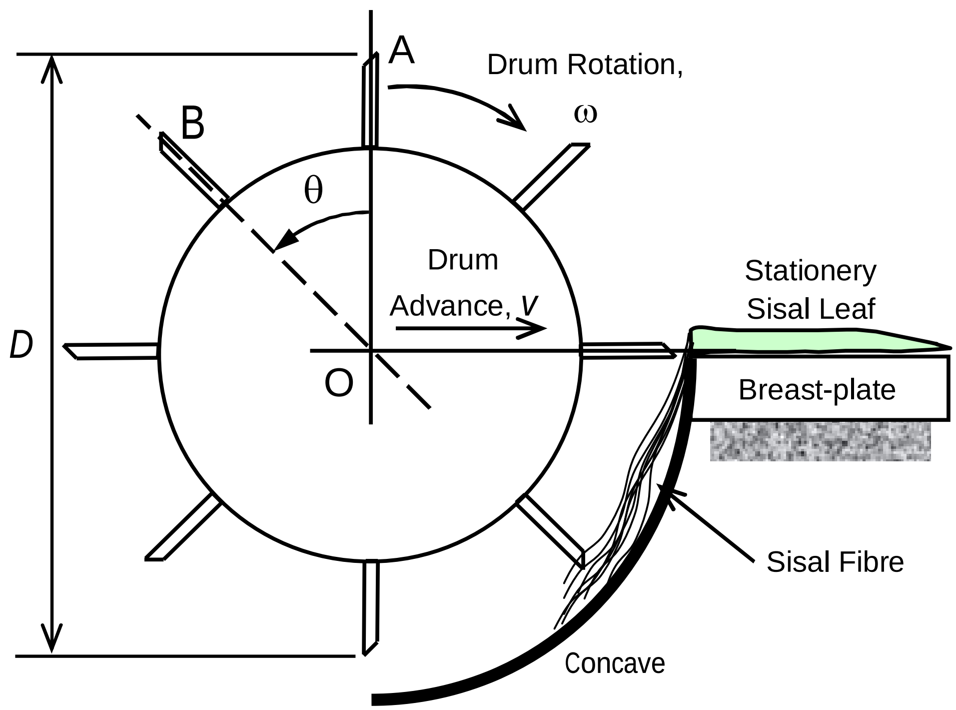



**Fig 3.3 Kinematical Model of the Raspador Principle**

From **Fig 3.3**, it should be evident that:

$$n = \frac{2\pi}{\theta} \qquad (3.1)$$

Where *n* is the number of blades on the beater drum and $\theta$ is measured in radians.

Moreover, if **Fig 3.3** illustrates the beater drum at the initial moment of consideration, then, at a subsequent moment in time, *t*, the positions of the tips of the two successive beater blades, A and B, will be given by the following parametric equations:

$$\left.\begin{aligned} x_A(t) &= vt + \frac{D}{2}\sin(\omega t) \\ y_A(t) &= \frac{D}{2}\cos(\omega t) \end{aligned}\right\} \qquad (3.2)$$

and

$$\left.\begin{aligned} x_B(t) &= vt + \frac{D}{2}\sin(\omega t - \theta) \\ y_B(t) &= \frac{D}{2}\cos(\omega t - \theta) \end{aligned}\right\} \qquad (3.3)$$

Now let us introduce the following notations, for convenience:

$$R = \frac{D}{2}; \quad R_0 = \frac{v}{\omega} \qquad (3.4)$$

Then equations (3.2) and (3.3) may be re-written as follows:

$$\left.\begin{aligned} x_A(t) &= R_0\omega t + R\sin(\omega t) \\ y_A(t) &= R\cos(\omega t) \end{aligned}\right\} \qquad (3.5)$$

and

$$\left.\begin{aligned} x_B(t) &= R_0\omega t + R\sin(\omega t - \theta) \\ y_B(t) &= R\cos(\omega t - \theta) \end{aligned}\right\} \qquad (3.6)$$

The trajectories traced by the tips of the two successive blades, A and B, are illustrated in **Fig. 3.4** below, for half a rotation. An important kinematical parameter of the beater drum will be termed the *pitch* of the drum, denoted $p$, and illustrated, in **Fig. 3.4**. If the tip of blade A first crosses the $x$-axis at time $t_1$, then

$$\left.\begin{aligned} y_A(t_1) &= R\cos(\omega t_1) = 0 \\ \cos(\omega t_1) &= 0 \\ \omega t_1 &= \frac{\pi}{2} \end{aligned}\right\} \tag{3.7}$$

It follows from equations (3.5) and (3.7) that:

$$x_A(t_1) = \frac{\pi R_0}{2} + R \tag{3.8}$$

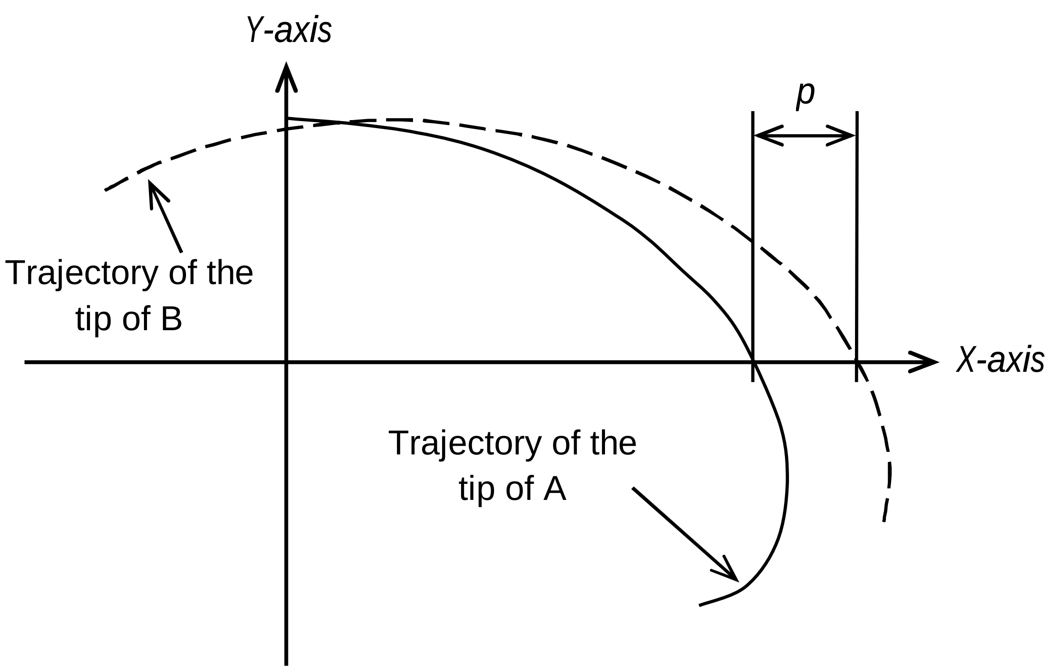



**Fig. 3.4 Trajectories of the Tips of the Beater Blades**

Moreover, if the tip of blade B first crosses the $x$ – axis at time $t_2$, then

$$\left.\begin{aligned} y_B(t_2) &= R\cos(\omega t_2 - \theta) = 0 \\ \omega t_2 - \theta &= \frac{\pi}{2} \\ \omega t_2 &= \frac{\pi}{2} + \theta = \frac{\pi + 2\theta}{2} \end{aligned}\right\} \tag{3.9}$$

Accordingly:

$$x_B(t_2) = \frac{R_0}{2}(\pi + 2\theta) + R \tag{3.10}$$

Thus:

$$p = x_B(t_2) - x_A(t_1) = \theta R_0 \tag{3.11}$$

From equations (3.1), (3.4) and (3.11), it is evident that:

$$p = \frac{2\pi v}{\omega n} \tag{3.12}$$

The pitch, *p*, represents the quantity of cortex (leaf tissue) material that is scraped off every time a beater blade interacts with the sisal leaf. If *p* happens to be too large then the resulting decortication would be incomplete. On the other hand, if *p* happens to be too small then the resulting sisal fibre would be far too "beaten" by the beater blades, thus spending energy unnecessarily and possibly damaging the fibre. Thus, the appropriate value of *p* would have to be carefully determined, through experimentation.

It is interesting to note that the value of *p* does not depend on the diameter of the beater drum at all. Thus, if the number of blades on the beater drum and the rate of feeding the leaf to the beater drum are predetermined, *p* may be varied merely by varying the angular speed.

On a small engine-driven portable decorticator, the engine (power source) would be the single most expensive component of all, hence the opportunity for substantially cutting the price of the machine through careful selection of the power source. On the other hand, the forces involved in decortication are not expected to be so large as to cause serious problems relating to structural integrity. Thus, kinetic modeling will be concerned, in the main, with determination of decortication power requirements.

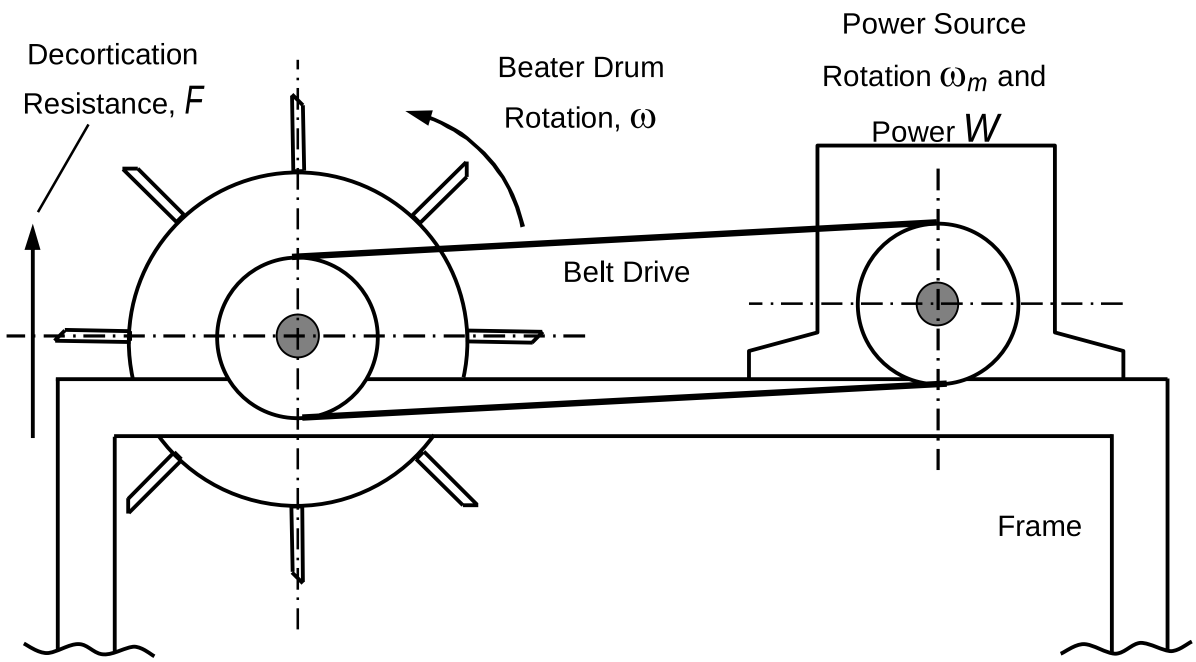



**Fig. 3.5 – Kinetic Model of the Decorticator Drive Train**

In **Fig. 3.5** above, decortication resistance is probably a function of time *t*, beater drum rotational speed , and clearance, *c*, between the beater blades and the breastplate. Thus we may write:

$$F = F(t, \omega, c)$$

However, if the values of □ and *c* are pre-selected, then *F* is expected to vary significantly only with respect to time. Thus, for a given time interval between $t_1$ and $t_2$, the energy, *E*, expended in decortication may be expressed as follows:

$$E = \int_{t_1}^{t_2} \omega \frac{D}{2} F(t)\mathrm{d}t = \frac{\omega D}{2} \int_{t_1}^{t_2} F(t)\mathrm{d}t \qquad (3.13)$$

Now, from the mean-value theorem of the integral calculus, for continuous functions, it follows that:

$$\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} F(t)\mathrm{d}t = F_e \qquad (3.14)$$

In equation (3.14), we may regard $F_e$ as an average or effective decortication resistance, which will be constant with respect to time. The average power expended over the time interval between $t_1$ and $t_2$ may be expressed as follows:

$$W = \frac{E}{t_2 - t_1} = \frac{\omega D}{2(t_2 - t_1)} \int_{t_1}^{t_2} F(t)\mathrm{d}t = \frac{\omega D F_e}{2} \tag{3.15}$$

Now, let the speed ratio of the belt drive be

$$G = \frac{\omega}{\omega_m}$$

Then the average power may be expressed as follows:

$$W = \frac{\omega_m G D F_e}{2} \tag{3.16}$$

In equation (3.16), $F_e$ would not be in the control of the design engineer, but, as we have seen earlier, this quantity is expected to vary with both $\omega_m$ and $c$. Thus, if $D$ and $G$ are predetermined, an experiment may be set up in which $\omega_m$ and $c$ may be varied, and the power consumed measured so as to determine the minimum power requirement that will give good decortication, since as $\omega_m$ is varied so will $p$ and hence the quality of decortication vary.

### *3.1.4 Automatic Sisal Decorticators*

**Fig. 3.6 Automatic sisal decorticator**

Most automatic decorticators consist of two covered drums located at right angle to, and offset on opposite sides of a central line along which the sisal leaves are conveyed and fibres are delivered after decortication.

Leaves are fed to automatic machine cross-wise unlike end-wise feeding in the raspadors. In cross-wise feeding the throughput is increased and a moderate automatic machine can process up to about 25000 leaves (10 to 20 tons of leaves) in an hour with a remarkable efficiency. Decortication takes place in one swoop in a single direction only along the fibre so that leaf tissue is crushed and scraped off the fibre on a continuous swoop as opposed to the nibbling action of the raspador which is followed by scrapping upon withdrawal of the leaf in the reverse direction. Feeding leaves into the machine sideways is an enormous advantage since they go through at a much faster rate than if the leaves are fed end -wise, as is the case with the raspador.

One of two drums of automatic sisal decorticators is designed for decorticating tip end while the other for butt- end decortication. Each drum functions in conjunction with a concave breast plate, the length of which normally extends for a quadrant of the drum wheel .The diameter of drum wheel varies according to length of portion of the leaf that it is intended to process. Beater knives which are fitted to the periphery of the drum wheels are rounded or tapered on one side so as allow for thickness of leaves to enter side ways.

A system of endless ropes which run over ropes wheel "sheaves" hold the leaves and function to convey them past each beater drum in turn . The drum wheel has a flange or "a combing ring" on the exit side to facilitate emergence of fibres.

There are two patterns of decorticators, depending upon order of decorticating the tip-ends or butt-ends of leaves.

In the first pattern leaves are held about the central point by rope gripping device, and the butt-ends are presented to the first drum, which decorticate about 30 to 40 cm of the length of each leaf. Next the rope grip is released on the undecorticated part and is transferred to freshly exposed fibre in order that the tip-ends may be decorticated in second drum on the other side of conveying ropes; this drum is a little bigger than the first one. Drums diameters are about 123 cm and 160 cm for smaller and bigger respectively. Finally completely decorticated fibre comes out as glistering wet tresses draped over delivery ropes.

Advantages of this type of decorticators are:

- It is possible to grip leaves firmly while the thick butt-ends are being decorticated.
- Furthermore load on machine is more or less equalized by that of the second drum of the opposite side dealing with longer tip-halves; together this contributes towards balanced running.
- There is less risk of fibres being pulled out in second drum when grip on decorticated portion is more slender because tugging action is not so severe.

However many fibres in butt- ends that are shorter than 30 cm or so ,which are not gripped by the ropes are liable to be whisked out by first drum and lost in waste effluent. 'Corona No 2' model is a well known example of this type.

In the second type of automatic decorticator pattern leaves are gripped at their butt-ends, and as much as possible of the length of each leaf is decorticated first in first drum. The first drum has a diameter of 2 m and is considerably larger and heavier than second drum which is only 122 cm in diameter because its function is solely to decorticate the remaining short butt-ends of leaves.

Theoretically the new arrangements of the drums represent an advance in design because fibres are decorticated in right direction in the first drum that is towards the tip- ends for almost their entire length, except for a short section at the butt-ends and for this reason they are not pulled out such as happens when butt-ends are decorticated before tip-ends. In practice few fibres are lost apart from a small number that may get broken. 'Corona No 4' model is the earliest of several makes which is an example of this pattern

# CHAPTER FOUR

## 4 MODIFIED DESIGN OF SISAL DECORTICATOR

## 4.1 THE DECORTICATOR PARTS

### *4.1.1 Beater Drum*

The beater drum consists of a cylinder, beater blades, end cover plates, hub and a shaft. The cylinder is made up of a standard mild steel pipe with an external diameter of 457.2mm, length 655 mm and thickness 5mm. The cylinder can also be made by rolling a plate to specified dimensions 457.2mm by 5mm .The blades are mounted on the cylinder circumference and the leading edge of the blades should be slightly rounded (blunted), so as to avoid damage (cutting) of the leaves.

The drum shaft is to be machined from common shaft material available. Based on the cost, mild steel was chosen as the preferred choice. The dimensions of the shaft are 35mm diameter and 975mm length.

The hub is made of cast iron of external diameter 70, internal diameter 35mm and length70mm .It was slid over the shaft during assembly and welded to the cover plates. A bolt of M8×1.5 was used to take up the slack where the resulting friction provides resistance to axial motion.

A handle is provided for the drum cover for ease of opening.

### *4.1.2 Belt selection*

A belt drive system was chosen to allow the drive system to slip without affecting the engine torque as opposed to a chain drive. The engine pulley diameter was chosen as 56.25mm, while the beater drum pulley was chosen as 135 mm, which gives a gear ratio (135/56.25) of 1: 2.4 and the approximate belt length was chosen to be 173 inches.

This was after considering the speed of engine as an average of 2400 rpm and that of drum as 1000rpm.

Vee –belt was chosen for the coupling of the power system and the beater drum. The criterion used in the selection of the vee -belt is as below:-

| Belt section | Width ,inches (a) | Thickness ,inches(b) | Minimum sheave diameter (inches) | Hp range , for one or more belts |
|---|---|---|---|---|
| A | $\frac{1}{2}$ | $\frac{11}{32}$ | 3.0 | 0.25-10 |
| B | $\frac{21}{32}$ | $\frac{7}{16}$ | 5.4 | 1-25 |
| C | $\frac{7}{8}$ | $\frac{17}{32}$ | 9.0 | 15-100 |

Since the source of power is a 5.5 horsepower engine, the belt section B is chosen because A has a smaller sheath diameter. If C-is the centre distance between the beater drum and the engine system i.e. 608mm long, obtained from measurements and calculations, $L_p$-pitch length of the belt, *D*- Beater drum pulley diameter and *d*- the Engine pulley diameter, then the following formulae are used for the calculation of the belt pitch length required.

$$L_p = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C}$$

$$L_p = 2 \times 608 + \frac{\pi(135+56.25)}{2} + \frac{(135-56.25)^2}{4\times 608}$$ = 4412 mm or 173.7 inches.

From the standard belt sizes, the closest size to the above calculated value is 173 inches which is then chosen as the size of belt required for this design.

Contact angle of the pulley and belt is chosen as 160 degrees

#### *4.1.3 Engine Pulley selection*

The thickness of pulley is to be chosen as 50mm since length of engine shaft is 56mm Internal diameter of engine pulley is 20mm with a key way of 56mm and 4mm deep groove.

#### *4.1.4 Engine mounting*

The engine will be mounted at the base of the back part of the decorticator with a conveyor belt transmitting power to the beater drum. The conveyor system is enclosed by a sheet metal. The engine is mounted on a flat plate of 320mm by 300mm from the wheels. The plate has elliptical holes. Welding is used to join Engine plate to the frame. M8 bolts are used to mount the engine and these holes are in the shape of the engine base.

#### *4.1.5 Anvil*

Considering the cost, the anvil is made from cast iron of 760 mm by 80mm by 25mm; the anvil still has filleted edges of 2mm so as to prevent damage to the leaf during decortications. Phosphor-bronze can be used since it is resistant to corrosion but it is expensive. Three slots have been made on the anvil to provide room for adjusting the gap clearance which is in line with the inlet cover.

#### *4.1.6 Chute*

It is used for disposal of waste products during decortications of the sisal. It is made up of 2mm thick hot rolled iron sheets to specifications as provided in the design drawings. This is designed in such a way that the waste products will easily be ejected during decortications.

#### *4.1.7 Protective Cover*

The drum protective cover is made of 2mm thick hot rolled iron sheets according to the specifications as provided in the design drawings. The purpose of the cover is to shield the worker from the rotating members of the beater drum as well as the acidic sap. To ensure the safety of the workers, a handle is also placed on the protective cover for ease in removing the cover which has two slots for the feeding process.

#### *4.1.8 Mobility and Stability*

A pair of wheels of dimension 195/ Yana kazi 70/R15 available at Sameer Africa Company were chosen with a coupling in front for towing using pickup or other means. The diameter of the wheel used is 614mm (standard wheel).

A rim of four lugs is used with 15" diameter. Mobility is also improved by use of two adjustable stands for mounting the decorticator on uneven terrain on the field.
Two supports are provided for at the front side of decorticator. The dimension of this rectangular support are 100mm by 100mm and 10mm thick .A rectangular bar of length 50mm by 50mm and height of 505mm is used. Holes are drilled on this support at a distance of 50mm apart. This stand adjust machine according to the terrain adjust and at the bottom, a metal plate of dimensions *100mm×100mm* and a thickness of *10mm* is used to enhance stability of the prototype.

### *4.1.9 Bill of Materials*

| Item number | Item description | quantity | Specifications |
|---|---|---|---|
| 1 | Beater drum | 1 | Circular hollow steel section, 457.2mm diameter, length 655 mm and 3mm thickness |
| 2 | Beater blades | 10 | L-bar of 40mm by 40mm by 5mm cross sectional dimensions equal length s of 655mm |
| 3 | Frame | 1 | Mild steel L-bars of 50mm by 50mm by 5mm cross sectional dimensions. |
| 4 | Anvil | 1 | Cast iron rectangular bar ,760mm by 80mm by 25mm with the top filleted edges of 2mm. |
| 5 | Beater drum protective cover | 1 | Hot rolled iron sheet, 2mm thickness developed as per design drawings. |
| 6 | Pulley and belt protective cover | 1 | Hot rolled iron sheet, 2mm thickness .developed as per design drawings. |
| 7 | Chute | 1 | Hot rolled iron sheet, 2mm thickness .developed as per design drawings. |
| 8 | Beater drum hubs | 2 | Circular steel bars 70mm external diameter, 35mm internal diameter and 70mm in length |
| 9 | Wheels | 2 | Wheels of dimensions 195/ Yana kazi 60/R14 (195mm width Yana kazi aspect ratio 60,Radial type of rim 14" and nominal diameter of 640mm ) |
| 10 | IC Engine | 1 | Approximately 5.5 horse power I.C engine. |

### *4.1.10 Weight Considerations*

The weight of the decorticator was estimated by calculating the volume of the parts used and using the density in the construction to approximate the mass and hence its weight. Density of mild steel is 7860kg/m$^3$ and acceleration due to gravity is 9.81m/s$^2$ .The angle bars used to construct the frame are *50mm×50mm×5mm* and the beater blades were *40mm × 40mm×5mm*, therefore the weight of the frame of the modified prototype is given by;

Weight= $6.36\times10^{-3}m^3 \times 7860 \times 9.81 = 490.4N$
Mass= 50 kg

The weight of the other parts and components are calculated as below.

- **The drum cover**

Weight = (volume ×density) ×9.81= ($5.4524\times10^{-4}$ × 7860) × 9.81=42.04N

- **The beater drum**

Weight = (volume ×density) ×9.81= ($8.0412\times10^{-3}$ ×7860) ×9.81=620N

- **Feed frame**

Weight= (volume × density) ×9.81 = ($9.52\times10^{-5}$ ×7860) ×9.81 = 7.34N

- **The chute**

Weight = (volume ×density) ×9.81= ($3.89s64\times10^{-3}$ ×7860) ×9.81=300.4N

- **Belt cover**

Weight = (volume ×density) ×9.81= ($1.\ 54128\times10^{-3}$ ×7860) ×9.81=118.84N

- **Drum pulley**

Weight = ($8.02\times10^{-4}$ ×7860) ×9.8 =61.8N

- **Engine pulley**

Weight = ($1.17\times10^{-4}$ ×7860) ×9.81 =9.02N

- **The anvil**

Weight = (volume ×density) ×9.81= ($9.32^{-3}$ ×7860) ×9.81 =7.19N

- **The I.C engine**

**Figure 4.1 -5.5 H.P engine**

The mass of the I.C engine, shown in the picture above, used is given as;
Dry weight =15.3kgs

Weight =15.3×9.81=150.1N

The total weight of the machine is given by:

Total weight = (490.4+42.04+620+7.34+300.4+118.84+9.02+61.8+7.19+150.1)=1807.13N

=184.21Kg

In this calculation chamfers, small holes and bolts holes have been considered to be of negligible volume thus weight.

***4.1.11 Power Requirement***

The source of power can either be a motor powered by electricity or by use of an internal combustion engine. This design is based on the internal combustion engine as the source of power because most of the areas where sisal is grown in small scale do not have access to electricity. The design incorporates the decortications of two leaves at a time to maximize the power available. From previous tests, the power to decorticate one leaf for optimum fibre quality was 1400 watts; the corresponding idling power for good quality decortications was 800watts.

The power required to decorticate 1 leaf =total power –idling power

=1400watts-800watts

=600watts.

The power required to decorticate 2leaves is given by;

Decorticating power = (no. of leaves× power per leaf) +idling power

= (2×600) +800

=2000wts

From the above analysis, an internal combustion engine of approximately 3 horsepower is recommended for driving the decorticator however a 5.5 horsepower engine was provided for this design

### *4.1.12 Gap and Speed*

Based on the observation and tests carried out for each speed at a given gap clearance, the results were analyzed and it was observed that good decortication was achieved at a speed range of 950rpm to 1165 rpm.

Speed lower than these speed ranges were observed to produce decortication of poor quality with leaves retaining more flesh after decortication and at speeds higher than the given range, the decortication greatly improved though fibre cutting was evident resulting in loss of fibres.

The optimum gap at the specified speed was 2-3mm; however this is adjustable according to the size of the leaf and the desired fibre grade.

### *4.1.13 Operational description.*

The machine operator turns on and starts the engine. When the machine attains optimum speed, the operator inserts two leaves simultaneously into the decorticator feed tray with the sisal end butt first while still holding the tip ends.

The already rotating decorticator blades then comes into contact with the leaves thus stripping the fibre against the breast plate for at least half the length. Then the operator pulls the leave out and inserts the tip ends which are also decorticated.

The decorticator can be shut off by switching off the engine. In the order to prevent the possibility of operator injury while running the decorticator, the feed tray has an opening just enough for the sisal leaf, thus making sure the operator cannot come into direct contact with the spinning blades.

Testing of the decorticator to determine if any other hazards exist as well as the amount of time it takes for the cylinder to stop following full speed operation can only be done during field testing and the results obtained can dictate the necessity of additional braking system.

#### *4.1.14 Design Improvements*

A primary improvement is the ease of transportation achieved through use of large wheels and the modifying of the frame such that towing is possible. The original design had two wheels but they were too small for the machine to be transported in a rugged terrain. There was thus the need to improve on their size in order to enable the machine to be transported in rather uneven terrain. The frame design had no provision for towing in case a need arose. The machine was very heavy for hand transport and thus there was the need to provide an easier means of transport.

Additionally, the engine which is the source of power for the machine was moved from its place below the rotating cylinder to the rear base of the machine where the wheels were also mounted. The mounting of engine was done in such away that the pulley and belt drive system gave the necessary gear train ratio of approximately 1: 0.417

Another significant change made as compared to the original design was the use of nuts and bolts in most of the components as compared to welding. This will be of great help in assembly of the machine and dismantling in case of a major or minor repair to any of the constituent components. This is also of great help to future redesign works on the project, by providing unlimited access to the components. The limitation, however, is that the initial assembly time is much increased not forgetting the added cost of materials.

#### *4.1.15 Bolt design*

Key parts in the design to be welded are: the main beater cylinder and shaft, the towing frame and the decorticator box. Parts that are to be bolted in place include the breast plate, beater cylinder bearings, engine, beater blades, wheels and sheet metal protective cover. As previously designed, the cylinder blades were made removable by using M8×1.5 bolts and spring washers

Property class of the bolt is 9.8 tensile strength of 900Mpa and yield stress of 720Mpa

The manufacturing techniques to be used in this design cover a wide spectrum of processes, from welding, milling to lathe work. Much of the frame construction utilized standard cutting and welding for assembly.

#### *4.1.16 Towing system design*

A horizontal towing system is used with a hook of outer diameter 100mm and inner diameter of 60mm is used .the length of towing system from the frame is 1311mm.

## 4.2 TRANSPORTABILITY

### *4.2.1 Tyre Types*

There are several different types of tyres that one can buy, depending on:

- The use,
- Place of residence
- Preference and a variety of other factors.

The different classifications and some representative are as follows:

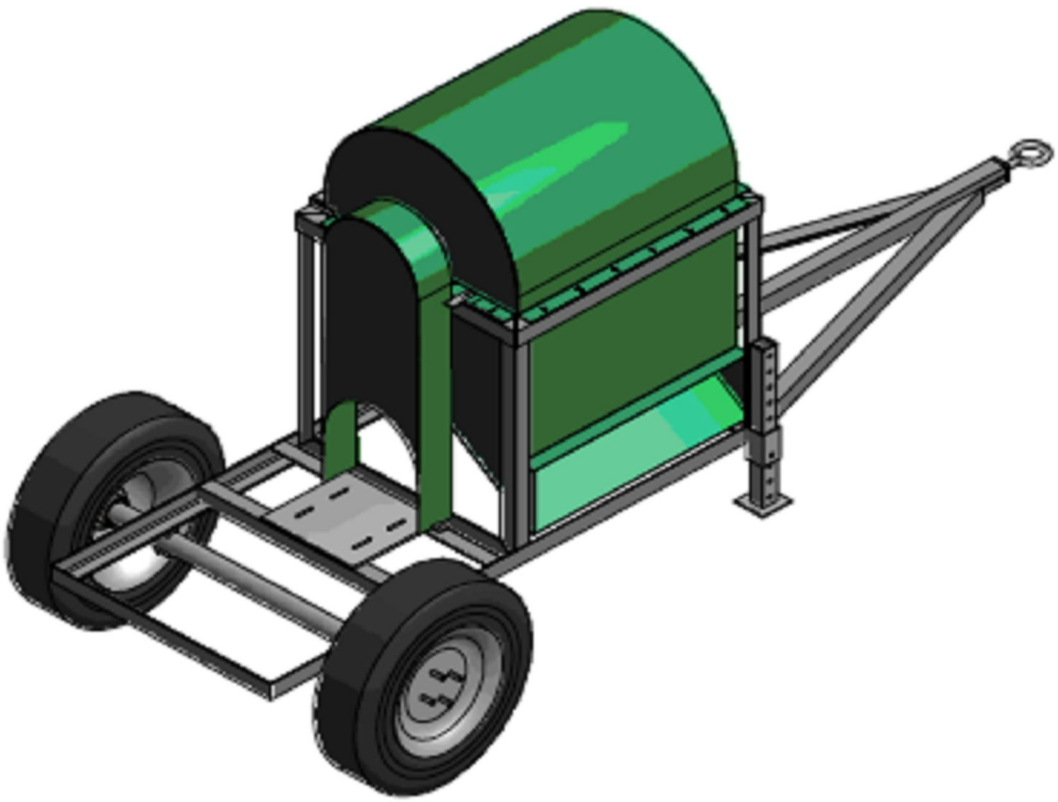


**Fig4.2: Model of decorticator fitted with the wheels**


**Figure 4.3 Different wheel classes**

**Performance / Summer Tyres**
They are designed for faster cars and typically put performance and grip ahead of longevity.

**All-round or all-season tyres**
They are designed to be a compromise between grip, performance, longevity, noise and wet-weather safety. For increased tyre life, they are made with a harder rubber compound, which sacrifices outright grip and cornering performance. All-season tyres are neither excellent dry-weather, nor excellent wet-weather tyres, but are at best a compromise

.

**Wet-weather tyres**

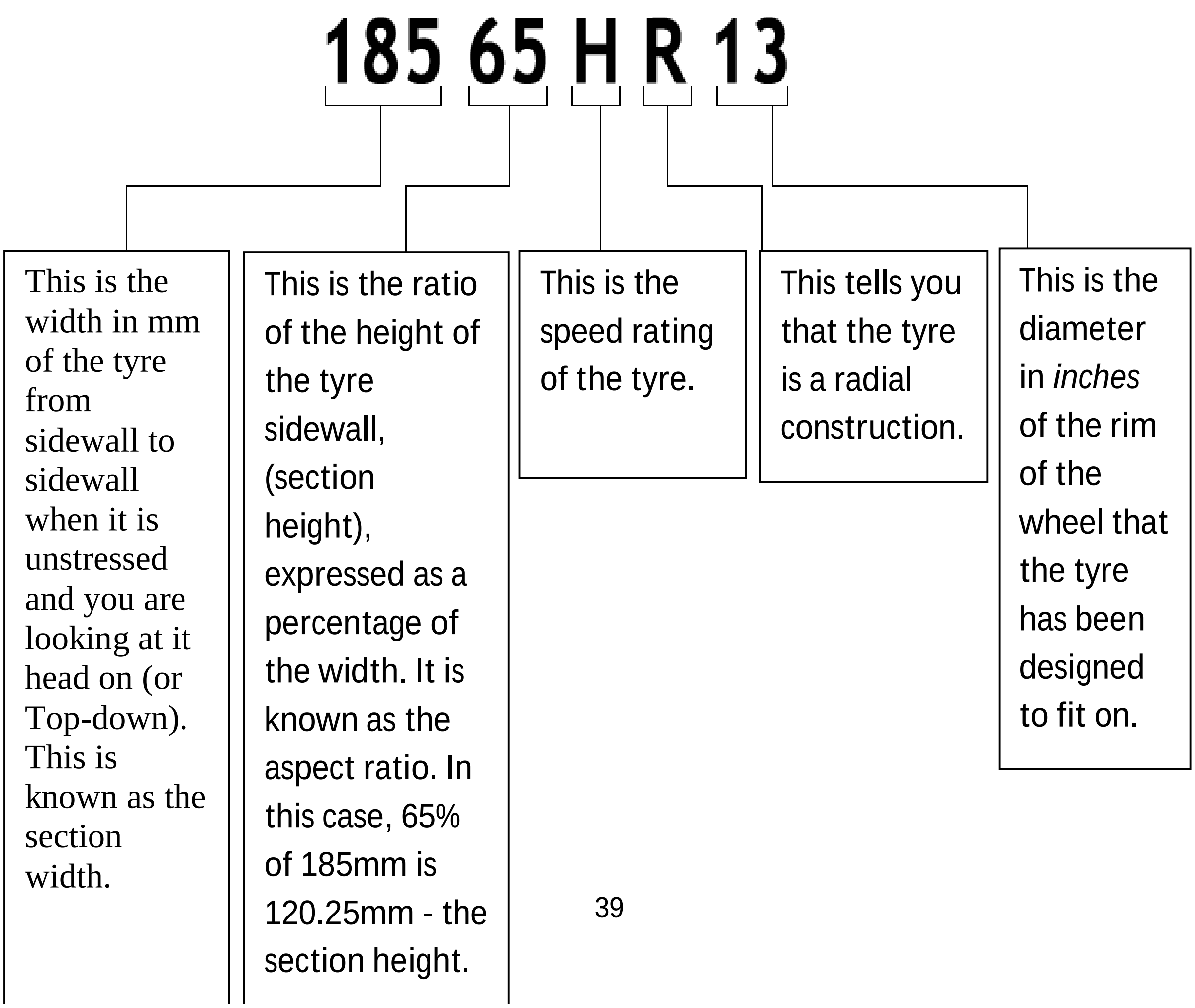
Wet weather tyres use a softer compound than performance tyres. The rubber needs to heat up quicker in cold or wet conditions and needs to have as much mechanical grip as possible.

**Snow & mud or ice: special winter tyres**
They are designed to work well in wintery conditions with snow and ice on the roads. Winter tyres typically have larger and thus noisier tread block patterns

**All-terrain tyres**
All-terrain tyres are typically used on light trucks. They are larger tyres with stiffer sidewalls and bigger tread block patterns.

**Mud tyres**
At the extreme end of the all-terrain tyre classification are mud tyres. These have massive, super-chunky tread blocks and really should not ever be driven anywhere other than loose mud and dirt.

### *4.2.2 Tyre Size Notations*



### *4.2.3 Tyre construction*

There are two types of tyre construction, namely:

- Radial construction
- Bias / Cross-ply construction

The primary reasons why radial tyres are almost used on almost all the world's vehicles, is due to their resistance to tearing and cutting in the tread, as well as the better overall performance and fuel economy. In other hand cross ply has self cleaning effect, easy to repair as well as good vehicle steadiness.

The features of the two tyre construction modes are diagrammatically illustrated figure 3.8 below.

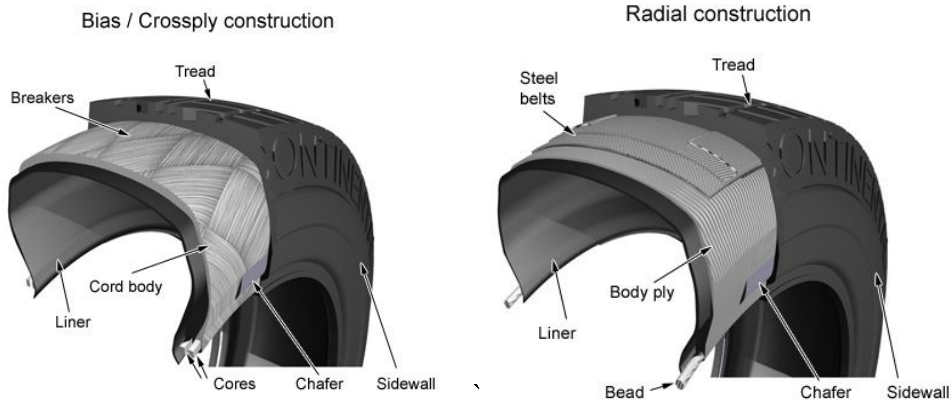



**Figure 4.4 Tyre construction modes**

### *4.2.4 Wheel Measurements*

- **Number of bolts or studs**

  It goes without saying that you can't fit a 4-bolt wheel onto a 5-bolt wheel hub i.e. the number of bolts of a wheel must be same those on the respective hub.

- **Pitch Circle Diameter (PCD)**

This is the diameter of the invisible circle formed by scribing a circle that passes through the centre point of each mounting hole as shown below. If you've got the right number of holes, but they're the wrong spacing, again the wheel just won't fit.

- **PCD notation**

Stud patterns and PCD values are typically listed in this notation: *5x114.42*. This means a 5-bolt pattern on an imaginary circle of 114.42mm diameter.

- **Centre spigot size**

The wheel bolts or studs are there to hold the wheel laterally on to the axle, but they're not really designed to take vertical load. That is the job of the centre spigot - the part of the axle that sticks out and pokes through the hole in the middle of the wheel. It's the load-bearing part of the axle and the wheel, as well as being the assembly that centers the wheel on the axle

The image below shows the PCD (the red ring and mounting hole centerlines) and the spigot size (the blue ring). The spigot hole on an alloy wheel is normally covered up with a centre cap or cover.

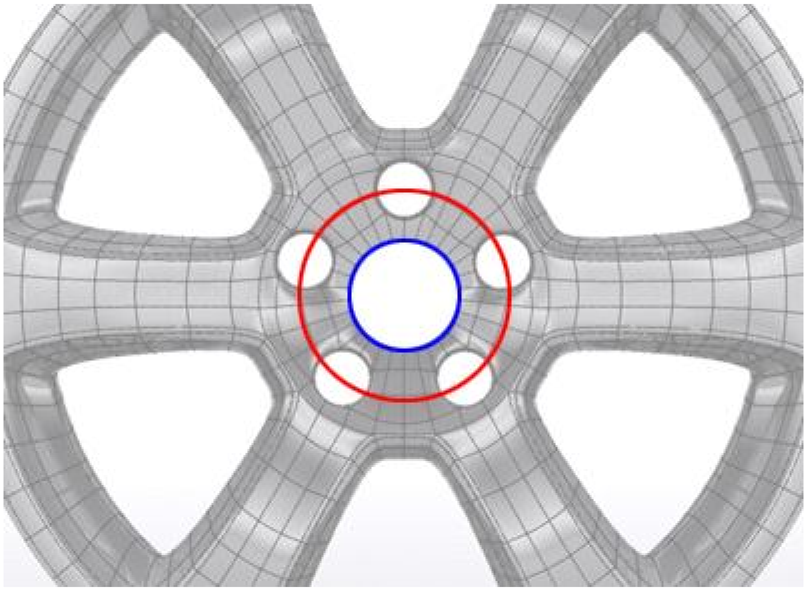


**Figure 4.5 PCD (the red ring) and Spigot size (the blue ring).**

### *4.2.5 The Axle*

This is a central shaft for a rotating wheel or gear. In some cases the axle may be fixed in position with a bearing or bushes sitting inside the hole in the wheel or gear to allow it rotate around the bearing or bushes provided at the mounting points where the axle is supported. The axle maintains the positions of the rotating wheels to each other and to the body, bears the body weight plus acceleration and breaking forces. It is a non rotating member that carries no torque.

Below are the three major types of axles:

a) **Straight Axle**

Is a single rigid shaft connecting a wheel on the left side to that on the right side. The axis of rotation fixed by the axle is common to both wheels.

Such a design can keep the wheel positions steady under heavy stress thus can support heavy loads.

b) **Split Axle**

I this design, the wheel on each side is attached to a separate shaft. This allows for independent suspensions of the left and right wheels, hence a smoother ride. Even when the suspension is not independent, split axles permit the use of differential allowing the left and the right drive wheels to be driven at different speeds as the automobile turns, improving traction and extension of the tyre life.

c) **Tandem Axle**

This is a group of two or more axles situated close together. Truck designs will use such configurations to provide a greater weight capacity than a single axle.

### *4.2.6 Bearings*

Bearing is a device that is used to fix an axle in position in the wheel or gear. Generally, it allows for constrained relative motion between two or more parts, typically rotation or rotational motion. Essentially, a bearing can reduce friction by virtue of its shape, its material or by introducing a containing fluid between surfaces or by separating the surfaces by an electromagnetic field.

There are six common principles of bearing operations, i.e.

- Plain bearing, also known by the specific styles, bushing, journal bearings, sleeve bearings, rifle bearings.
- Rolling element bearing.
- Jewel bearing in which the load is carried by rolling the axle slightly off-centre.
- Fluid bearing, in which load is carried by a gas or liquid.
- Magnetic bearing, in this the load is carried by magnetic fields.
- Flexure bearings, in this motion are supported by a load element which bends.

**Motions**

Common motions permitted by bearings are:

- Axial rotation; shaft rotation
- Linear motion; drawer
- Spherical rotation; ball ad socket joints
- Hinge motion; door, elbow, knee.

**Loads**

Bearings vary greatly over the size and directions of forces that they support. Forces can predominantly be radial, axial, thrust bearings or forces perpendicular to the main axis.

**Speeds**

Different bearing types have different operating speeds. Generally, there is considerable speed range overlap between bearing types. Plain bearing, typically handle only lower speeds, rolling element bearing are faster, followed by fluid bearings and finally magnetic bearings which are limited ultimately by centripetal force overcoming material strength.

# CHAPTER 5

## 5.0 BUSINESS PLAN

### 5.1 Strategy and Implementation

***Competitive Edge***

The main customers of the small scale sisal decorticator are the small scale farmers. This decorticator has been designed with the small scale farmers being given the first priority. The international companies mainly dominate the large scale or estate production. They provide large decorticators that are only suitable to large estates. The proposed decorticator is supposed to be favorable to small scale sisal farmers in different ways:

- There will be relatively low cost of production since the decorticator will be made from readily available materials.
- The machine shall be portable, reliable and long lasting
- The machine should be easy to maintain (low maintenance costs) in that it has fewer parts.
- Spare parts are to be made readily available
- Training the artisans from amongst the small holder sisal producers on the general maintenance and repair of the machine.
- The use of the machine should inhibit environmental pollution by sisal waste but allow for the use of this waste as farm manure.
- Transport and operational costs will be reduced. Dry leaf decortication is undertaken at the field. Low volumes of water are required.

## 5.2 Marketing Strategy

### *Advertising and Promotion*

A significant amount of investments will be made in advertising to promote the decorticator and to create awareness among the customers. If there will be limited funds from the budget for advertising and promotion, then it will be better to reach to fewer, more likely prospects, more often, than to too many people occasionally who are not into the business of sisal production. An effective advertising generally relies on message repetition in order to motivate the small holder farmers to make a purchase. The following are the methods that will be used to reach to the small scale sisal producers:

1) Direct product demonstration
2) Workshops and seminars
3) Media

### *Direct Product Demonstration*

This is an effective way to get close to the small scale farmers. This will be done in the fields near the farmers thus it will cover the small scale farmers' traveling expenses. This method will provide an opportunity to prove the capability of the decorticator, educate the farmers on the usage of the machine and will help to establish a healthy relationship with the small holder farmers.

### *Workshops and Seminars*

Seminars and workshops can be arranged close to the farmers. Certain people representing the groups from amongst the small holder farmers can be chosen and sent to the workshops to represent the other farmers. The workshops and seminars will be mainly to elaborate and to demonstrate the usage and the working principles of the decorticator. All the benefits of the machine will be highlighted in the workshops. This will be another way of reaching out to the small scale sisal farmers.

***Media***

The media comprises of the print media, the audio or the audio-visual media;

1. ***Audio***

Radio is the common medium to the small scale farmers. By using the most listened radio station, the firm can reach out to many customers within the shortest time possible. The choice of the radio station will also depend on the language that the local people can understand. Vernacular radio stations in the selected geographical market place will also be utilized to convey the message easily and effectively. Radio communication has a wide coverage in the shortest time and the radio is at least found in every home including the sisal growing areas in the ASALs. The target farmers will be informed through the radio on the new decorticator usage, how to and where to acquire the machines.

2. ***The Print Media***

It is evident that some small scale farmers have access to daily newspapers and business journals. The disadvantage is that it has small customer coverage and is relatively expensive.

## 5.3 Pricing Strategy

A low market price attracts a large market share. Total costs required to develop the machine and bring it to the ultimate hands of the customer is Kshs105412. Given that the charges for decorticating one kilogram of sisal fibre is Ksh10, and the machine outputs 120kg of fibre per day, the total gross income it generates is Ksh1200 on a daily basis, or Ksh36000 per month.

***1 Pricing objectives***

- get competitive advantage
- be perceived as “fair” by customers and potential customers

- survival
- discourage new entrants into the industry
- company growth
- Obtain a target rate of return on investment (ROI) of 35%.

***The Rate of Return Pricing***

We wish to target at least 35% Return on Investment. With the investment of Ksh105918 per machine, the profit margin will be;

35% of 105412= Ksh36894.20

Therefore the selling price of the machine is set at;

105412+36894.20= Ksh142306.20

Thus the price of the decorticator is approximately Kshs150000.

**Table 5:** Investment and profit for different number of decorticators

| NUMBER OF DECORTICATORS | INVESTMENT(Kshs) | PROFIT(Kshs) |
|---|---|---|
| 23 | 2,424,476 | 848,566.60 |
| 47 | 4,954,364 | 1,734,027.40 |
| 68 | 7,168,016 | 2,508,805.60 |
| 93 | 9,803,316 | 3,431,160.60 |
| 116 | 12,227,792 | 4,279,727.20 |
| 140 | 14,757,680 | 5,165,188.00 |
| 162 | 17,076,744 | 5,976,860.40 |
| 186 | 19,606,632 | 6,862,321.20 |
| 209 | 22,031,108 | 7,710,887.80 |
| 233 | 24,560,996 | 8,596,348.60 |

## 5.4 Sales Strategy

***Branding of the Decorticator***

Naming or branding of the product is a means of identification within the market place. It will identify the source of the decorticator and will help the small-scale farmers to distinguish it from similar products in future. It will also render a strong sense of pride in the creation of the product that will be affordable to small-scale sisal farmers. Trade marks, patents and copyrights will be needed to confer real ownership of the intellectual property and will make the rights of owners defensible against trespass and overall development of the product personality. In this way, a series of non-practical and non-tactile qualities will be developed that will manifest themselves in the market place.

Factors that are considered in the branding of the small-scale decorticator include the following:

- Language in which the name must function
- The beginning letter
- Meaning and pronunciation
- Competitive environment
- Usage of the product
- Performance characteristics of the decorticator

Naming or branding will assist in the market acceptance of the small scale decorticator. Of all the purposes of a name or a brand, the key issue is to get the small scale farmers to buy the decorticator. English and Kiswahili are the languages that will be used. The name to be considered is to be memorable, distinct, and protectable and should not convey any wrong connotation in this complex social structure we are living in.

***Product Sales Plan***

Since sales and distribution network are not developed, it will be important to decide between the company-owned sales force and an independent agent's sales force. Direct sales to retailers or end-users can be used. There is the option of going through distributors or through only the selected distributors. Much is going to depend on decorticator availability, current competition and on the sales objectives.

### *Direct Sales*

This is the company owned sales force. This method will need training, turnover, time and costs so as to be developed. In the initial stages, the company's sales force will be utilized with the aim of creating a firm base and a good reputation for the smallholder sisal farmers. It may be seen, though, that it is wise to use representatives or agents in a certain market segment and a company sales people in others. Direct sales using the company owned sales force has the advantage that there is a total control of all the sales activities from the top management. The customers get the real picture of the company and any feedback is communicated almost immediately. This is because most customers like to deal directly with the manufacturers. This direct sale by the company has some shortcomings in that it requires more financial input to train the company's sales people thus marketing costs will be high.

### Sales Agents or Independent Distributors

We may have different sales agents and distributors to cover different geographical regions on a commission basis. This method is preferred because it generally offers the manufacturer the following advantages:

- There is an already existing sales force
- There is a quick and effective market penetration in different regions by the distributors. Since this method is based on the commission basis, the sales agents will try their own best to get the small-scale farmers buy the decorticator; a marketing advantage.
- The sales agents and distributors have the specialized sales and marketing knowledge. So the firm may not spend more on training special sales persons.
- The sales agents and the distributors have the knowledge of their own market place and their customers.

- There will be a fixed cost to sales ratio.

Employing the sales agents or distributors on behalf of the manufacturer has its own disadvantages as follows:

- There will be usually lack of control because it will not be easy to monitor all the activities that go on between the small scale sisal farmers and the sales agents.
- Once the distributors have acquired a specific region, it will be difficult to move them around into different territories.
- Customer's loyalty will be built first on the independent sales agents and then to the manufacturer. The customer's perception of the manufacturer will depend on how the sales agent will handle the situation. If the sales agents handles anything in a bad way, then the whole issue will be reflected back to the manufacturer,
- Most customers like dealing with the manufacturer directly.

## Financials

### *Projected cash flow*

Assuming that 20 decorticators will be sold each year, although the number is subject to change depending on the economic performance of the sisal industry, the expected cash flow will be as follows:

**Table 6:** Projected cash flow

| Cash flow | Amount (Kshs) |
|---|---|
| Cash receipts (20×142,306.20) | 2,846,124 |
| Cash outflow<br><br>Inventory and other expenses(105412×20) | <br><br>2,108,240 |
| Ending Cash | 737,884 |

On a monthly basis, the above benefits translates to Kshs61500 approximately

# CHAPTER SIX

## CONCLUSION AND RECOMMENDATION

### *6.1 CONCLUSIONS*

This project involved the application of sound engineering principles to redesign a suitable decorticator for the small scale sisal farmer. Throughout the design process, affordability, transportability, reliability, availability of material and assembly constraints were taken into account.

The redesigned machine was fitted with wheels to enable its portability from one location to the other. This will eliminate laborious leaf transportation over long distances.

Sisal industry in Kenya has a great future. The use of the small scale sisal decorticator would play a vital role in ensuring a major small holder sisal fibre contribution to the national production. One decorticator outputs about 43 metric tons on an annual basis.

This fibre amounts to Ksh1720000 when exported (one kg sisal fibre fetches Kshs40 export market price). The price of the decorticator is set only at Kshs150000. A trader, offering decortication services using the small scale decorticator, can generate a gross income of up to Kshs36000 per month.

### *6.2 RECOMMENDATIONS*

Farmers should be sensitized on the benefits of sisal plant. These benefits should act as a driving force to have people plant as many sisal plants as it is possible. Then more decorticators will be required. The market price for the decorticator is estimated to be around Kshs150000 and most small holder farmers can not raise this kind of money. It is therefore recommended that the farmers should form several small groups among themselves. These groups can then be able to secure decorticator even at credit and payments made later. The Kenyan Government should also be able to assist the farmers in acquiring the decorticators.

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