DEVELOPMENT A CINNAMON BARK PEELING EQUIPMENT

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Abstract

The Cinnamon Industry has been in Sri Lanka for hundreds of years and the product is commonly known as Ceylon Cinnamon. Sri Lanka is the dominant supplier in the world cinnamon market from the past due to its special taste and quality. Therefore, this has been a solid export earner over the years for Sri Lanka. At present it accounts for 80 % of the global cinnamon market and brings in an annual income of LKR 3,000 million.

Although the cinnamon industry is bringing in foreign exchange to the country, development activities in the cinnamon industry have been rare compared to the other industries. There is potential to develop the industry in various facets. The cinnamon peeling is one such process that needs development in this industry. It is a time consuming process. This is also a labour intensive process, and requires highly skilled labour to perform the task. Therefore, the new generation is reluctant to work in this sector. This has badly affected the entire cinnamon industry. In addition, only primitive tools are being used in the cinnamon peeling process. Thus, mechanization of process is one of the options available to overcome the existing issues in the industry.

In the current study, a new cinnamon peeling equipment was developed by introducing a new peeling technology. Existing cinnamon peeling method and other peeling technologies have been scrutinised to propose an appropriate peeling method.

Cinnamon peelers' (n = 12) and exporters (n = 2) feedback was gathered to improve the design. It was identified that the introduced equipment in general can be used with minimal training and knowledge. The study also showed that the safety and efficiency of the cinnamon peeling process is increased significantly when the equipment was used. Apart from that, there is a possibility to automate the process and it is suggested as future work.

Key Words

Cinnamon Peeling
Cinnamon Production
Cinnamon Bark
Cinnamon Quills
Peeling Equipment

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Declaration

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.
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Abbreviation	Description
USFDA	United States Food and Drug Administration
MPM	Mycroanalytical Procedures Manual
AOAC	Association of Official Analytical Chemists.
HACCP	Hazard Analysis and Critical Control Point
ITI	Industrial Testing Institute
DEA	Department of Export Agriculture
SFD	Shear Force Diagram
BMD	Bending Moment Diagram
S/S	Stainless Steel

CHAPTER 1 INTRODUCTION

1.1 Background

Cinnamon was one of the first traded spice in the ancient world. Cinnamon Barks Exporting was a main export good in Sri Lanka for past hundreds years and it was a unique product to ancient Ceylon. Most of merchants came here to buy Ceylon Cinnamon due to the quality of the product. Still there are no competitors to Sri Lanka in the world Cinnamon market, because the quality of Sri Lanka Cinnamon is higher than other countries products. So Sri Lanka could remain as the market leader among the world Cinnamon suppliers. Therefore the cinnamon represents the considerable share of the export earning of the country.

However the technology development of this industry is poor. Still primary level tools are used to produce cinnamon. Therefore cinnamon production has become a labor intensive process, so productivity is depend on the skill of the labors. The lack of skill labors and new generation reluctance to work in Cinnamon industry are main issues directly affected to the development of the Industry. So there is a huge requirement of a machine which is increase the efficiency of the Cinnamon production. This will increase the export earnings and affect to the development of the country. The government attention also has turned to this matter due to the importance of increasing the efficiency of Cinnamon Production. There are few introduced machines, but those are not in required level. So there is a good opportunity for Inventors to introduce a new machine.

This Study is focused to develop equipment which increases the efficiency of Cinnamon bark peeling process. The traditional tools involve high labor skill to achieve required efficiency, especially in bark peeling process. New equipment will be a solution to scarcity of skill labors too. This equipment will be a low cost tool that beneficial for small and medium size cinnamon producers also.

Objectives and Scope of the thesis.

- Study and understand the Cinnamon Production process
- Study the developed machines in Cinnamon Producing Industry

- Study the bark peeling methods and select a suitable technique to Cinnamon bark peeling.
- Propose and Implement an equipment that Increases the Efficiency of the Cinnamon Bark Peeling Process.
- Develop The Designed Equipment to Achieve The Required Efficiency and Cost.
- Validate The Developed Cinnamon Bark Peeling Equipment.

1.2 Ceylon Cinnamon

Cinnamon is a valuable spice that is obtained from the bark of the cinnamon tree that belongs to the Lauraceae family. The scientific name of cinnamon is Cinnamomumzeylanicum[1]. Cinnamon trading is an ancient business that pursues from the hundreds years ago. The cinnamon is native to Sri Lanka and Myanmar. The crop is now grown in India, South America and West Indies. But best quality true Cinnamon is produced in Sri Lanka.

The Ceylon cinnamon or true cinnamon is indigenous to Sri Lanka. *Cinnamomumzealanicum*is an evergreen perennial plant with spirally arranged [1], broad laminated dark green leaves having palmate venation. Under natural conditions, the plant grows to a height of 10 - 15m with the girth of 30-50cm. When coppiced from time to time it could be maintained as bush of 2-2.5m height with multiple stems arising from its base. The flowers are small, creamy and inconspicuous developing into dark purple ovoid one seeded berries, about 1.5 - 2.5cmlong [2].In Sri Lanka, cinnamon seems to have originated in the central hills where several species of cinnamon occur sporadically in places such as Kandy, Matale, BelihullOya, Haputale and the Sinharaja forest range. Although cinnamon cultivation is presently concentrated along the coastal belt stretching along from Kalutara to Matara, it has also made inroads to the inland of Kalutara, Ambalangoda, Matara and Ratnapura [2]. The extent under cinnamon in Sri Lanka is 25,500ha. Although, the bulk of cinnamon plantations are about 70 - 80 years old, the size of holdings has been diminishing and only about 5-10% of the plantations are of sizeable extent ranging from 8 - 10ha. Cinnamon is a hardy plant which can grow well in almost all types of soils under a wide verity of tropical conditions. The most suitable temperature is between 25^0C and 30^0C. Rainfall should be in the region of 1,875 - 3,750 mm. Generally, cinnamon does not thrive in the drier parts of the low-country. It is found as a forest tree at 300 – 350m above sea level [2].

The quality of bark is greatly influenced by the soil and factors. The best quality cinnamon is produced on white silicacious sandy soils like the ‘silver sands’ of Negombo District. Yield is higher in order soils but quality is coarser than in sandy soils.There are eight cinnamon species in Sri Lanka. Among them only *Cinnamomum zealanicum*is grown commercially. Currently ten cinnamon selections have been identified and those selections are under evaluation in different agro climatic zones [2].

Cinnamon gets its distinctive smell and aroma from a volatile oil that is in the bark. The oil can be distilled from off-grade bark, leaves and roots. Cinnamon must be dried before it is stored and sold for market. This brief outlines the important steps that should be taken pre-harvest and post-harvest to ensure that the dried cinnamon is of top quality for the market.

1.3 Cinnamon Production

The cinnamon tree is a bushy evergreen tree that is cultivated as low bushes to make harvesting easier. The bushes grow well in shaded places with an average rainfall and without extremes of temperature. The optimum temperature for production is between 27 and 30°C. The soil should not be waterlogged as this produces a bitter-tasting bark.

Processing accounts for about 60% of the cost of production of cinnamon [1]. This is because the peeling of bark from the stems is labor intensive and is usually done by hand, by skilled peelers. The quality of cinnamon depends on how well the bark is removed from the stems. The larger pieces or quills can be sold for more than the smaller broken pieces.

The main steps involve to cinnamon production have been described in below sections. The sketch shows steps of whole Cinnamon production process.

- Harvesting the suitable Cinnamon sticks
- Remove the tender stems (with diameters less than 1.2cm) and use these for mulching.
- Stems with diameters of more than 5cm are not used to prepare cinnamon bark. Remove these and use for oil distillation.

• Remove the soft outer bark using a fine rounded rasp knife.

• Rub the stripped stem with a brass rod to loosen the inner bark. It is important to use a brass rod so that the bark does not become discolored.

• Make cuts around the stem at 30cm intervals using a small pointed knife. The knife blade should be stainless steel or brass to prevent staining the bark.

• Make long cuts along the length of the stem, so that the bark can be carefully eased off the stem. Use the pointed knife and the rubbing rod to help ease off the bark.

• The pieces of removed bark are known as quills. Place these curled quills inside one another to make long compound quills (up to 1m long). Use the best whole quills on the outside and fill in the center with broken pieces of bark.

• Drying under shade. Drying is also an important stage of the processing of cinnamon. It contributes to the quality of the final product.

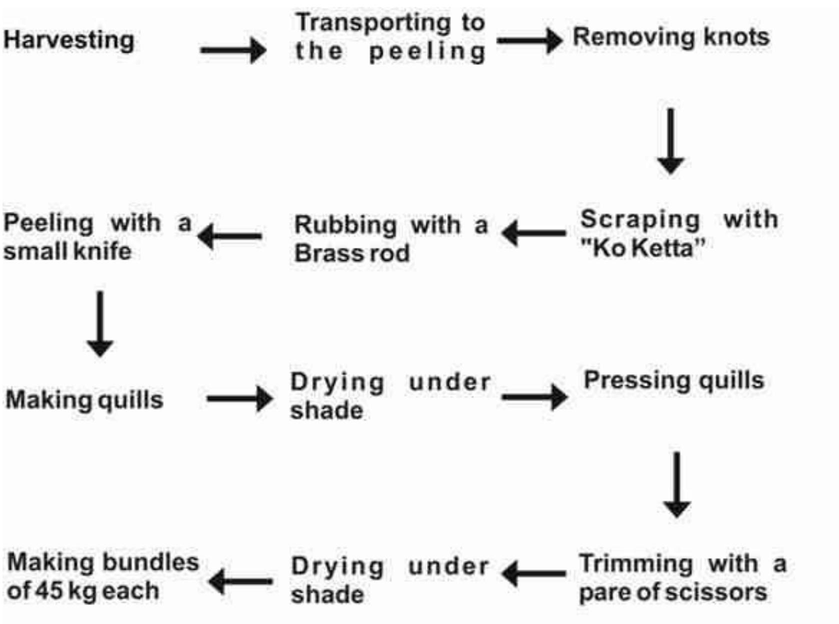


Figure 1.0.1: Cinnamon Production Flow Chart

Source: http://www.agri.ruh.ac.lk/Department/Engineering/Cinnamon/Procesing.html

1.3.1 Harvesting

Changing of the bark colour into brown, it indicates the enough maturity of stems harvesting. New cinnamon seedling will attain maturity in about 2 to 2 ½ years of age and the other shoots emerged after harvesting will attain the maturity in 1 ½ years' time [3]. In a well-managed plantation, harvesting could be done twice in a year.

Cinnamon bark is harvested twice a year immediately after each of the rainy seasons when the humidity makes the bark peel more easily. The trees are first harvested when they are three years old, one year after pruning. The side stems that are about three years old are removed and the bark is stripped off. Cinnamon bark is only obtained from stems that are between 1.2 and 5cm in diameter.

Harvesting carried on May-August (Mahamosama) is main harvest period. During this period bark peels off easily [3]. Harvesting begins early morning, 5.30-6 am. Skilled peeler visually identifies maturity and keeps several immature shoots for the next harvest. The peeler makes a cut and lifts the bark to test bark detachment. If there is any difficulty in peeling, the peeler rejects the shoots. After harvesting and removing leaves the sticks are collected, tied and carried to the open area for further cleaning. Peel ability of bark is low during fruits bearing and late flushing periods.

In General cinnamon can be harvested throughout the year except during the dry periods which in average is about two months. Peeling is quite difficult during the dry periods when soil moister depletes. Adoption of mulching practices with cinnamon leaves is a good practice to conserve soil moisture.

All the harvesting operations are done by a simple tool Ketta, it has a very sharpen blade and long handle. The blade is made of quality steel and local blacksmith usually fabricate it from a disposed leaf spring.

Figure 1.0.2: Cinnamon Harvesting

1.3.2 Removing Knots

Peeler holds the stick in one hand and works with other hand with Ketta along the stick remove all the knots. Usually men are engaged with this job at standing or sitting position. After removing knots, scratch should be a button shape.

Figure 1.0.3: Removing Knots

1.3.3 Scraping

Scraping is the cleaning or removing the outer cocky tissue layer from the sticks. It is not laborious but time consuming

Traditional hand tool " Kokatta" is used for this.. There are two types of tools, one with curved sharpen blade and other with a blade and small handle. That is called Sawthtuwa. Curvature of the blade is selected to match the diameter of the sticks. Sometime people use two or three scraping tools with different curvature for efficient scraping. Understanding the physical quality of the sticks (roughness, maturity) is very important for proper scraping. Therefore mechanization of this step is complicated. Physical properties of the sticks (stick diameter, number of knots, straightness ...etc) are effecting the scraping time.

*Figure 1.0.4:*Traditional Kokatta

Figure 1.0.5: Sawthtuwa

1.3.4 Rubbing

Figure 1.0.6: Brass Rod for Rubbing

Historically bark was detached without rubbing. Subsequently a piece of wooden rod (Keppitiyakotu) was used for rubbing. After a copper rod was used, that was subsequently replaced by brass rod. Average diameter, length and weight of the brass road is 15mm, 20.3 cm, 110g respectively. Rubbing is the most laborious step in cinnamon processing which helps to detach the bark from the stick.

Time taken for rubbing vary with the diameter of the sticks, crookedness and other abnormalities, number of knots, season, cultivars, etc. During the off season extra effort has to be applied for rubbing. After 4-6 hrs of rubbing, performance of the peeler falls down resulting bark damage and producing poor quality quills.

Peelers usually change their posture to prevent muscle pain. About 40-60 strokes have to be applied around selected length of the sticks for proper rubbing and 9-30 N of vertical force have to be applied during rubbing. During the rubbing process bark sap oozes, which indicates the proper rubbing. Extreme rubbing damage the bark.

1.3.5 Peeling

This is the skilled and time consuming step in cinnamon processing. Just after rubbing, stick is examined to decide the maximum length of bark portions that can be peeled off to make outer cover of the quills. Then make two cuts around the sticks with maximum length of intervals using a small pointed knife. Then draws longitudinal slit form end to end and works the knife carefully between the bark and hard wood to raise the bark. Finally draws the other longitudinal slit opposite to the first slit. Bark can be detached in two equal halves with the little knife. When the diameter of the sticks is higher bark can be divided to three or four strips. The rest of the bark (on the bended sticks and close to the knots, or other bark abnormalities) cannot detach as complete peels to make outer cover of quills, Those detached as small strips to fill the quills.

The knife is handled safely and tolerantly because of harmfulness of the process. Therefore normally peelers wear rubber clips in fingers.

Figure 1.0.7: Cinnamon Peeling

1.3.6 Drying

After peeling the bark long peace that are used to make the outer cover of the quills are kept 2-3 hours, for shade drying. During this period bark curls inversely. In rainy season this period is extended up to 5-8 hours [2]. At present rope racks or steel racks are used to shorten the drying period.

The compound quills are placed on coir rope racks and dried in the shade to prevent warping. After four or five days of drying, the quills are rolled on a board to tighten the filling and then placed in subdued sunlight for further drying. In humid climates or during the rainy season it will be necessary to use a mechanical dryer to complete the drying process. There are a range of dryers available to suit different situations (electrical, gas fired, biomass fuelled).

Figure 1.0.8: Quills Drying on Rope Rack

1.3.7 Quills Making

Cinnamon quills are prepared by experienced peelers to maintain uniform thickness from end to end. Bark halves are packed one inside the other until cigar like quills are formed. When it reaches the required length the end is trimmed with scissors and it is gently lifted and kept on the mat for drying. The hollow inside of the quills is then packed with pieces of thin bark, which are unsuitable to use for the outer cover of the quill. A pair of scissors and a measuring stick 107cm long, to which is attached a wooden lifter called “Pethi Kotuwa” is used for Quill making [2].

Standard length of a quill is 106.7 cm (42in), and trimmed with a pair of scissors when it is necessary. Quills are air drying indoors for about 4 – 7 days. The air dried Quills are pressed by hand to stack properly. Yield varies widely according to the age of the plantation and adopted management practices. However the identified present average annual yield rate is about 470 kg of quills/ha [2].

Quills will be covered by gunny bags to prevent from direct sun light. The processed quills will be bundled in to 45 Kg each for the marketing purposes.

According to information gathered from the Cinnamon Research Station, Thihagoda, Sri Lanka a skilled labor can produce 4 to 5 Kg of dried processed cinnamon per day. To achieve this target he has to peel about 50 sticks per day consuming 10 to 15 hrs. A shortcoming of the existing method is low efficiency and high labor cost which is about 50 % of the income.

Figure 1.0.9: Quills Making

1.4 Products of Cinnamon Quills

The quality of cinnamon is judged by the thickness of the bark, the appearance (broken or entire quills) and the aroma and flavor. The Sri Lankan grading system divides the cinnamon quills into four main groups according to diameter.

Scraped peel of the inner bark of mature cinnamon stems first dried in the sun (not direct sun) to curl and join together by overlaps, the hollow of which has been filled with small pieces of peeled cinnamon to form length of 1050 ± 50 mm and thereafter dried in the sun, if necessary after air curing. Quills are graded on the basis of the diameter of the quill and the level of foxing. Nature of dried quills according to the production quality has been shown below figure [1].

Table 1.1: Cinnamon Products Grading

Classification	Description	Measurements
1. Quills	Alba	Less than 6mm diameter
	Continental	Less than 16mm diameter
	Mexican	Less than 19mm diameter
	Hamburg	Less than 32mm diameter
2. Quillings	Pieces of bark less than 106mm long	
3. Featherings	Inner bark of twigs and twisted shoots	
4. Chips	Trimmings of quills, outer and inner bark that can't be separated	
5. Powder		
6. Leaf oil		
7. Bark oil	Cinnamaldehyde 30-70%	

Source: www.exportagridept.gov.lk/web/index.html

Figure 1.0.10: Quills 5Maxican

*Figure 1.0.11:*Quills 5Continental

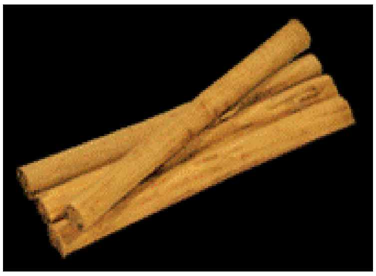


*Figure 0.12:*Quills ALBA

Table 1.2: Classification for quills (ISO 6535:1997) (SLS 81:2000)

Commercial designation of grades and qualities	Diameter of quills Max in mm	Number of whole quills (1050mm) per kg min	Extent of foxing[1] % max [2]	Minimum length of quills in a bale mm	Pieces of tube and broken pieces of the same quality per bale max % (m/m)
Alba	6	45	Nil	200	1
Continental					
C 00000special	6	35	10	200	1
C 00000	10	31	10		
C 0000	13	24	10		
C 000	16	22	15		
C 0	17	20	20		
	19	18	25		
Mexican					
M 00000special	16	22	50	200	2
M 00000	16	22	60		
M0000	16	18	60		
Hamburg		|			
H 1	23	11	25	150	3
H 2	25	9	40		
H 3	38	7	60		

Source: www.exportagridept.gov.lk/web/index.html

1.4.1 Packaging

Cinnamon quills are cut into pieces up to 10cm in length and packed into moisture-proof polypropylene bags for sale. The bags should be sealed to prevent moisture entering. Sealing machines can be used to seal the bags. Attractive labels should be applied to the products. The label needs to contain all relevant product and legal information – the name of the product, brand name (if appropriate), details of the manufacturer (name and address), date of manufacture, expiry date, weight of the contents, added ingredients (if relevant) plus any other information that the country of origin and of import may require (a barcode, producer code and packer code are all extra information that is required in some countries to help trace the product back to its origin). See the Practical Action Technical Brief on labelling for further information on labelling requirements.

1.4.2 Storage

Dried cinnamon quills must be stored in moisture-proof containers away from direct sunlight. The stored cinnamon quills should be inspected regularly for signs of spoilage or moisture. If they have absorbed moisture, they should be re-dried to a moisture content of 10%.

The storage room should be clean, dry, cool and free from pests. Mosquito netting should be fitted on the windows to prevent pests and insects from entering the room. Strong smelling foods, detergents and paints should not be stored in the same room as they will spoil the delicate aroma and flavor of the cinnamon.

1.4.3 Cinnamon Quillings (broken tubes)

Broken pieces below 200 mm in length (other than quills cut in specified short length) and splits of varying sizes of all grades of cinnamon quills which may include quantities of chips and featherings as specified.

Figure 1.0.13: Cinnamon Featherings

Pieces of inner bark, obtained by peeling and/ or scraping the bark of small twigs and stalks of cinnamon shoots, which may include a quantity of chips as specified.

Dried bark of unpeel able cinnamon stems, branches and trimmings inclusive of the outer bark, which has been obtained by chipping or scraping.

1.4.4 Ground Cinnamon

Grinding can be a method of adding value to a product. However, it is not advisable to grind spices. After grinding, spices are more vulnerable to spoilage. The flavor and aroma compounds are not stable and will quickly disappear from ground products. The storage life of ground spices is much less than for the whole spices. It is very difficult for the consumer to judge the quality of a ground spice. It is also very easy for unscrupulous processors to contaminate the ground spice by adding other material. Therefore most consumers, from wholesalers to individual customers, prefer to buy whole spices.

Cinnamon is sometimes ground to a powder prior to sale. The ground powder should be packaged in moisture proof packaging (polypropylene bags) to retain the flavor.

1.5 Quality Requirements

The cinnamon is sold generally as quills. In addition to this, cinnamon is also exported as quislings, featherings and chips. The quills shall be of light brown color and shall be well formed and well dried. The occurrence of reddish brown patches on the quills which may become dark - brown with time is known as foxing. These are defects and the value of quills gets depreciated depending on the amount of foxing. Foxing can be categorized as below [3].

(a) Superficial patches (*"malkorahedi"*) – appearing on the surface of the quills

(b) Heavy patches (*"korahedi"*) – resulting in damage to the surface of the quills and making the quills uneven

Table 1.3: Commercial Specifications of Cinnamon

Color	Pale brown to slightly reddish color Ground cinnamon – yellowish to reddish brown in color
Odor	Characteristic fresh aroma
Flavor	Delicate and sweet flavor characteristic to Ceylon cinnamon. It shall be free from foreign flavor. Including mustiness.
Moisture	Not more than 15% for quills and 12% for other grades
Volatile Oil	Minimum 1% for quills and 0.7% for other grades on dry basis.
Shelf Life	Minimum of 1 year
Packing	Packaged in clean, sound, dry packages, made of jute, cloth, paper or polyethylene bags.

Source: www.srilankanspices.com/sl_spices_cinnamon.html

Table 1.4: Defect Action Level – USFDA from Cinnamon

Cinnamon Whole	Mold (MPM – V32)	Average of 5% or more pieces by weight is moldy
	Insect filth (MPM – V 32)	Average of 5% or more pieces by weight are insect infested
	Mammalian excreta (MPM – V32)	Average of 1 mg or more mammalian excreta per pond
Cinnamon Ground	Insect filth (AOAC 968’38B)	Average of 400 or more insect fragments per 50 grams
	Rodent filth (AOAC 968.38	Average of 11 or more rodent hairs per 50 grams

Source: www.srilankanspices.com/sl_spices_cinnamon.html

USFDA – United States Food and Drug Administration
MPM – Mycroanalytical Procedures Manual
AOAC – Official Method of Analysis of the Association of Official Analytical Chemists.

CHAPTER 2 IMPROVEMENTS IN CINNAMON INDUSTRY

True cinnamon is native to Sri Lanka may be the oldest and the most important spice in the island. Mainly, five important products are produced from cinnamon plant namely, quills, featherings, chip, bark oil and leaf oil. Quills are the major product of export, which accounts for 90% among the other products of cinnamon. As the quality is of paramount importance, highly valued higher grades should be processed for the export market. Processing is the most expensive operation in the cinnamon industry that requires about 60% of all the production cost. Processing operation in cinnamon is fairly flexible. It is determined by both agronomic and economic factors such as monsoons, availability of labor, cash need of farmer, etc.[4].

Sri Lanka is the only country that process in the form of quills. These pipe shape quills are processed by using the finer portions of the inner bark of cinnamon stick, which were harvested at correct stage of maturity. Having scraped off the brownish outer layer, the inner bark is rubbed with a brass rod. The bark is then peeled off and made into 42 inches long pipes, which are dried in shade later.

Trained and skilled peelers if paid accordingly will make higher quality grades of quills. Mechanization of all the steps in cinnamon processing is not possible. Even if machine is devised, it should be able to produce an improved quality product than manually processed quills.

The peelers are rare to find and other attractive well recognized and/or highly paid opportunities in the society are a challenge to the cinnamon industry today. Presently, the peelers are paid by fraction of crop processed, ½ or 1/3 or on a per-round of quills made basis. A peeler can prepare about 2-3.5 kg of quills per day. Through a satisfactory income is received, the new generation is reluctant to join the industry due to social problems [4].

Cinnamon grades with high quality receive a premium price in the market. Although the peelers are paid according to the fineness or grade of quills, they make mostly medium grade quills. The finer grades with thin bark have less weight than the lower grades. The quality of fine grades a peeler can produce in a day is less and therefore he receives less. This leads him to make medium grade quality quills.

Sri Lanka the major producer of good quality, true cinnamon quills for the export market. Therefore to remain the industry and market demand, good quality quills should be produced. Hence more attention should be given for quills processing and to produce quills of finer grade. Quills of finer grades could be produced, by educating and training the peelers. The quills are entirely manually produced so that training of new peelers is a very necessary to make a good quality product.

Peeling of cinnamon is more time consuming and a skilled person can prepare about 3 kg per day. A peeling machine may be another approach to solve the labor problem as well. A single, simple machine cannot handle all the steps in quill making other than a robot. The scraping step of outer bark, the rubbing of the stick and the bark removal step may be possible by mechanical devices. The machine may reduce the time of processing. However, it should not affect the quality, as quality is governing factor in the market.

Cut quills are another product in the customer-producer sector. The quills of lengths shorter than 42 inches are also produced and exported. They are mostly around 8 to 10 cm length these are easily used for culinary and other purposes. Some are used as swizzle sticks in the liquor trade.

Evenly shaped sticks are hardly available. However, more or less evenly shaped short pieces of stick could be taken from long sticks. They are easily handled by a mechanical device.

However, mechanization of cinnamon peeling should be considered with reservation since some superior quality products in the world with exotic value are still made by manually.

2.1 Machines Introduced In Cinnamon Processing

Cinnamon processing is a laborious and a tedious task requiring a high level of skill and knowledge. Technical knowhow is passed down from generation to generation. By deskilling these tasks by mechanization and Automation and making them a flow line production operation will enable much greater productivity. Due to social attitudes although up to 35-50% of sales revenue per kg of finished product is paid as wages, the younger generation of peelers do not readily come into the industry.

A peeler can process about 2.0 - 3.5 kg of quills per day. As per the present market price of about 1350 Rs/ kg , the peelers income exceeds Rs2000 a day. As such most crucial issues faced by the producer today is that of the peeler. There is a dearth of peelers, the cost of labor and demand is high, as result planters reluctant to allocate inputs to upgrade the plantations [4].

Currently Peeling, and post-harvest operations are carried out under poor hygienic and working condition and will not meet the Euregap, HACCP, food Safety, health & safety and sanitary standards [4].

Although the cinnamon grown in Sri Lanka for centuries there has been little improvement in productivity in peeling technologies as well as the distillation process in the last hundred years. Therefore there has been no significant improvement in harvest and post-harvest technology, The Department of Export Agriculture (DEA) and Industrial Technology Institute (ITI) have been carried out research and development program related to Pre – Harvest and Post – Harvest activities separately. ITI has introduced improved versions of distilleries, however those are still to be popularized. Research into these activities should be initiated under a Cinnamon Research Program covering cradle to grave value addition Chain. However the industry still operates with the traditional technology and the exporters are complaining about the lack of demand driven research and stressed the need for research on product development [5].

Compare with the other facts Labor-intensive and costly peeling and quill preparation is the most acute problem in Cinnamon Industry. Hence, mechanization of the peeling process is very important in order to safe guard the cinnamon industry in the future.

Department of Agriculture Engineering University of Ruhuna had commenced a research program in year 1997 to study the whole processing steps and attitude and habits of the peeling groups to design and test appropriate devices for cinnamon processing.

Here the focused areas were

Replace the laborious steps by new strategies (Transporting, rubbing, etc).

Shorten the time consuming steps (scraping, rubbing, drying, etc)

Keeping with peelers health and comfort.

Modernize the process to attract new generations.

Promote phyto - hygienic production to meet higher demand of export market.

The developed equipment are briefly described in below sections.

2.2. Scraper

A simple improvement to Koketta is made by doubling the scraping surface with a provision to manual adjustment of the scraping surface using a spring mechanism. Scraping surface of the device can be changed to suit the diameter of the Cinnamon stick. Preliminary results of the applicability of the device revealed that time consumption for scraping is reduced by 30% when the suggested mechanism is used [4].

Figure 2.1: Cinnamon Scraping Device

2.3. Cinnamon Bark Scraping Machine

This machine has been implemented by the University of Moratuwa. The efficiency of the scraping process has been increased using this machine. A worker has to be kept a Cinnamon stick on the rotating drum while rotating the stick to ensure touching every area of the stick. The rotating drum has been made as a tapered one as suitable to various shaped cinnamon sticks. The teeth created on the surface of the drum, scrape off the outer bark from the cinnamon stick when rotate the drum. This machine is more efficient than current manual process, the scraping quantity per person per day can be increased more than double using this machine.

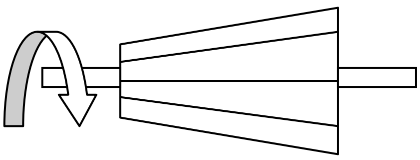


Figure 2.2: Cinnamon Scraping Machine

2.4. Cinnamon Rubbing Machine

RUWEEKA_CG is a rubbing device introduced by university of Ruhuna after series of experimentation. This is the first attempt ever made by the researchers to mechanize the cinnamon peeling. This device replaces the heavy labor involvement by increasing the efficiency up to 59.7% [4].Device consists of brass ended spindles, springs, nuts and casein. Spindles are mounted on spring in a circular arrangement in three plans on the casein. . Springs provide optimum force evenly on entire surface of the sticks for rubbing that reduce the heavy labor involvement and operation could be done by single person easily. People can engage with rubbing process in better working posture preventing muscle pain and fatigue.

Operation could be done by inserting the scraped sticks through the spring loaded spindles and moving several strokes. In this way entire sticks could be rubbed in 25 seconds [4].

Appearance of the Rubbing Devices

Figure 2.3: Cinnamon Rubbing Device – RUWEEKA_CG

Table 2.1: Efficiency of rubbing with RUWEEKA Machine

Method of Rubbing	Time requirement for the stick (mean value)
Manual	72 seconds
RUWEEKA-CG	25 seconds

RUWEEKA-PG RUWEEKA-PG is patented by Weerasinghe and Pushpitha (2004) as an improved design of RUWEEKA-CG by scaling and incorporating the suitable mechanisms to insert the stick [4].

RUWEEA-PG

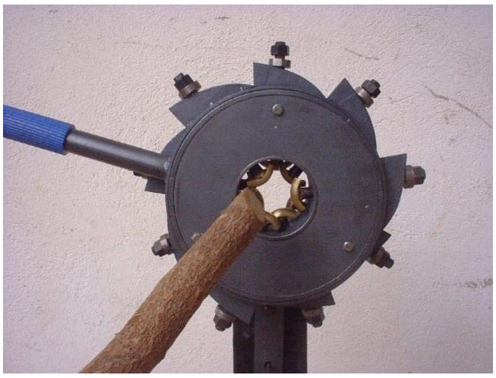


Figure 2.4: Cinnamon Rubbing Device – RUWEEKA-PG

This device is working in the same principle and sticks up to 5.6 cm diameter can be processed with it [4].

A simple mechanism is incorporated to the device which helps for inserting sticks to the rubbing device without any difficulties. Pressing or pulling the handle of the mechanism spring-loaded spindles can expand at once to insert the stick and then shrink it. Machine mounted in a stand could be rotated around its horizontal axis. This helps to change the rubbing ends of the sticks easily.

2.5. Cinnamon Processing Bench

This device helps to improve and modernize the cinnamon processing by enhancing the quality and quantity of the production, adhering to peelers comfort and health [4].

Figure 2.5: Cinnamon processing bench

At the moment cinnamon processing is very tedious and slow job. People works wearing dirty clothes in unhygienic state, sitting on the ground as a group with poor working posture. It causes health hazards, postural stress, fatigue and pain. Impurities are mix with products. Young generations cannot be attracted due to primitive technology.

This newly designed Processing bench consists of basically rotating comfortable chair with half rounded table which could be adjusted to suit with personal body dimensions. This equipment are now adopt in the estate sector, who may take the lead to change the technology of peeling by adding new production lines.

The machineries and equipment so far developed for cinnamon processing is proved to be an appropriate approach to break down the social stigmas associated with cinnamon peeling, to convert cinnamon processing in to a flow line operation, while attracting more people to combat the labor shortage and expenses incurred on labor.

Sri Lanka has a great opportunity to expand the export of cinnamon for two reasons. First, Sri Lanka is the largest producer as well as the leading exporter of cinnamon. Second, Sri Lanka Cinnamon has shown high financial benefits as per economic analysis. Therefore it is necessary to introduce improved technology mostly with mechanization in processing to upgrade quality and reduce costs. Today one of major constrains is the scarcity of labor for peeling of cinnamon and hence the cost of peeling represents over 50 percent of the cost of production [5].

CHAPTER 3 SELECTING A MECHANISM

3.1. Study the Cinnamon Peeling Method

Cinnamon Bark peeling operation is the main operation of the cinnamon manufacturing process. This is a most difficult and time consuming task. The quality of the main production totally depends on this operation. So the Cinnamon peeler should has the knowledge about the types and quality requirements of cinnamon products according to that he should decide the size of the bark. His skill and experience in the process will increase the productivity of the cinnamon production, Due to these factors this process has become a labor intensive process.

The mechanism of the cinnamon peeling process is focused mainly under this section. As described in above chapters Stainless Steel sharp knife is used to remove the bark from the stem. The reason for use stainless steel is the cinnamon bark will discolor if mild steel knife is used, then it will directly affect to the taste and quality of the cinnamon product. The steps involve in this process are described below.

- Cut the border of the bark deciding the width and length of it. The peeler should has an idea about the sizes of cinnamon products and he should study the nature of the cinnamon stick, according to that he should get rapid decision about the size of cinnamon bark.
- Cut the inside of the bark to remove the bark from the stem, the inside of the bark should be cut and pull out from the stem carefully. If the cinnamon stick is peel able one this operation is easy effortless than unpeel able stick, because the bond in between the stick and bark is high in unpeel able stick.
- Finally cut the edge of peeled bark to remove from stick –this is the final step of this operation, the place of this cut depend on decided length of the bark.

After peeled the bark from the Cinnamon Stick, check the straightness of the bark and fine cut carried out to keep the shape of the peeled cinnamon bark as required.

The size and shape of the bark is very sensitive to final production price of it. Therefore this is the main activity of cinnamon production which is affected to the final production price. So production price of the cinnamon totally depend on the skill of peeler. If the peeler unskilled or inexperienced person, then he produced product quality and price may be declined unexpectedly. So the optimum value of the production cannot be achieved.

This peeling process involves with a sharp knife, therefore this is a vulnerable process comparatively. Cinnamon peelers handle the knife quickly to achieve the daily target. Most of times peelers have get injuries under this operation though they wore rubber clips in fingers.

Drawbacks of current process

- The product quality highly depend on the skill of the bark peeler
- The efficiency of the process is not in required level and it depends on the bark peeler skill
- The safety of the current process is not in standard level, due to speedy work with sharp knife.
- The peeling workers have to work long time in same manner; it will affect uncomfortable feeling.

By considering above disadvantages in present bark peeling method, there is a high requirement of new peeling method which improve the efficiency, safety and product quality of the cinnamon products. Then it will increase the remuneration of the company and workers as well as demand of the product due to increase the quality of the products.

3.2. Study the Existing Methods for Bark Peeling

There are few bark peeling mechanisms exist in the industry. Because the complexity and difficultness of this process. So technology improvement in this regard is rare. Peeling techniques are used in various processes in industry such as log preparation process, fruit and vegetable preparation processes and Ayurvedic medicine processing process. Existing bark peeling mechanisms used in various activities are briefly discussed under this section [6].

3.2.1. Remove the Bark Scraping

This is a common and simple method. Hard chip is used here to scrape out the bark. The force applied on the chip determines the depth of the bark removed. However this is depend on the hardness of the bark. Bark can be removed by scraping the chip on the stick in upward or downward. But this process damages the removing bark. So if the quality of the bark consider, then this process is not suitable. Even though if the scraped wood stick is the final product, this is a good method.

3.2.2. Cut &Remove the Bark Using Sharp Knife

This is a fairly modernized method, good method for easily peel able sticks, but time consuming is high for unpeel able sticks. This is a manual method and the efficiency and quality depends on the skill of the worker. The safety of this method is in low level, strangers may be vulnerable easily from knife. The cutting method is varying according to the application and shape of the knife. For a normal knife, the boundaries of the bark should be cut firstly and the bark should be pulled out from the stem by entering the knife under the bark. The workers should have knowledge to determine the cutting boundaries according to the shape of the stick. The bark can be removed straight by a curved shape draw knife which is used for log cutting in furniture industry. The force and angle applied on the bark depends on the hardness of the wood stick. This method is suitable for both final products such as Bark or peeled wood stem.

3.2.3. Remove the Bark by Hammering

This is a basic technique. The impact force is used to break the bond in between bark and wood stem under this method. This method is used to remove bark in large scale. Because of doing this in small scale is time consuming and energy wasting activity. Large rotating drum is used normally to break out the bark from logs in large scale logs preparation process. The cross bars welded inside the drum help to brake the bark from wood stem. However this method might be suitable to logs those have hard barks, because it will waste the log. The quality of removed bark cannot be ensured here, since the bark is damaged and the sap is squeezed out under this method.

3.2.4 Remove the Bark by Grinding

This is a mechanized method. Grinding roll or disc is used to remove the bark from the log. The grinder is rotated in high speed by an engine or an electric motor as normal grinder. The shape and hardness of the grinding wheel should be selected according to the nature and hardness of the bark. Even hard bark can be removed easily and accurately using this method. The efficiency of this method is high compare with manual tool used method. However this method damages the bark when remove it, so rap may leak out from ripe wood sticks when grinding. Therefore this method is better for dry logs. This method is more suitable for the process which is get wood stems as final products.

3.2.5 Remove the Bark Using Vacuum

This is an innovative and complex method. The bark is pulled out from the stick using the vacuum force here. The force should be adequate to break the bond between the bark and wood stem. The removed bark size may be change according to the strength of the bond. Therefore a quality bark product cannot be achieved from this method. Fairly considerable cost has to be afforded to develop apparatus and vacuum pump.

3.2.6 Remove the Bark Using Chemicals

Here a chemical liquid is used to break the bond in between bark and wood stem. A chemical should be selected according to the bond of the bark and effectiveness to the final product. This method is suitable if final products bark and log. However it is a challenge to select a suitable chemical which can break a strong bond of wood stick and that is not affecting the quality of final product. So many developments should be taken place in this area to introduce proper chemical washing techniques for various products. The cost involvement in this method is fairly high due to high chemical cost and chemical handling equipment cost [7].

3.2.7 Remove the Bark Using Torsion

Under this method the bond of bark is broken by applying a torsion force on it. The amount of the force depends on the strength of the bond. But high strength bond may damage the bark without peel it. So this method is suitable for peel able and straight wood sticks. Still this technique has not been developed, so there are more opportunities to develop this technique. This method also can be used for get both products as final product.

3.3. Discussion of Methods

By examine existing bark peeling techniques as mentioned under this chapter, some techniques are not suitable to cinnamon bark peeling and some techniques cannot be applied directly to the cinnamon bark peeling process considering nature of the process and requirement of the bark quality. The existing bark peeling techniques are evaluated under the weighted main requirements of the proposed cinnamon bark peeling method [8].

Main Requirements of the technique

1. The proposed method should be easily applicable to the cinnamon bark peeling process – Suitability to Remove Cinnamon Bark (Weight 0.3)
2. The proposed method should be protect the quality of the peeled cinnamon bark as required – Quality of Removed Cinnamon Bark (Weight 0.5)
3. The cost involvement to implement the technique for cinnamon bark peeling should be low – Low Cost Method to Remove Cinnamon Bark (Weight 0.2)

Evaluating categories are mentioned below, each level has given individual marks from 100.

High – 80%   Medium – 60%   Low – 40%

The each value after multiplied the weight of each category has been mentioned in the table below.

Ex: X1 - High = 80% x 0.3 = 24%

The technique adaptation to the process has been calculated by adding the values of each categories and it appears at the last column of the table below.

Table 3.1: Bark Peeling Technique Evaluation

Bark Removing Technique	**Suitability to remove bark /(x1)**	**Quality of removed bark /(x2)**	**Cost of the Technique /(x3)**	**Adoption to the Process /(x1+x2+x3)**
Scraping	High 24%	Medium 30%	Low 16%	**Applicable – 70%**
Cutting	High 24%	High 40%	Medium 12%	**Applicable – 76%**
Hammering	Medium 18%	Low 20%	Medium 12%	Inapplicable – 50%
Grinding	Medium 18%	Low 20%	Medium 12%	Inapplicable – 50%
Vacuum	Medium 18%	Medium 30%	High 8%	Considerable – 56%
Chemical Wash	Medium 18%	Low 20%	High 8%	Inapplicable – 46%
Torsion	Low 12%	Medium 30%	Medium 12%	Considerable – 54%

Considering the data in the table cutting and scraping methods have got higher marks than other methods. So these two methods can be selected as most applicable methods than others. Therefore other methods cannot be used for cinnamon bark peeling. Because the main production of this is cinnamon barks and it should be in good finish and quality standard. The cinnamon bark peeling process is divided in two main tasks for the simplicity. Firstly the boundary of the bark should be cut according to the required standard size. Secondly remove the bark from the wood stem. Therefore cinnamon bark peeling process involve two operations, first one is cut the bark and second one is remove the bark from the stem. The bark removing methods which were selected from above table are categorized under these main operations of Cinnamon bark peeling to select suitable techniques for each operation.

Cinnamon Bark Boundary cutting (Sizing) Methods

- Size the bark to required standard by cutting (Shear force)
- Size the bark to required standard by scraping (Tear force)

Cinnamon Bark Removing Methods

- Remove the bark from the stem by cutting
- Remove the bark from the stem by scraping

The Design Tree method is used to select the appropriate methods to cinnamon bark peeling machine [9].

3.4. Design Tree to Selecting Appropriate Mechanisms

Engineer's Perspective – Design a Cinnamon Bark Peeling Equipment

Principle Problem PP1– Cutting the boundaries of Cinnamon Bark

Solution S1PP1 – Cut boundaries of the bark to required size using shear force

Principle Problem PP2 – Removing the Cinnamon Bark from the wood Stem

Solution S1PP2 – Remove the bark from the stem by cutting

Solution S2PP2 – Remove the bark from the stem by scraping

Dependent Problem DP – Changing the sizes of bark

Solution S1DP – Adjust the bark size manually

Secondary Problem SP – Production Cost

Solution S1SP – Low Cost Simple Mechanism

Solution S2SP – High Cost Complex Mechanism

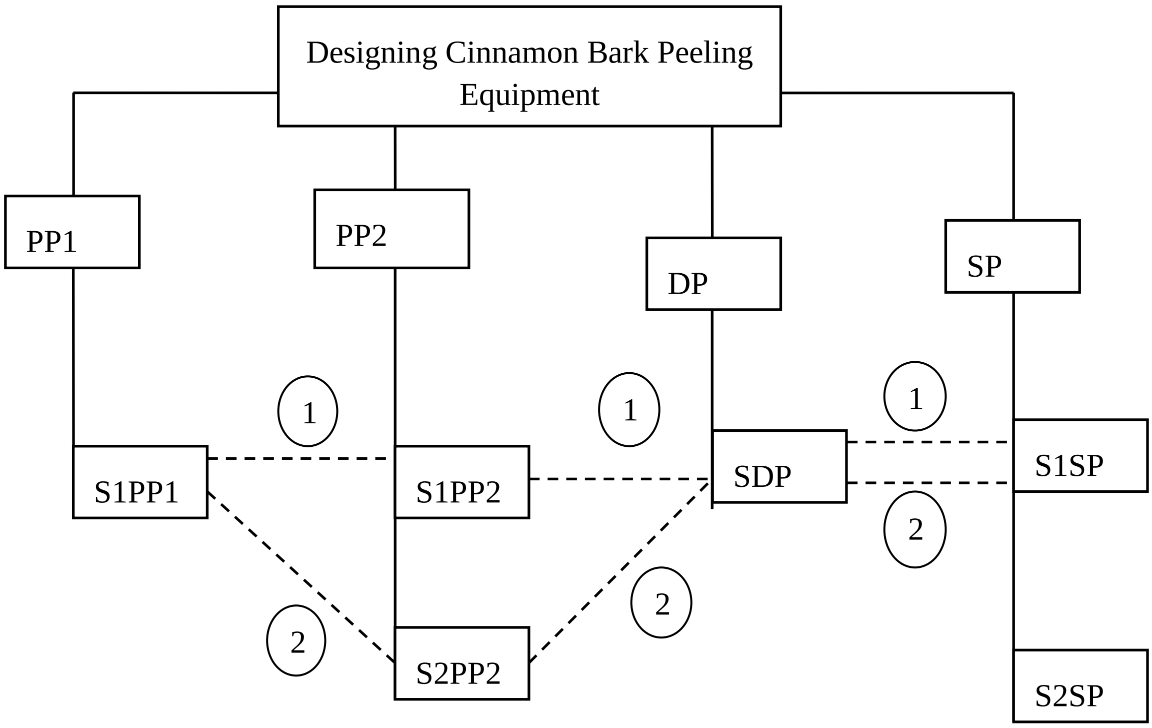


Figure 3.1: Design Tree – Design Cinnamon Bark Peeling Equipment

There are 1X2X2 = 4 alternative solution sets. These candidate solution sets are mentioned below.

S1PP1 – S1PP2 – SDP – S1SP

S1PP1 – S1PP2 – SDP – S2SP

S1 PP1 – S2PP2 – SDP – S1SP

S1PP1 – S2PP2 – SDP – S2SP

Alternatives are reduced to 2 sets by considering only the low cost production for secondary problem.

These possible solutions have been shown by dotted lines in the design tree.

Candidate Solution Sets

S1PP1 – S1PP2 – SDP – S1SP

S1PP1 – S2PP2 – SDP – S1SP

First solution represent the existing manual method, hence second solution is selected to propose a simple equipment.

3.5. Design Constrains

Cinnamon Bark peeling generally carried out by manually as described earlier. The mechanization of this process should be implemented step by step. Still this process is in primary stage. Therefore introducing a manually operated simple tool is better than highly complicated heavy machine for this process. Most of cinnamon processing companies are operating in small and medium scale. Therefore machine cost should be low. Because of they do not tend to invest high capital cost for the machines. But they need to increase the efficiency of the machine within reasonable budget. Considering these practical factors, the machine or component should be designed under below guidance.

Cinnamon Bark Peeling efficiency should be higher than 400g per hour

The cost of the machine should be below Rs. 10,000/=

Then the machine may be a manual operating component

Its weight should be below 1kg, because it should be a hand held machine.

It should be a mechanically operated machine, because of cost and weight of electrically operated machines are higher than required levels, due to a battery and motor have to be used for these type machines.

Material of the cutting blade should be Stainless Steel, because the cutting lines of the bark may be discolored by other materials and it directly affect to the quality and taste of the final product.

CHAPTER 4 PROPOSED DESIGN

4.1. Design Concept

Considering design constrains mentioned in previous chapter, the equipment should be manually operated hand held equipment. After studied the existing process design objectives, a prototype equipment was designed as satisfy the below design factors [10].

- Simple mechanism
- Increase the efficiency
- Portable
- Ease of use (user friendly)
- Maintainability
- Safety
- Durability
- Repeatability

Highest weight has been given for Increase the efficiency and Ease of use for the design. Because of those are the main design objectives of the equipment.

The mechanisms which are selected from previous chapter are applied to propose a conceptual design for the application.

The Application of the Design –	Peeling the Cinnamon Bark
Selected Mechanism for Design –	Shear cut by Sharp Knife to cut the boundaries of the bark
	Peel out by Sharp cable to remove the bark from the stem

4.1.2. Design Dimensions

Dimensions of the cinnamon bark peeling device are selected considering below factors [11].

- Suitability to operating by hand.
- Sizes of peeling Cinnamon sticks.
- Available sizes of material in the market.
- Adequate Strength of the parts of the component

The handle of the instrument has been made with adequate diameter and length to easily capture the instrument by whole hand as well as that is able to give an adequate force to the cinnamon stick to achieve proper cutting.

4.2. Material Selection

When selecting the material for a design, below mentioned factors also should be considered rather than the strength of the material [11].

Capacity of the Design

Application of the Design

Availability of the material

Operating Conditions

Environmental Conditions

Handle -	Moderate tensile strength	Stainless Steel
	Machinability	Aluminum
	Corrosion resistivity	Cast Iron (Selected)
	Low Weight	Wood
Fork -	Moderate tensile strength	Stainless Steel (Selected)
	Machinability	Aluminum, Mild Steel
Knife -	High tensile strength	Stainless Steel (Selected)
	Corrosion resistivity	High Carbon Steel
Cable -	High tensile strength	Stainless Steel (Selected)
	Corrosion resistivity	Alloy Steel
Spring -	High tensile strength	Gun metal
	Corrosion resistivity	High Carbon Steel

Considering these design objects and constrains, developed a prototype equipment as shown below figure for testing purposes. This tool is used to determine cutting force, Best cutting angle and identify the defects of the equipment.

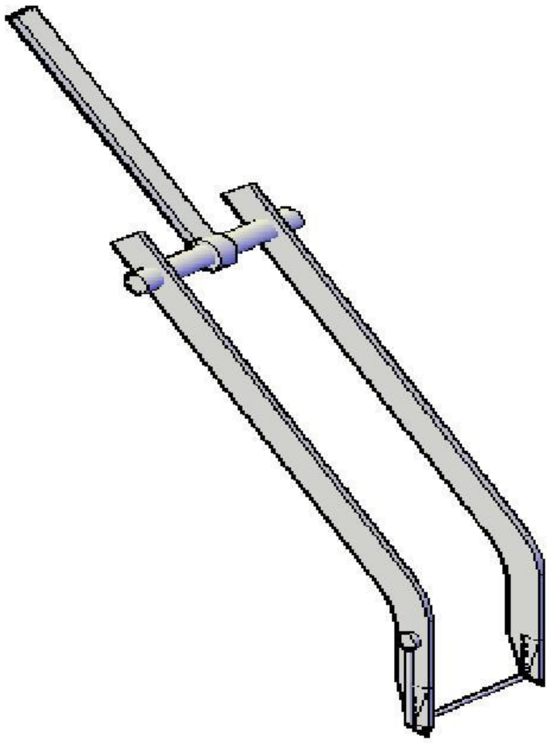


Figure 4.1: Prototype Cinnamon Peeling Equipment

4.2.1. Calculate Maximum Cutting Force

The maximum force exerted on the cinnamon stick through the cutting equipment was measured by the weight scale which was placed under the cinnamon stick as shown in the figure. The maximum value of the cutting weight can be get using this test for each diameter of cinnamon sticks. The cutting force relevant to the weight is calculated by the formula mentioned below.

Cutting Force, F_c = Cutting Weight, Wc X Acceleration of Gravity, g (9.81 ms^{-2})

Figure 4.2: Cutting Load Measuring

The summarized data got by the test is shown in below table for 8 samples.

Table 4.1: Maximum Cutting Load on the Peeling Device

Diameter mm	Cable Cutting Length mm	Cutting Thickness mm	Max. Cutting Weight /Kg	Max. Cutting Force/N
18.2	19.5	0.4	1.7	16.7
20.7	27.0	0.4	2.2	21.6
24.5	32.3	0.7	3.5	34.3
30	40.3	0.9	3.9	38.3
34.5	44.3	1.2	4.6	45.1
40.2	51.6	1.3	5.7	55.9
44.6	54.8	1.5	6.9	67.7
48.3	61.2	1.7	9.4	92.2

Following the result in the table, maximum force on the cinnamon stick is 92.2 N. But considering the experimental errors, maximum cutting force on the equipment is selected as 100 N.

Suitable safety factor to the design is selected by referring general recommendations of the safety factor which are mentioned below.

Table 4.2: Safety Factor for Mechanical Design

Applications	Factor of Safety
For use with highly reliable materials where loading and environmental conditions are not severe and where weight is an important consideration	1.3 - 1.5
For use with reliable materials where loading and environmental conditions are not severe	1.5 - 2
For use with ordinary materials where loading and environmental conditions are not severe	2 - 2.5
For use with less tried and for brittle materials where loading and environmental conditions are not severe	2.5 - 3
For use with materials where properties are not reliable and where loading and environmental conditions are not severe, or where reliable materials are used under difficult and environmental conditions	3 - 4

Source:http://www.mechengg.net/2015/02/factor-of-safety-used-in-machine-design.html

Since the loading and environmental conditions are not severe for the application, and reliable materials are used for the design. Safety factor is selected as 2, therefore the design load on the forks of the equipment is calculated as 200 N.

4.2.2. Find Suitable Fork Angles of the Equipment

Three cutting devices which have various angles are distributed to the 8nos. cinnamon peelers, and most suitable angle was selected based on them preferences. Peelers preferences for three peeling instrument angles are tabulated in below table.

Table 4.3: Cinnamon Peelers Feedback for Various Fork Angles

	Fork Angles		
Peeler No.	90deg.	135deg.	150deg.
Peeler 1	good	good	good
Peeler 2	fair	good	fair
Peeler 3	fair	fair	fair
Peeler 4	fair	good	good
Peeler 5	good	good	fair
Peeler 6	fair	good	fair
Peeler 7	good	good	good
Peeler 8	good	fair	fair

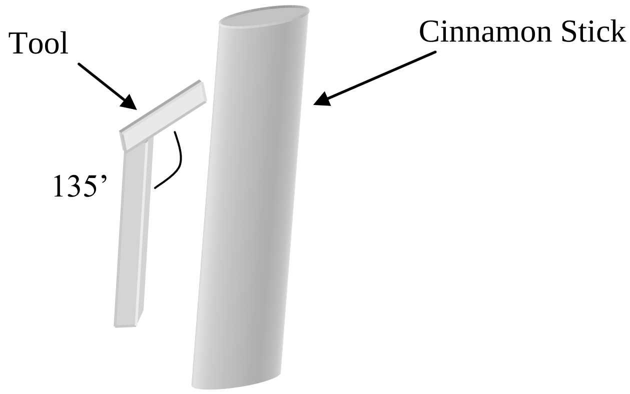


Figure 4.3: Fork Angle of the Peeling Device

As per the peelers’ feedbacks, six persons have mentioned that better fork angle is 135 degrees. In addition, they pointed out that this angle gives convenient orientation to hand when operate it, as shown in above figure. Therefore considering preference &ergonomic features, selected the fork angles for final design as 135 deg.

4.2.3. Identified Drawbacks of the Prototype

The prototype model created with selected angle was handed over to three cinnamon peelers separately to identify the drawbacks of the equipment. The questions mentioned below were asked from them after one hour operating time.

1. What are the differences in this method and old method?
2. Can you achieve the target from this equipment?
3. What are the propose improvements of the device to achieve the aim?

The answers got from the peelers are summarized below.

- All peelers decided that the introduced peeling method is convenient than convention method.
- Two peelers said that they can partially achieve the target, one peeler had mentioned that he can't achieve the target. But they deemed that with the improvements aim may be realized.
- They suggested improvements are as follow.
    1. There should be a quick forks adjusting facility for avoid unnecessary tool setting times.
    2. Cutting cable should have an ability to cut wider barks (at least 40 mm) which are required for making Cinnamon quills.

4.2.4. Forks Adjusting Mechanism

Forks adjusting mechanism was proposed as mentioned below to satisfy the requirement of Cinnamon peelers. This is a simple screw adjusting method. A thread bar that created threads in both ways from the center, was used to achieve the forks adjusting functions. When rotate the knob of the adjusting bar both forks run along the bar guiding the handle connecting bar.

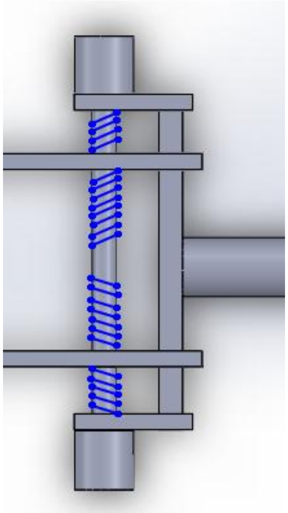


Figure 4.4: Forks Adjusting Mechanism

4.2.5. Cutting Cable Assembly

The sharp cable has been fixed in between two forks such as it is able to scrap the cinnamon bark from the stem effortlessly.

The cutting cable should have adequate tension ability to get the curve shape of the wood stem. Apart from that the cable should be able to drag through knots of the stick without damage. In addition to that the cable assembly should have special feature to cater adjusting ability of the forks. When adjust the forks gap as the size of Cinnamon stick, the cable cutting length also should be adjusted accordingly. The cable mounting bar has been introduced to facilitate this feature to the cable. The cable is mounted to the bar at the ends of it with the adjustable springs. The adjusting length of the forks are claimed by the cable where goes along the bar as shown in below figure.

4.2.6. Analysis Force Distribution on Cutting Cable

The bark cutting force mainly exert through the cutting cable of the equipment. This cable should distribute cutting force around the stick to cut the bark. This force is mitigating along the cable from the middle of it to the ends. The force distribution of the cutting cable can be calculated as mentioned below.

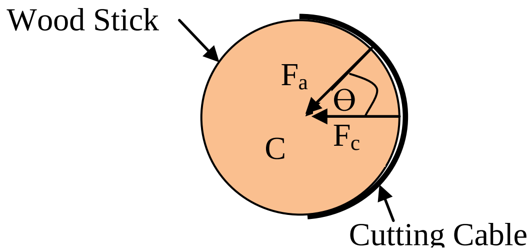


Figure 4.5: Forces on Cutting Cable

Force exert on stick at the middle of the cable (Maximum) $= F_c$

Force exert on the stick at "Θ" angle from the middle of cable $= F_a$

Therefore, $F_c \text{ Cos } (\Theta) = F_a$

When F_c taken as 100 N

Table 4.4: Force Distribution of Cutting Cable

No	Angle (Θ) Rad.	Angle (Θ) Deg.	Max. Force on Cable /N	Force Dist. /N
1	1.57	90	100	0.08
2	1.31	75	100	25.95
3	1.05	60	100	50.05
4	0.79	45	100	70.74
5	0.52	30	100	86.62
6	0.26	15	100	96.60
7	0	0	100	100.00
8	-0.26	-15	100	96.64
9	-0.52	-30	100	86.78
10	-0.79	-45	100	70.38
11	-1.05	-60	100	49.76
12	-1.31	-75	100	25.79
13	-1.57	-90	100	0.08

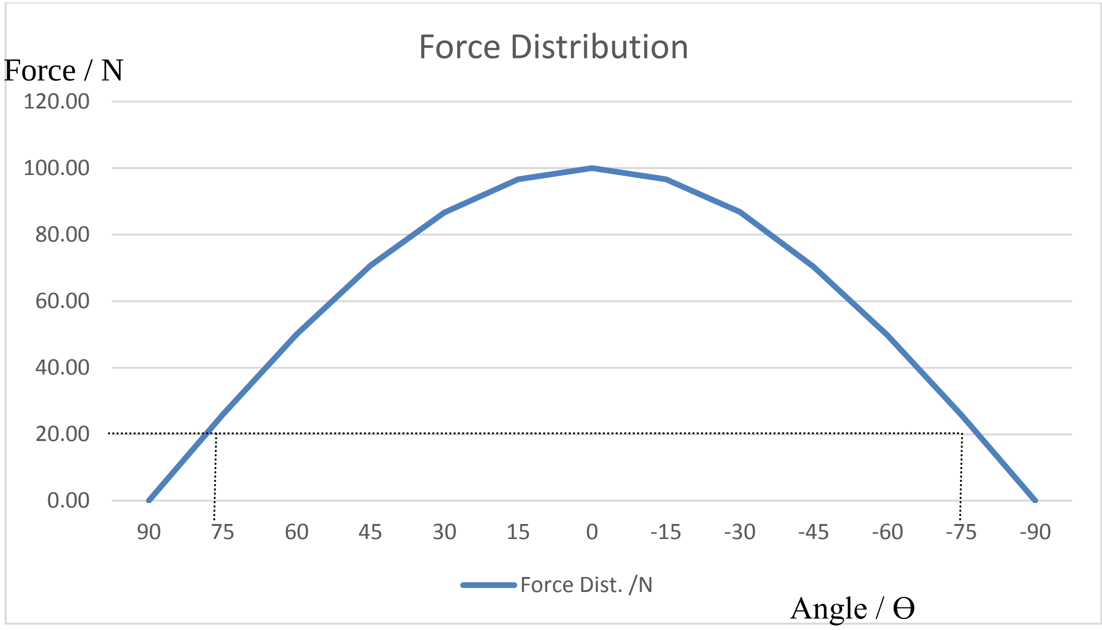


Figure 4.6: Force Distribution along Cutting Cable

This is a function of Cos ϴ, then values will be zero at the ends of the cable (90'). Bark cutting ability is decreasing when bark length is increase around the stick. When selected a large cutting angle, edges of the bark may not cut properly due to applied force on the bark is minimum.

But more than 25% of the applied force is utilized below 75' in the graph. Therefore 150' cutting angle is selected as optimal cutting part of the cable. Then whole 360' of the stick has to be covered by three times such as two 150' cuts and one 60' cut.

Maximum bark width can be cut from various diameter sticks are tabulated below.

Table 4.5: Maximum Cinnamon Bark width for Various Stick Diameter

Diameter of the Stick /mm	Max. Cut Angle /Rad	Max. Cut Angle /Deg.	Max. Bark width /mm
10	2.62	150	13.1
15	2.62	150	19.65
20	2.62	150	26.2
25	2.62	150	32.75
30	2.62	150	39.3
35	2.62	150	45.85
40	2.62	150	52.4
45	2.62	150	58.95
50	2.62	150	65.5

The width of the bark is important to the production quality. Large diameter quills can be produced using wider barks. If the bark width is not enough to achieve required diameter of quills, two bark piece can be used by overlapping more than 25% of them. Then bark width can be increased maximally by 50%. Hamburg is the highest quality cinnamon product which has highest quills diameter according to the first chapter. However Continental is the most popular and cost effective product in Sri Lanka, though it's quality is next to the Alba.

The maximum bark width that can be cut using the designed equipment, is varies according to the diameter of Cinnamon stick as shown in the table below. For produce Hamburg quality Cinnamon, large diameter sticks are needed (more than 50mm) those are rare in the industry, then Mexican size two bark pieces have to be used for that.

Table 4.6: Cinnamon Bark width for Product Grading

Cinnamon Quills Dia. /mm	Cinnamon Quality Grading	Cover Bark Width /mm	Cinnamon Stick Dia. /mm
6	Alba	18.84	14.38
10	Continental	31.4	23.97
13	Continental	40.82	31.16
16	Continental	50.24	38.35
19	Mexican	59.66	45.54
25	Hamburg	78.5	59.92
32	Hamburg	100.48	76.70

4.2.7. Selecting Optimum Blades Angle

Fork blades are used to cut the edges of the cinnamon bark. When selecting the angles of blades, maximum cutting angle of the cable is consider, if edges of the bark are able to cut easily, then the bark can be separated from the stem effortlessly. Though the force exert on the bark at the edges of it is low. Therefore the blades angles should be 90’ to the bark at the maximum cutting angle of it.

Maximum cutting angle is 150’ as discussed in prior section. Then the blades should be focused to the center of the stick, as create a 90’ angle with the bark to ensure proper cut as shown below picture.

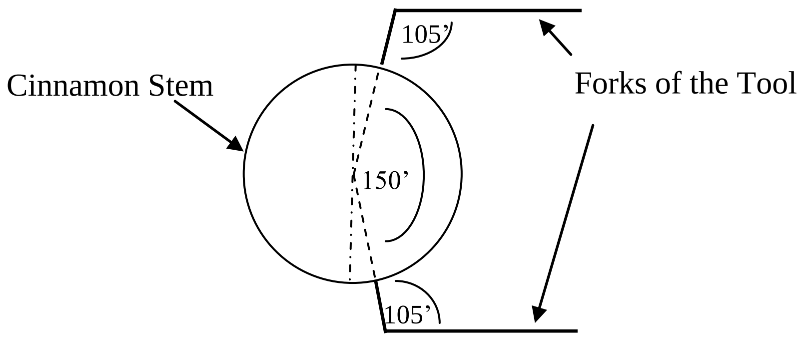


Figure 4.7: Blade Angle of the Peeling Equipment

Blade angle is calculated according to the geometry of the sketch. Then angle in between blade and fork come as 105’ deg.

Cutting tips of the instrument have to be bended by 75 deg. angles towards each other, due to this significant shape of the cutting blades are able to touch the cinnamon stick by 90 deg. to accomplish a proper cutting.

4.3. Special Features of the Improved Design

According to identified drawbacks and defects of the prototype equipment as mentioned in prior sections, some special features were added to the design to achieve better function and efficiency. Those are mentioned in below.

- Forks have angles for convenient handling purpose
- Fork Blades have angles for catching wider bark on the stick
- Adjusting Mechanism to adjust the cutter according to sizes of sticks
- Cable assembly for proper cutting and adjustments

4.4. Design Calculations

The dimension details of the improved design is attached in the Appendix A according to satisfy the specification of the design.

Under this section stress calculations were carried out for the final design to ensure the operation of the equipment without failure.

Maximum Cutting Force on the forks of the equipment = 100N

Safety Factor for the design = 2 [12]

Therefore Design force on the equipment = 200 N

Then, Design force per fork = 100 N

All components of the equipment except cutting cable are designed for minimum yield stress of the material for avoiding deformations of components.

For the Cutting Cable:

Tensile Strength Calculation

Maximum Tension of Cutting cable = 100 N

Cross section area of the 0.5 mm dia. cable = 0.196 mm^2

Maximum Tensile Stress of the cable = 510.2 N mm^{-2}

Maximum Tensile strength <=Ultimate tensile strength of the Steel

Ultimate Tensile strength of Stainless Steel = 600 Nmm^{-2}

510.2 N mm^{-2} < 600 Nmm^{-2}

Therefore Cutting Cable is safe under maximum load applied.

4.4.1 Calculate Stresses on Handle

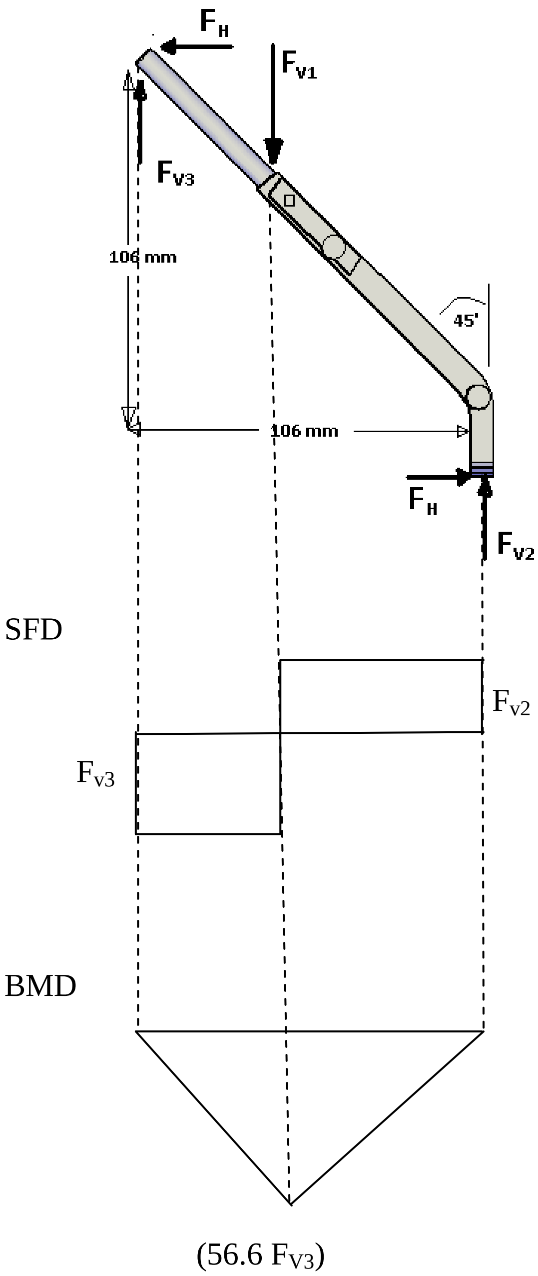


Figure 4.8: Forces on the Handle

Pressing Force exerted on the Handle, $= F_{V1}$

Holding force exerted on the Handle, $= F_{V3}$

Bark cutting force per fork (Max.) $F_{V2} = 100$ N

Bark Shear cutting force per fork (Max.) $F_H = 50$N

Diameter of Handle, D = 25 mm

For Vertically Equilibrium

$F_{V1} = 2F_{V2} + F_{V3}$

Getting Moments at the handle end,

56.6mm X F_{V1} = 106mm X $(2F_{V2} + 2F_H)$ = 106mm X 300N

Therefore, $F_{V1} = 561.8$ N

Then, $F_{V3} = F_{V1} - 2F_{V2} = 361.8$ N

Calculate Shear Stress, $\tau = VQ / Ib$ [13]

Maximum Shear force apply at the F_{V1} load apply point of the Handle,

Maximum Shear Force, $V_{V1max} = 561.8$ N

$Q = Ay = (\pi D^2/4) \times (D/3\pi) = 1302.08\ mm^3$

$I = (\pi D^4/64) = 19174.76\ mm^4$

Maximum Shear Stress, $\tau_{max} = (561.8N \times 1302.08\ mm^3) / (19174.76mm^4 \times 25mm)$

$$\boldsymbol{\tau_{max} = 1.53\ Nmm^{-2}}$$

Allowable shear stress of Mild Steel

$\tau_{Allowable} = 250\ Nmm^{-2}$ for Mild Steel

For the safe operation of the connecting bar

$\boldsymbol{\tau_{CBmax.} < \tau_{Allowable}}$

$1.53\ Nmm^{-2} < 250\ Nmm^{-2}$

Therefore Connecting bar is safe under operation.

Bending Moment Calculation

Maximum Bending moment apply at the maximum force applied point of the handle.

$M_{max.} = F_{V3}$ X 56.6 mm = 361.8 N X 56.6 mm = 20477.88 Nmm

Bending Stress, $\sigma_B = My / I$

Maximum Bending Stress, $\sigma_{B\ max.} = M_{max} X y / I$

$\sigma_{B\ max.}$ = 20477.88 Nmm X (D/3π) / 19174.76 mm^4

$\sigma_{B\ max.}$ = 2.83 Nmm^{-2}

Allowable Bending stress of Mild Steel [14]

$\sigma_{B\ Allowable}$ =250 Nmm^{-2}

For the safe operation of the Handle

$\sigma_{B\ max.} < \sigma_{B\ Allowable}$[13]

2.83 Nmm^{-2} < 250 Nmm^{-2}

Therefore Mild Steel handle is safe under operation.

4.4.2. Stress Calculation for the Connecting Bar of the Handle

Consider Vertical Load on Handle Connecting Bar:

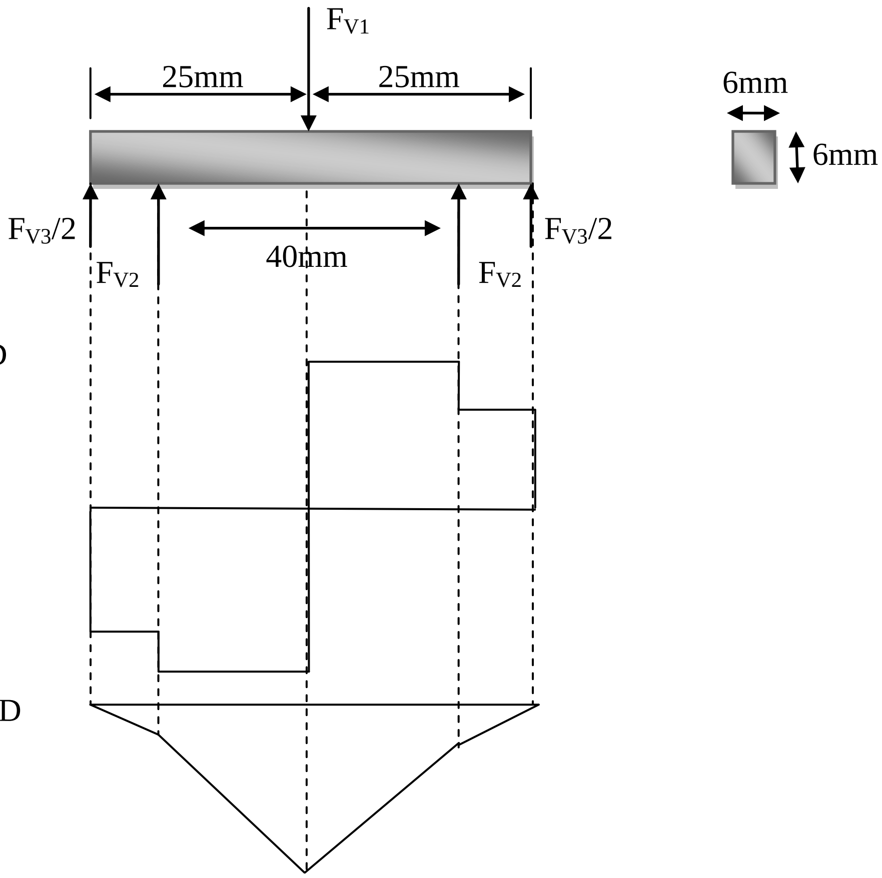


Figure 4.9: Forces on the Forks

Shear Stress, $\tau = VQ / Ib$

Maximum Shear force is acting on the middle of the bar,

Maximum shear force on connecting bar, $V_{CB\ max.} = F_{V1} = 561.8$ N

Therefore Maximum shear stress, $\tau_{max} = V_{CB\ max.}$ Q/ I b [13]

For a Solid Box Bar (6mm X 6mm)

Q = Ay = 3mm X 6mm X 1.5mm = 27 mm^3 [13]

I = $bh^3/12$ = 6mm X 6^3 $mm^3/12$ = 108 mm^4 [13]

$\tau_{CBmax.}$ = 561.8 NX 27 mm^3 / 6mm X 108 mm^4 = 23.41 Nmm^{-2}

$\boldsymbol{\tau_{CBmax}}$ **= 23.41 Nmm^{-2}**

Allowable Shear stress of the Mild Steel is

$\tau_{Allowable}$= 250 Nmm^{-2}

For the safe operation of the connecting bar

$\boldsymbol{\tau_{CBmax.} < \tau_{Allowable}}$

23.41 Nmm^{-2}<250 Nmm^{-2}

Therefore Connecting bar is safe under operation.

Bending Stress Calculation for the connecting bar

Bending Stress ,σ_B = My / I [13]

For a box, y = h/4 = 6mm/4 = 1.5 mm

For a box, I = $bh^3/12$ = 108 mm^4 [13]

Maximum bending moment is acting at the middle of the bar.

$M_{CB\ max}$ = (180.9 N X 25mm) + (100N X 20mm) = 4522.5 Nmm + 2000 Nmm

$M_{CB\ max}$ = 6522.5 Nmm

Therefore $\sigma_{B\ max}$ = $M_{CB\ max}$ X y / I = 6522.5 Nmm X 1.5mm / 108 mm^4

$\boldsymbol{\sigma_{B\ max}}$ **= 90.6 Nmm^{-2}**

Allowable Bending stress of Mild Steel [14]

$\sigma_{B\ Allowable}$ =250 Nmm^{-2}

For the safe operation of the Mild Steel connecting bar

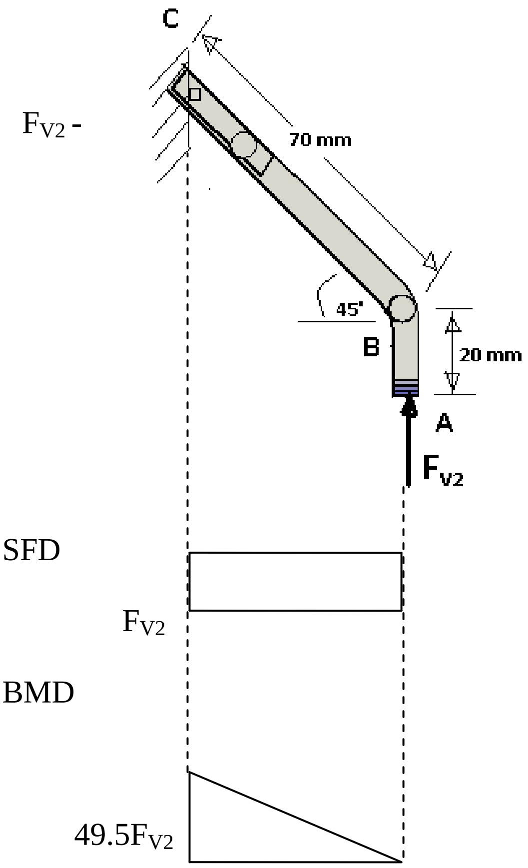
$\boldsymbol{\sigma_{B\ max.} < \sigma_{B\ Allowable}}$

90.6 Nmm^{-2}<250 Nmm^{-2}

Therefore Mild Steel handle is safe under operation.

4.4.3. Stress Calculation for a Fork

For the simplicity of the calculation consider the end C has been fixed.



Maximum Cutting force = 100 N

w – Width of the fork = 12.5 mm

t – Thickness of the fork = 4 mm

d – Pin Diameters = 6 mm

Figure 4.10: Force on the Blade of the Fork

Considering A-B part of the fork

Maximum Axial force acting along A-B Part

F_{V2} = 100 N

Calculate the compressive stress on the part

Maximum stress take place at the Minimum Cross section Area of the part, It is at the point B pin jointed area.

Then, $A_{min.} = t(w-d) = 4 \text{ mm} \times (12.5 - 6) \text{ mm} = 26 \text{ mm}^2$

$\sigma_{C\ max.}$ = 100 / 26 mm^2 = **3.85 Nmm^{-2}**

Allowable compressive stress of the Stainless Steel is

$\sigma_{C\ Allowable}$ = 200 Nmm^{-2}

Consider safe operation for the A-B part of the fork

$\sigma_{C\ max.} < \sigma_{CAllowable}$

3.85 Nmm^{-2}<200 Nmm^{-2}

Therefore A-B part of the fork is safe under operation.

Considering B-C part of the fork

Axial Force acting, F_{V2} Cos 45’ = 100 /1.414 = 70.7 N

This is lower than the acting force on A-B part, therefore compressive strength is not considered here.

Calculate Shear Stress acting on the Fork

Maximum Shear Force acting on the fork, $V_{max.}$ = 100 N

Shear Stress, τ = VQ / Ib [13]

For the rectangular bar

Q = Ay = 12.5mm X 4mm X 3.125mm = 156.25mm^3 [13]

I = $bh^3/12$ = 4mm X 12.5^3 mm^3 / 12 = 651.04 mm^4 [13]

Therefore, $\tau_{max.}$= (100 NX156.25mm^3) / (651.04 mm^4 X 4mm)

$\tau_{max.}$ = 6.0 Nmm^{-2}

Allowable Shear Stress for Stainless Steel

$\tau_{Allowable}$ = 200 Nmm^{-2}

For the safe operation of the Fork

$\tau_{CBmax.} < \tau_{Allowable}$

6.0 Nmm^{-2}<200 Nmm^{-2}

Consider Shear Stress on the Stainless Steel pin at the point B

Shear force on the pin, $S_{P\ max.}$ =100N

Therefore, Shear Stress on the pin, $\tau_{P\ max.}$ =100 N X 4 / πd^2 [13]

$\tau_{P\ max.}$ = 3.54 Nmm^{-2}

Allowable Shear strength of Stainless Steel, $\tau_{allowable}$=200 Nmm^{-2}

For safe operation, $\tau_{P\ max.} <= \tau_{allowable}$

3.54 Nmm^{-}2<200Nmm^{-2}

Consider moment at the fixed end C

$M_{C\ max.}$ = 100 N X 70 cos 45' mm = 4949.75Nmm

Bending stress at point C, $\sigma_{B\ max.}$= $M_{C\ max}$ X y. / I [13]

$\sigma_{B\ max.}$= 4949.75Nmm X 6.25mm / 651.04 mm^4

$\sigma_{B\ max.}$= 47.52 Nmm^{-2}

For safe operation, $\sigma_{B\ max.} < \sigma_{BAllowable}$

Allowable Bending Stress for Stainless Steel

$\sigma_{B\ Allowable}$= 200 Nmm^{-2} [15]

47.52 Nmm^{-2}<200 Nmm^{-2}

Therefore the Fork is safe under the operation.

4.5. Detailed Design

The equipment should be get from one hand and operate easily. Therefore when we consider the equipment dimensions, sizes of cinnamon sticks and size of cutting cinnamon barks as well as the size of hand also should be considered.

Diameter of Cinnamon sticks – 20mm to 40mm

Average Length of Cinnamon Sticks – 1100 mm

Width of cutting barks – 10mm – 65mm

Safety Factor of the Design – 2

Considering above mentioned details, the forks of the equipment should have the ability to adjust them up to 50mm. for Maximum angle 150 deg.

Therefore maximum peeled bark width $= \frac{10\,\pi\, r}{12} = \frac{31.4 \text{ X } 25 \text{ mm}}{12}$

$= 65.4\text{mm}$

4.6. Stress Analyses

Stress analysis was proceeded using Solid Works software. The final design was drawn as a 3D model as shown below for generate Detailed Drawings and analysis.

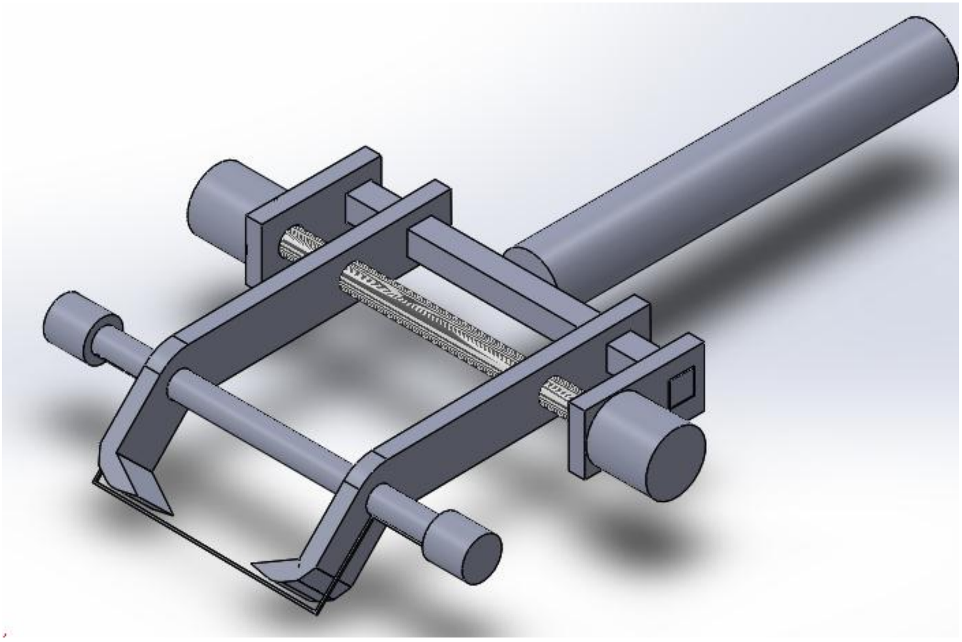


Figure 4.11: Final Design of Cinnamon Peeling Equipment

Von Misses stress exerted on the equipment under the maximum load operation is shown in below figure. The equipment is in safe mode under the operation due to the maximum stress is lower than allowable stress. The maximum load on the equipment has been calculated here by considering safety factor as two.

Maximum Cutting force on the tool = 100 N

Then tool design load considering safety factor = 200 N

Therefore Design Load per Fork =100 N

Maximum stresses are generated on the handle connecting bar and on the fork blades of the equipment. But this is less than the allowable stress of the each components' materials according to the given details

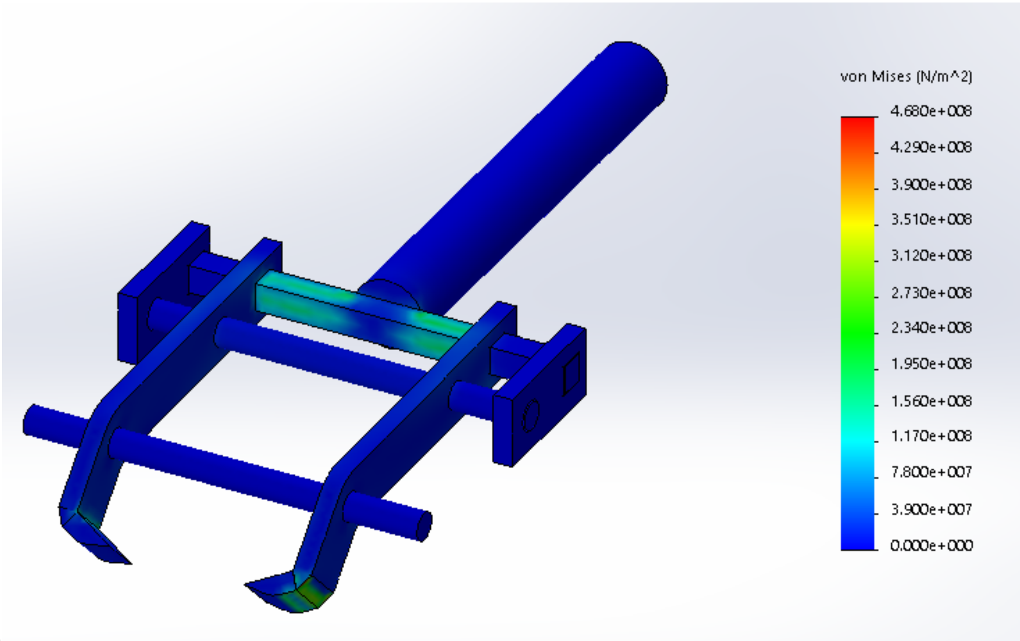


Figure 4.12: Stress Analyze of Bark Peeling Equipment

The maximum deformation when the equipment is operated under maximum load is shown in below figure.

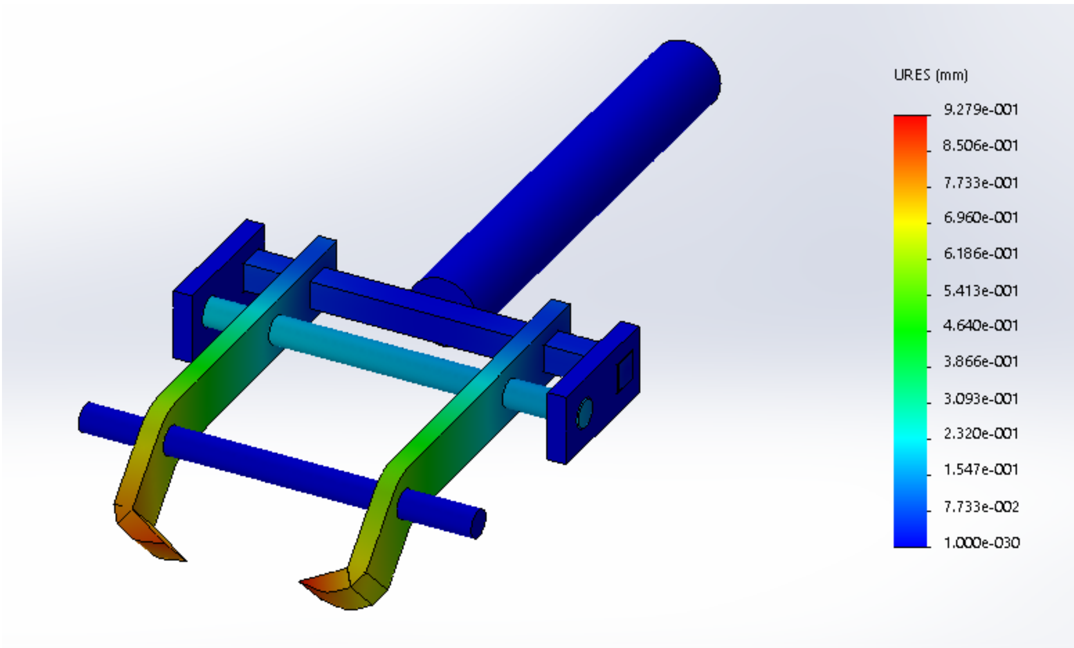


Figure 4.13: Deformations of Peeling Equipment

A complete stress analysis report generated by Solid Works software is attached in the Appendix B.

4.7. Cost Analyses

Mainly the cost incur to the Cinnamon peeling equipment can be divided in two groups. Cost components for material and cost components for manufacturing. Therefore manufacturing process of each component has to be studied firstly. For the simplicity of analysis the equipment is divided to four main components as mentioned below. The time taken for each manufacturing steps are mentioned in the brackets following the actually measured values [18].

4.7.1. Manufacturing Steps

I. Manufacturing steps fora fork

1. Size a 4 mm X ½" mm S/S Bar 6" - (labor hrs – 0.20)
2. Bend the bar by 45' angle to its longitudinal axis at the 1" from the end Manual press machine can be used for this process. – (labor hrs – 0.25)
3. Make two holes according to the fork drawing using bench drill machine. – (labor hrs – 0.30)
4. Make and sharpen the S/S cutting tip, Cutting and Grinding machines are used for this process – (labor hrs – 0.50)
5. Weld a S/S cutting tip about 15mm from the bended edge of the fork. TIG welding plant has to be used for this process.– (labor hrs – 0.25)

Total Labor hours spend to make two forks is 3 labor hrs.

II. Manufacturing steps for Handle

1. Size the 1" dia. handle bar as per required, using lathe machine - (labor hrs – 0.25)
2. Size the 6mm squire connecting bar according to the drawing, shaping machine is used to this process - (labor hrs – 0.50)
3. Weld handle bar & connecting bar, using arc welding – (labor hrs – 0.25)

Total Labor hours spend to make handle assembly is 1 labor hr.

III. Manufacturing steps for adjusting bar assembly

1. Size the 6mm adjusting shaft according to the drawing, using lathe machine - (labor hrs – 0.25)
2. Make threads on the shaft in both direction as per required, using lathe machine - (labor hrs – 0.50)

3. Size two brackets of the adjusting shaft - (labor hrs – 0.30)
4. Drill the holes on the bracket according to the drawing, Bench Drill machine is used for this process - (labor hrs – 0.20)
5. Weld two brackets to both ends of handle connecting bar using arc welding - (labor hrs – 0.25)

Total Labor hours spend to make Adjusting bar assembly is 1.5 labor hrs.

IV. Manufacturing steps for Cable assembly

1. Select and Size the cutting cable as per required - (labor hrs – 0.20)
2. Size the 6mm dia. Cable fixing shaft according to the drawing, late machine is use to this process - (labor hrs – 0.30)
3. Make two cable guide pins as per required using, bench drill - (labor hrs – 0.50)
4. Make two spring fastening brackets for cable cutter according to the drawing Late machine is used for this process - (labor hrs – 0.50)

Total Labor hours spend to make Cable assembly is 1.5 labor hrs.

4.7.2. Labor Cost Calculation

Time spend for assemble each four components and adjusting tension is 1 hour.

Therefore total labor hours spend to prepare one unit is 8 hrs.

Cost for one skill labor hour	= Rs. 250.00 per hr.
Calculate labor cost incur for manufacturing the equipment	= Rs. 250 per hr. X 8 hrs.
	= **Rs. 2000.00**

4.7.3. Machine Cost Calculation

Here machine cost means total machine cost including running cost and rent cost. Current market values are considered to calculate Machine Cost.

Table 4.7: Machine Cost for Peeling Equipment

Used Machine	Machine Usage / Hours	Machine Cost / Rs. per hour	Total Machine Cost / Rs.
Arc Welding Plant	0.50	200	100
TIG Welding Plant	0.50	300	150
Bench Drill	1.3	200	260
Cutting Grinder	1.5	200	300
Manual Press	0.50	100	50
Lath Machine	1.80	400	720
Shaping Machine	0.25	400	100
TOTAL COST			**1680**

4.7.4. Material Cost Calculation

Current market values are considered to calculate Material Cost.

Table 4.8: Material Cost for Peeling Equipment

Component	Material	Unit	Required Qty.	Cost per Unit / Rs.	Total Cost/ Rs.
Handle	Mild Steel	1” Rod / ft	4 in.	240	80
Connecting Bar	Mild Steel	6X6bar/ ft	3 in.	160	40
Forks 2Nos.	Stainless Steel	½”X4M/ft	8 in.	300	200
Adjusting Bar	Stainless Steel	6M Rod/ft	3 in.	320	80
Adj.Bar Brackets	Mild Steel	½”X4M/ft	4 in.	180	60
Cutting Cable	Stainless Steel	0.5 mm / ft	6 in.	400	200
Cable fixing bar	Mild Steel	6M Rod/ft	3 in.	180	60
Cable spring fixing Brackets	Mild Steel	½”X4M/ft	2 in.	240	40
TOTAL COST					**760**

Total Production cost of the Equipment = Labor cost + Machine cost + Material cost

= Rs. 2000 + Rs. 1680 + Rs. 760

= Rs. 4440

Profit share from the production cost = 20%

Therefore sale price of the equipment = Rs. 4440 + Rs. 888

= **Rs. 5320**

Therefore this is lower than the allocated budget limit of the design

Rs. 10000 > Rs. 5320

CHAPTER 5 DESIGN EVALUATION

5.1. Evaluate Improvement of the New Design

The improvement of the finally designed equipment over the currently using primary method is calculated. Fifteen numbers of selected sample cuts have been done under factory condition by three cinnamon peelers using both peeling methods. Before start the test, five Cinnamon sticks were given them to peel by new equipment as training. All Cinnamon sticks were selected for the test was same length (600 mm) and shape to ensure same sample condition. Samples were selected as per two same size diameter sticks were in one sample, for testing in both methods. The results of the test are tabulated below.

$$\text{Improvement of the Equipment, } \lambda = \frac{\text{Primary Method Time} - \text{New Method Time}}{\text{Primary Method Time}}$$

Table 5.1: Compare Improvement of Designed Peeling Equipment

Sample No.	Size of Cinnamon Stick / Dia. (mm)	Time taken to Primary Method	Time taken to New Method	Efficiency
1	28	56 Sec	41 Sec	27 %
2	28	51 Sec	38 Sec	25 %
3	31	55 Sec	43 Sec	22 %
4	24	49 Sec	37 Sec	24 %
5	26	56 Sec	45 Sec	20 %
6	34	62 Sec	48 Sec	23 %
7	27	48 Sec	38 Sec	21 %
8	33	65 Sec	51 Sec	22 %
9	27	52 Sec	39 Sec	25 %
10	29	55 Sec	40 Sec	28 %
11	26	53 Sec	42 Sec	21 %
12	23	57 Sec	41 Sec	28 %
13	26	49 Sec	37 Sec	24 %
14	28	53 Sec	41 Sec	23 %
15	32	63 Sec	47 Sec	25 %

According to the data in the table, improvement is vary from 20% to 28%. The skill of the peeler and the nature of the Cinnamon sticks may affect to this variation. However it can be determined that new Cinnamon Peeling Equipment is able to achieve at least 20% improvement than currently using primary method.

Improvement of Cinnamon Peeling Equipment	= 20% at least
Average per day production, rate in conventional method	= 3 Kg /10 hrs
Average Production Rate	= 300 g per hour
Therefore average production rate in new equipment	= 300 X 1.2 g per hour
	= 360 g per hour

Figure 5.1: Cinnamon Peeling by Introduced Peeling Equipment

5.2. Evaluate Safety of the New Design

The safety features of new Cinnamon peeling equipment were evaluated following the feedbacks of Cinnamon peelers. Finally designed equipment was given to three peelers separately to peel the Cinnamon for one hour. The questions mentioned below were asked from them after one hour operating time.

1. Do you feel any risk when peel the Cinnamon by new equipment?
2. Do you feel any touching or rubbing parts when operate the equipment?
3. Is there any risk to slip the equipment when peel?
4. Do you think that you should wear safety equipment when peel using new device?
5. What is the most safe peeling method when compare with the conventional method?
6. What are the reasons for the answer of question No. 4?
7. Do you want Training for new peeling equipment? If so what is the training period?

The peelers answers are mentioned below in brief.

1. All the peelers said that they was not feel risk when operate new equipment. Because the convenient handling manner of it.
2. All peelers said that they did not feel any rubbing part of the equipment to the hand when peel.
3. Two cinnamon peelers said that there are no possibility to slip the equipment, as the equipment has catch the stick by forks when peel it. The other person said that there is a possibility to slip the equipment when handle through a knots of the cinnamon sticks.
4. All the peelers said that it is not necessary to wear the safety equipment.
5. All three peelers commented that the new equipment is safer than convention knife peeling method.
6. Peelers pointed out following factors for this problem.
    - There are is a more possibility to slip the knife than new equipment.
    - There is a high vulnerability when directly handle a sharpen knife.
    - Due to the shape of the equipment, it can be peeled by operating outward of the body.
7. Two persons have said that it is better arrange at least one hour training period to familiar to the equipment and operation. The other person have said that the training is not necessary due to the simplicity of the equipment.

Therefore considering the comments of the Cinnamon peelers, the safety level of the new peeling equipment is higher than the existing primary peeling method.

Safety of the cutting tool is very important because of if they're not handled properly it can cause wounds and cuts. Therefore workers should be trained at least one hour to ensure proper tool operation and familiar to the tool.

CHAPTER 6 CONCLUSION

Cinnamon production is a main exporting commodity in Sri Lanka from ancient Ceylon. There are much potentials areas in Cinnamon industry, Cinnamon quills production is one of least developed area in the industry. Therefore still primary methods are used to product the Cinnamon quills.

Cinnamon Peeling is the main process in Cinnamon quills production. The improvements of this process directly affect to increase the productivity of Cinnamon quills production sector. Therefore studied the Cinnamon peeling process to identify the drawbacks.

Cinnamon peeling is a manual method, small knife is used to peel the bark from the Cinnamon stem. This is time consuming method. Therefore the efficiency of the method is low. The peeler has to think the cutting path according to the nature of the Cinnamon stick. Therefore the peeler should have adequate knowledge and skill to do this job. Then the laymen cannot adopt to the process without adequate training. Therefore this is a labor intensive process. Not only that, the peeler has to handle the knife speedy to achieve the target, then there is a vulnerability in the task, therefore safety of this process is low. Due to these facts laymen are reluctant to involve this industry, it has been a main barrier to succeed the industry.

Mechanize the peeling process is the best solution to overcome the drawbacks. Therefore mechanized instrument was introduced to the industry under this research. The equipment was developed as a low cost and hand operating tool to popular among the Cinnamon peelers. A prototype peeling device was constructed as a first step and it was distributed among peelers to identify deficient. The final effective Cinnamon peeling equipment was designed by addressing to the identified deficient and following the peelers requirements.

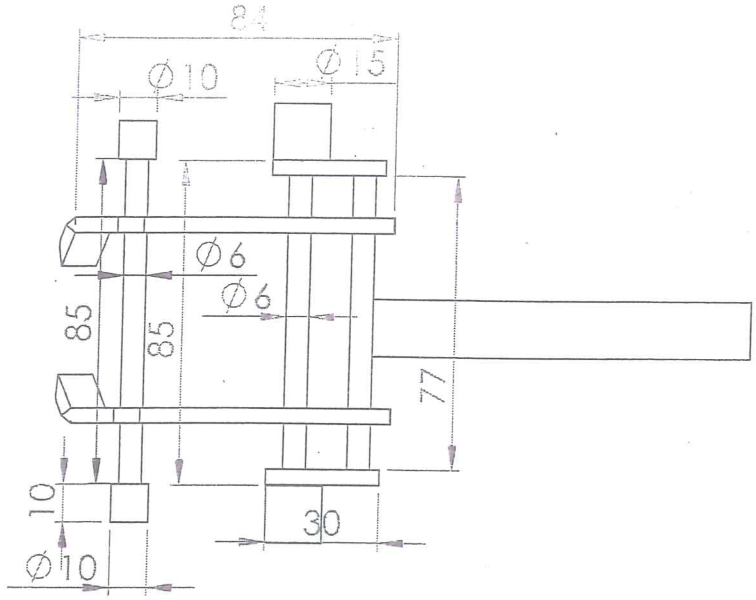
The advantages of the introduced Cinnamon peeling equipment are as follows.

- The improvement of Cinnamon peeling process can be increased at least 20% by the designed instrument.
- The cost of the designed equipment is low it is Rs. 5320/= this is an affordable value for Cinnamon peelers and Cinnamon producers.

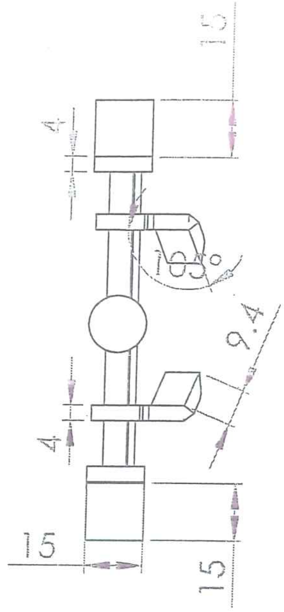
- Same width barks can be cut by the equipment, it will be an advantage when make quills.
- New equipment can be used for various shaped cinnamon sticks easily.
- Simple cable cutting mechanism has been used to cut the Cinnamon bark. Then repair and maintenance of the equipment is easy.
- The handling of the equipment is convenient due to the shape. Therefore minimum training is required to laymen.

The designed peeling equipment can be improved to achieve more functions and efficiency as follows.

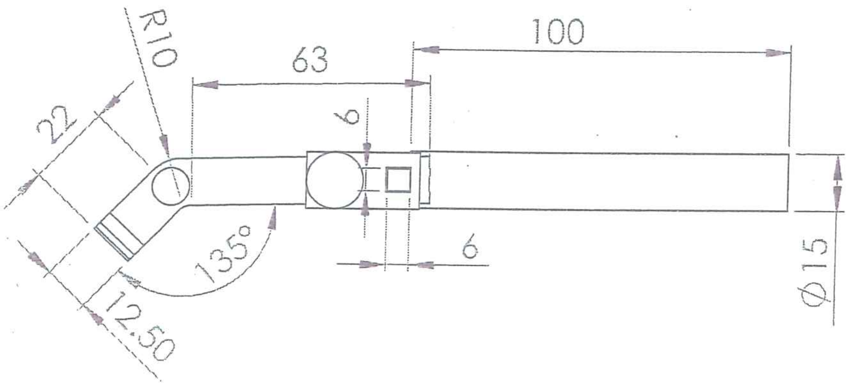
- The proposed equipment can be modified to do rubbing and scraping functions too, then one equipment can be used to do all the processes of Cinnamon peeling.
- The proposed mechanism of the equipment can be used to automate the Cinnamon peeling process, this will be a solution for the low efficiency and labor intensiveness of the process.



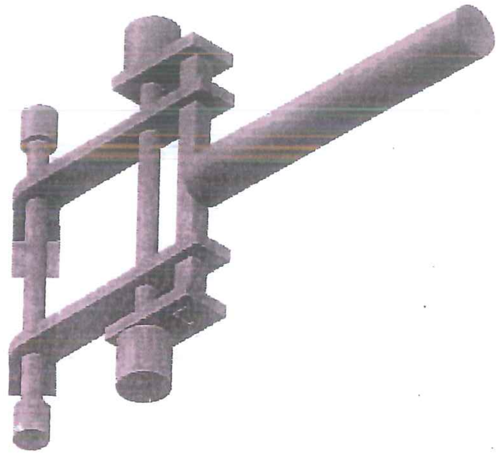
Plan View



Front View



Side View



Isomatric View

Note; All Dimentions are in mm

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND
BREAK SHARP
EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

MATERIAL:

DWG NO.

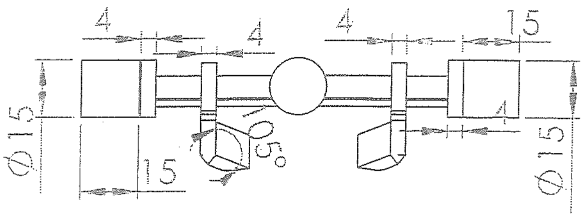
Peeling Tool 1

A4

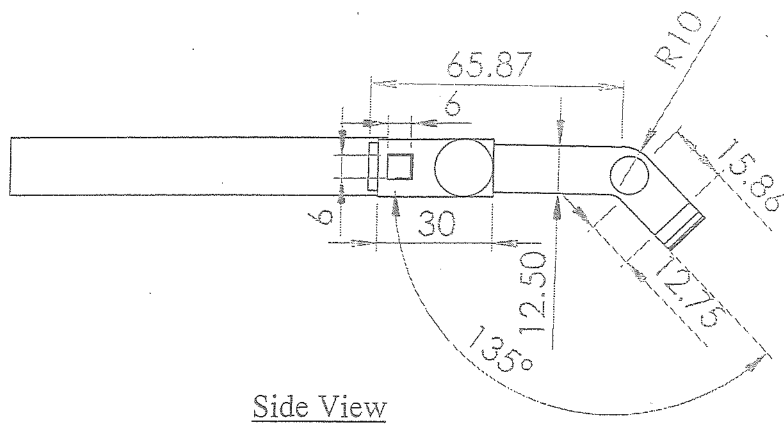
WEIGHT:

SCALE:1:4

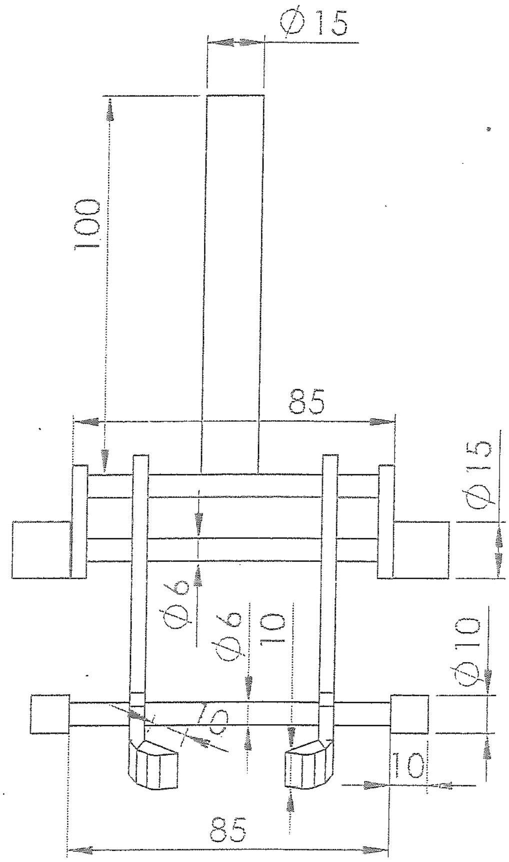
SHEET 1 OF 1



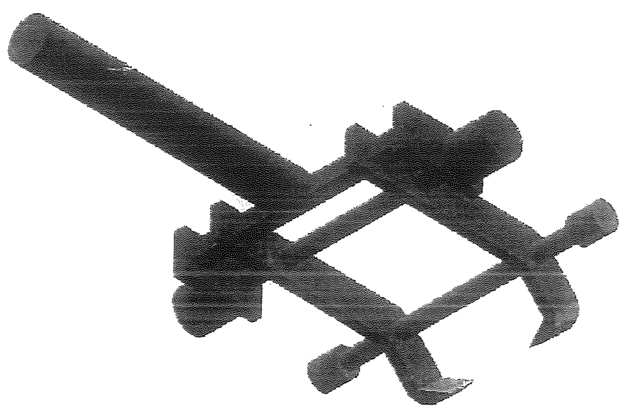
Fron View



Side View



Plan View



Isomatric View

Note: All Dimentions are in mm

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND
BREAK SHARP
EDGES

DO NOT SCALE DRAWING

REVISION

NAME	SIGNATURE	DATE
DRAWN		
CHK'D		
APPV'D		
MFG		
Q.A		

TITLE:

MATERIAL:

DWG NO.

Peeling Tool 2

A4

WEIGHT:

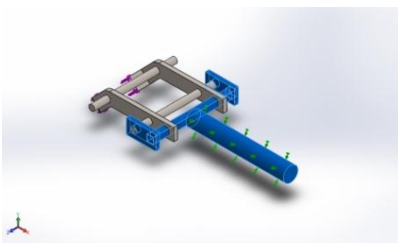
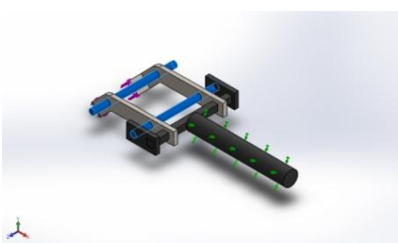
SCALE:1:2

SHEET 1 OF 1

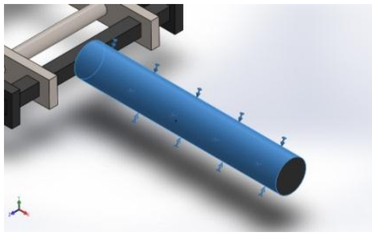
Study Properties

Study name	Static 2
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (C:\Users\kalum.me\Desktop\design)

Material Properties

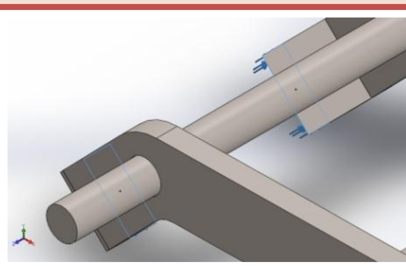
Model Reference	Properties	Components
	**Name:** AISI 316 Stainless Steel Sheet (SS) **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 1.72369e+008 N/m^2 **Tensile strength:** 5.8e+008 N/m^2 **Elastic modulus:** 1.93e+011 N/m^2 **Poisson's ratio:** 0.27 **Mass density:** 8000 kg/m^3 **Thermal expansion coefficient:** 1.6e-005 /Kelvin	SolidBody 1(Fillet3)(Part1-1), SolidBody 1(Fillet3)(Part6-1)
Curve Data:N/A		
	**Name:** Ductile Iron **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 5.51485e+008 N/m^2 **Tensile strength:** 8.61695e+008 N/m^2 **Elastic modulus:** 1.2e+011 N/m^2 **Poisson's ratio:** 0.31 **Mass density:** 7100 kg/m^3 **Shear modulus:** 7.7e+010 N/m^2 **Thermal expansion coefficient:** 1.1e-005 /Kelvin	SolidBody 1(Boss-Extrude1)(Part2-1), SolidBody 1(Boss-Extrude1)(Part3-1), SolidBody 1(Cut-Extrude6)(Part5-6), SolidBody 1(Cut-Extrude6)(Part5-7)
Curve Data:N/A		
	**Name:** AISI 316 Annealed Stainless Steel Bar (SS) **Model type:** Linear Elastic Isotropic **Default failure criterion:** Max von Mises Stress **Yield strength:** 1.37895e+008 N/m^2 **Tensile strength:** 5.5e+008 N/m^2 **Elastic modulus:** 1.93e+011 N/m^2 **Poisson's ratio:** 0.3 **Mass density:** 8000 kg/m^3 **Thermal expansion coefficient:** 1.6e-005 /Kelvin	SolidBody 1(Boss-Extrude1)(Part4-1), SolidBody 1(Boss-Extrude1)(Part4-2)
Curve Data:N/A		

Loads and Fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

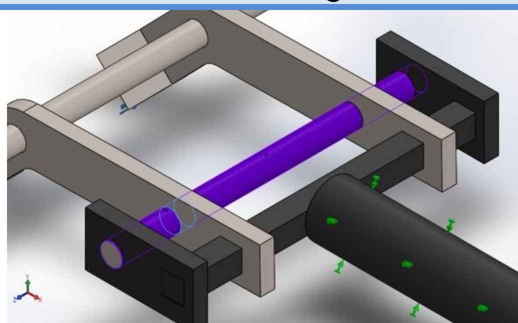
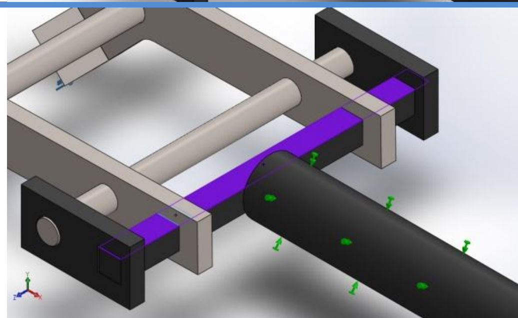
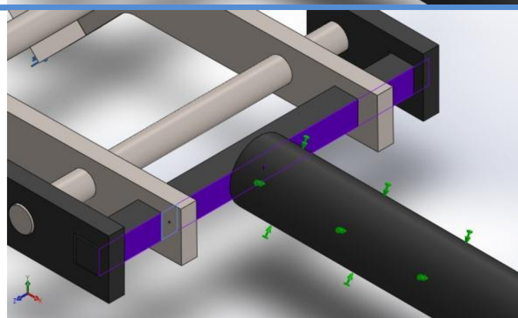
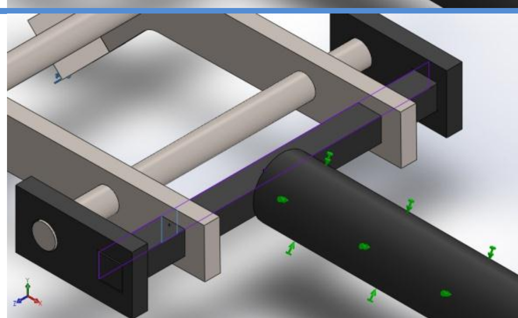
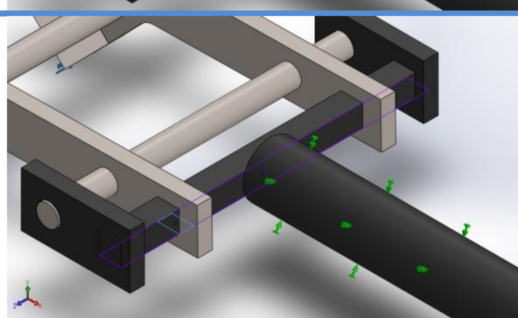
Components	X	Y	Z	Resultant
Reaction force(N)	-137.564	-141.561	2.16984	197.403
Reaction Moment(N.m)	0	0	0	0

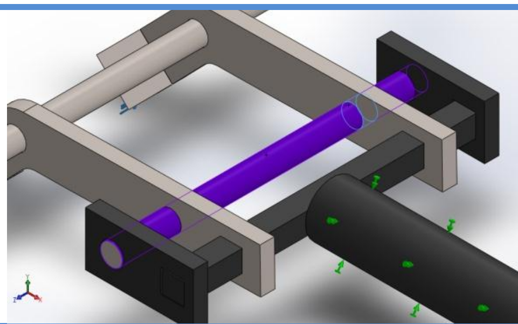
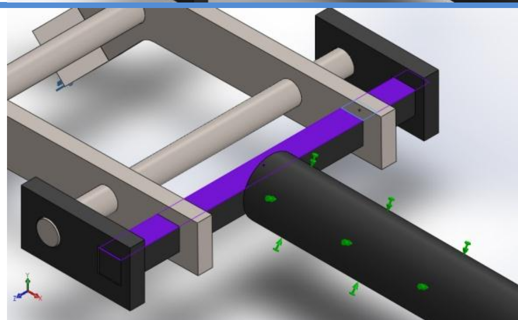
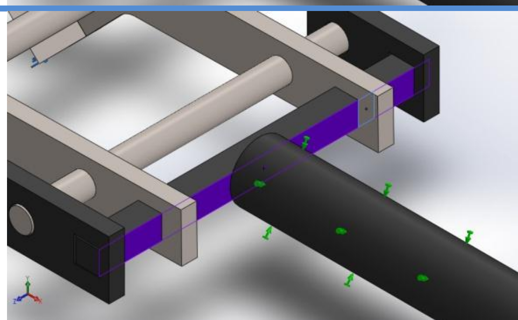
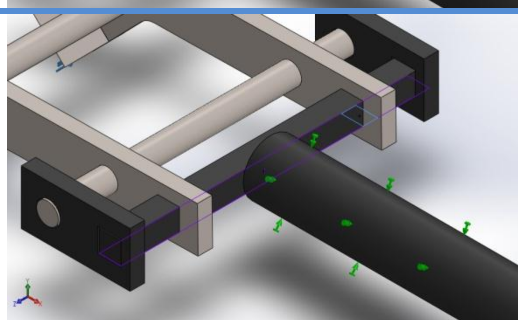
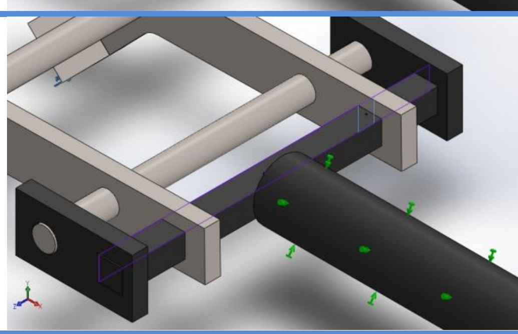
Load name	Load Image	Load Details
Force-1		**Entities:** 2 face(s) **Type:** Apply normal force **Value:** 100 N

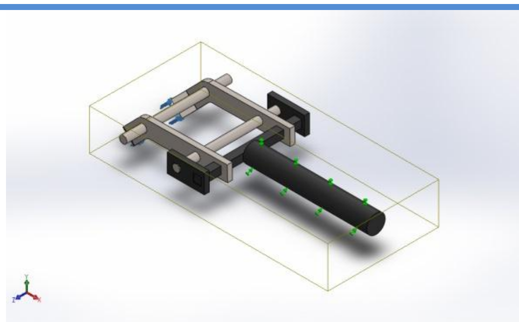
Connector Definitions

No Data

Contact Information

Contact	Contact Image	Contact Properties
Contact Set-1		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-2		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-3		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-4		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-5		**Type:** Bonded contact pair **Entites:** 2 face(s)

Contact Set-6		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-7		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-8		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-9		**Type:** Bonded contact pair **Entites:** 2 face(s)
Contact Set-10		**Type:** Bonded contact pair **Entites:** 2 face(s)

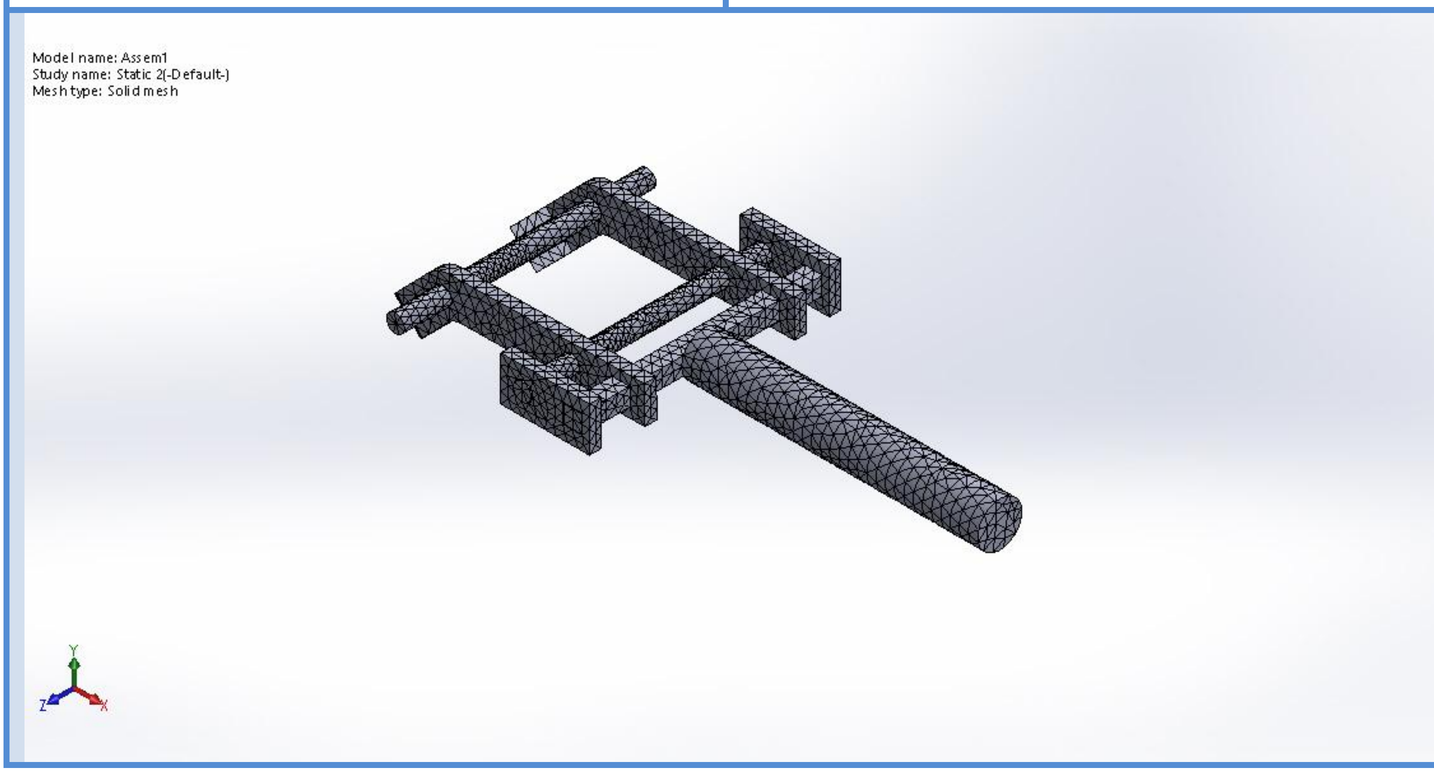
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	3.33831 mm
Minimum element size	0.166916 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	On

Mesh Information - Details

Total Nodes	23051
Total Elements	13099
Maximum Aspect Ratio	18.638
% of elements with Aspect Ratio < 3	99.2
% of elements with Aspect Ratio > 10	0.191
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:02
Computer name:	ME-ENG1-1170-D



Sensor Details

No Data

Resultant Forces

Reaction Forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-137.564	-141.561	2.16984	197.403

Reaction Moments

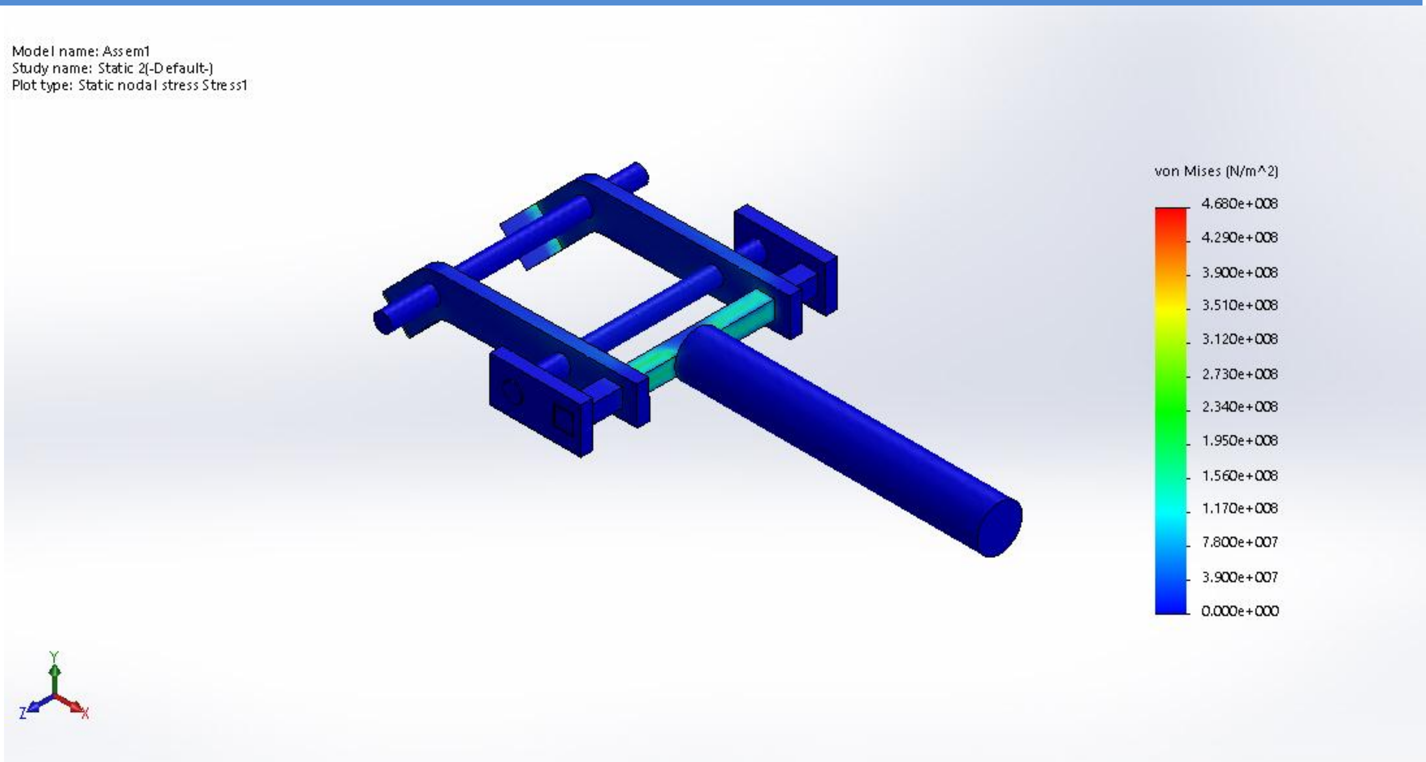
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Beams

No Data

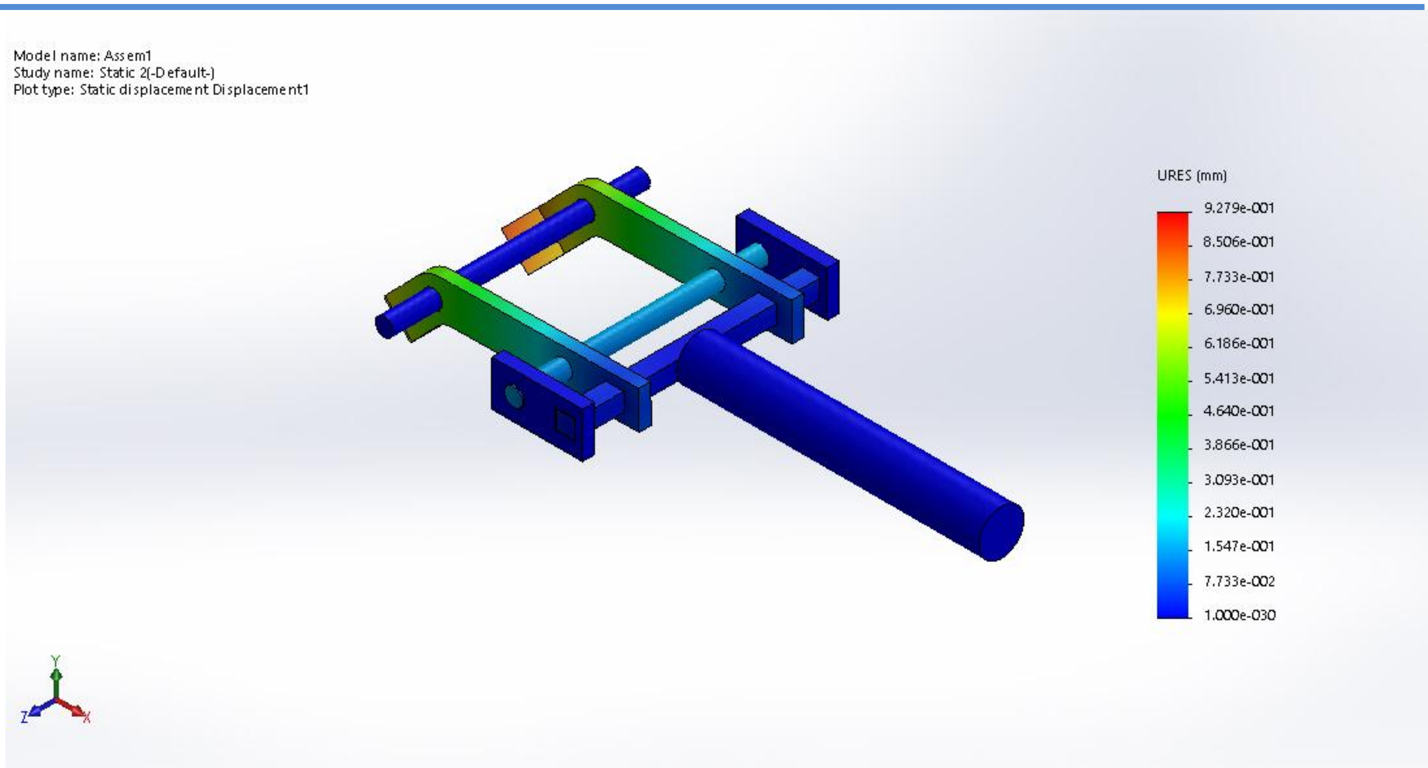
Study Results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0 N/m^2 Node: 14662	4.67981e+008 N/m^2 Node: 666



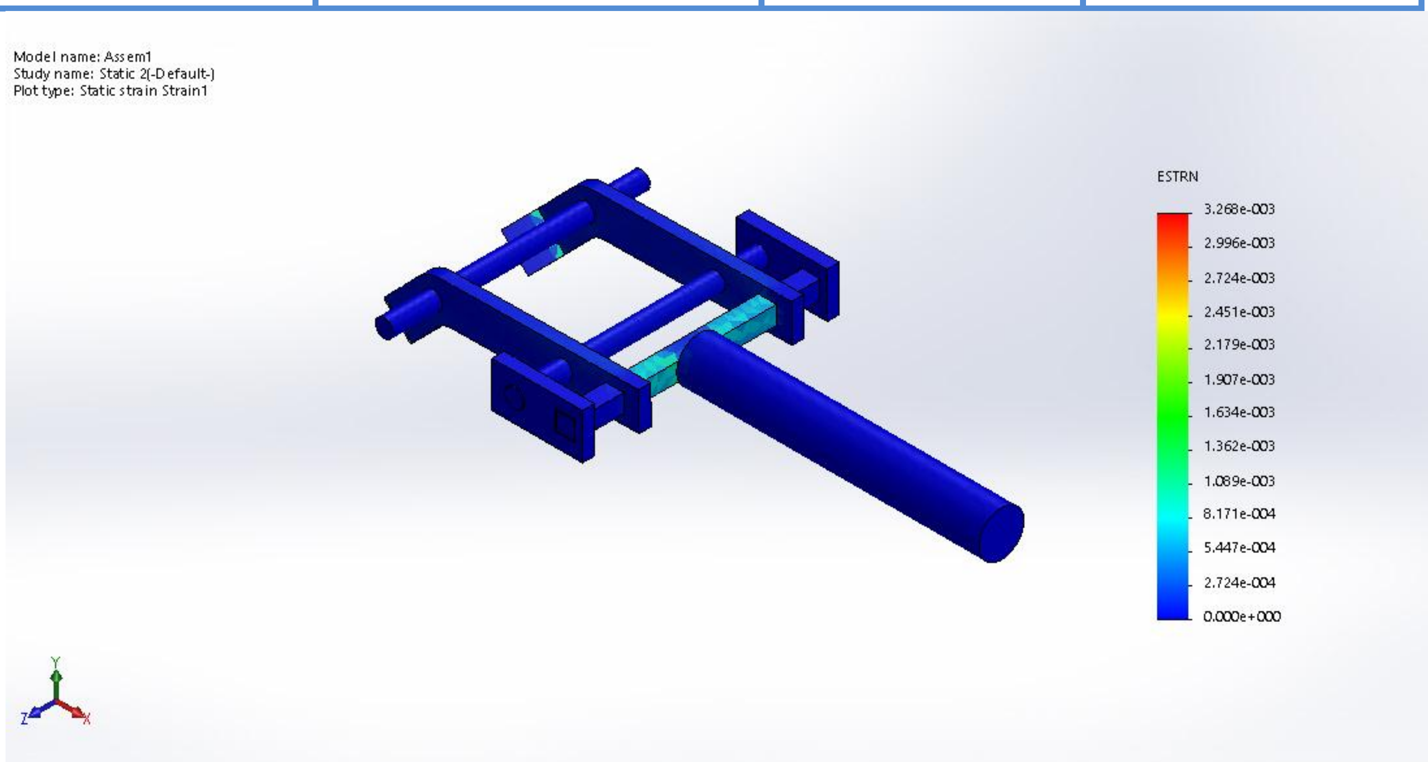
Assem1-Static 2-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 2995	0.927947 mm Node: 38



Assem1-Static 2-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0 Element: 8549	0.00326849 Element: 759



Assem1-Static 2-Strain-Strain1

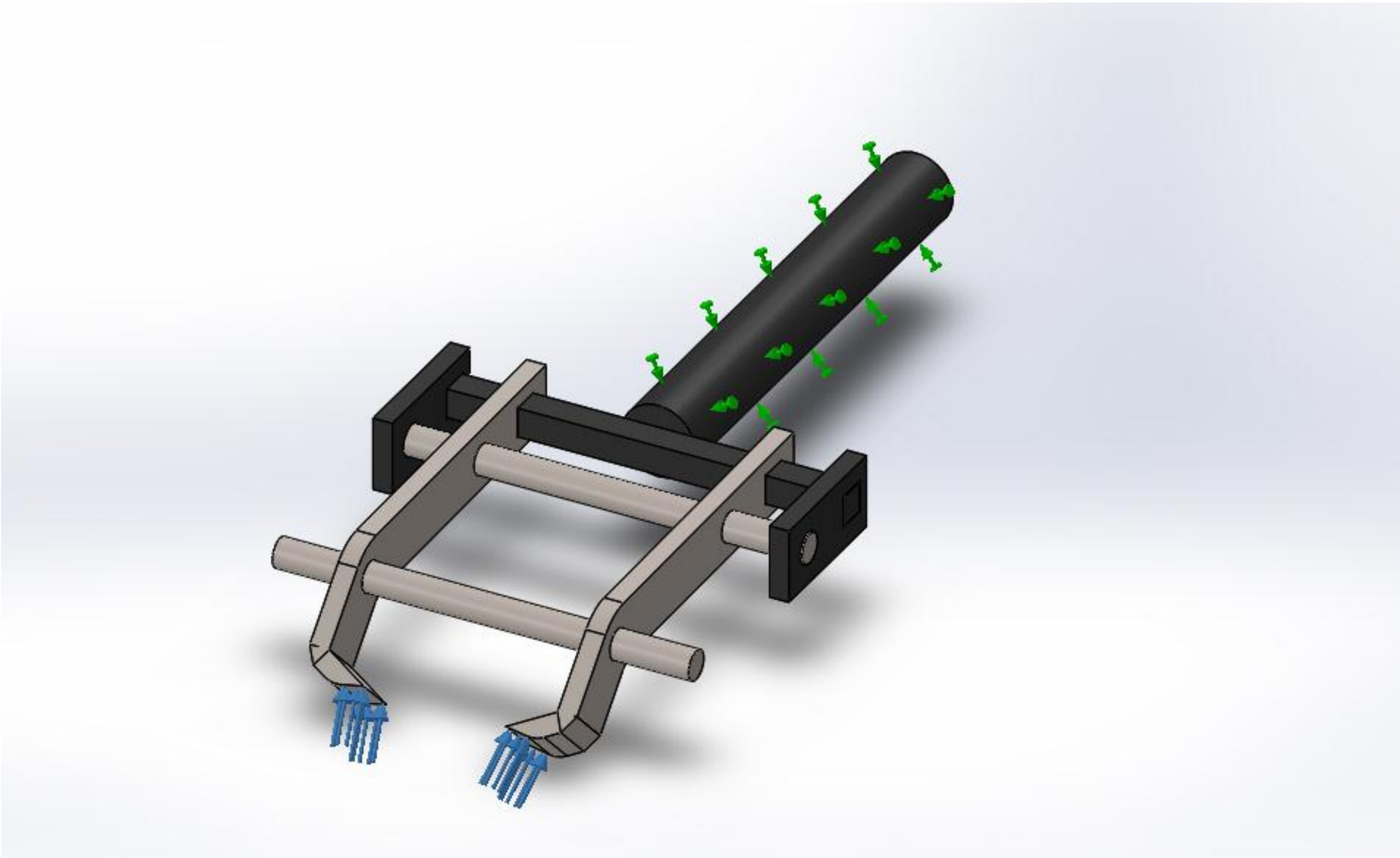


Image-1

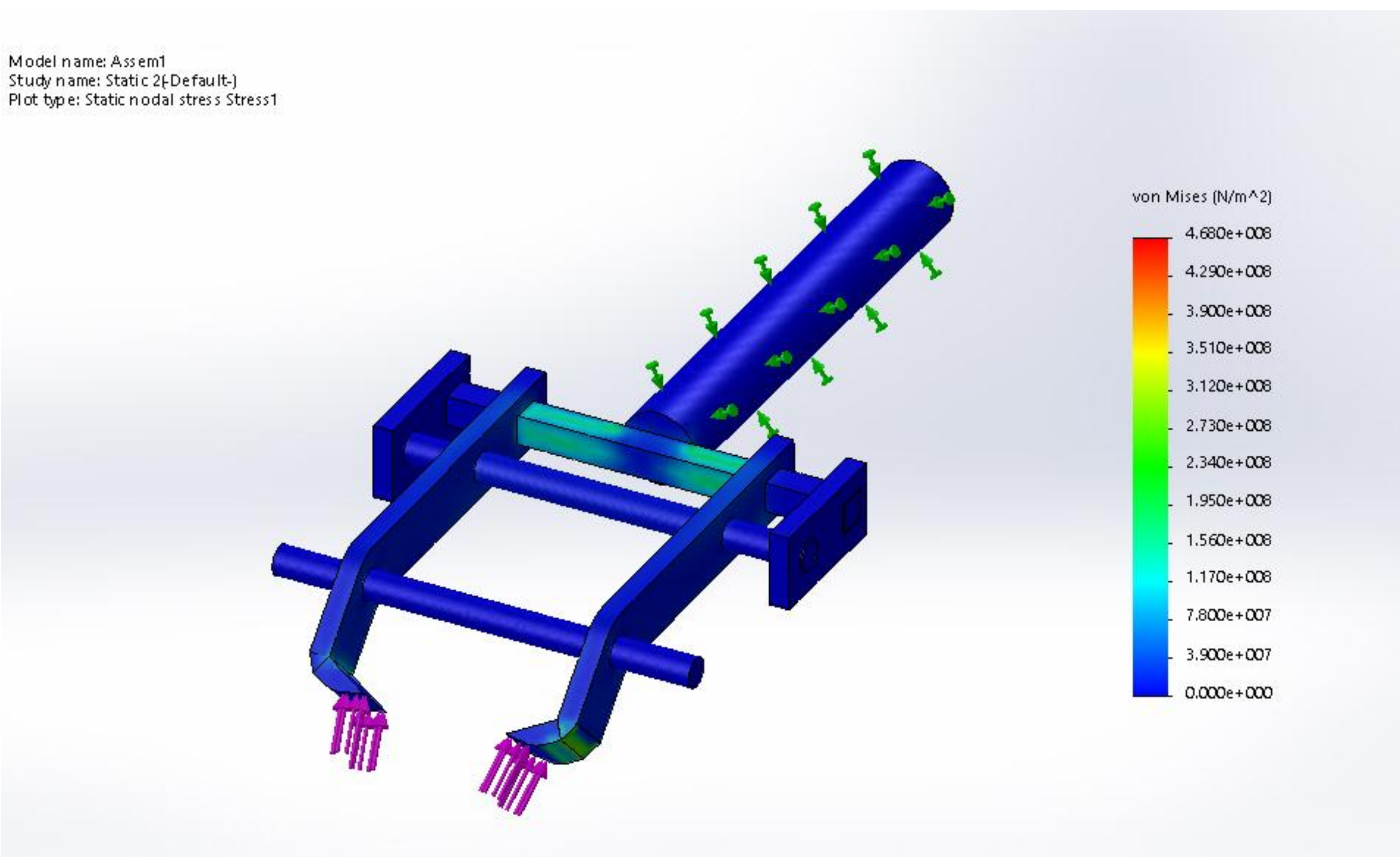


Image-2

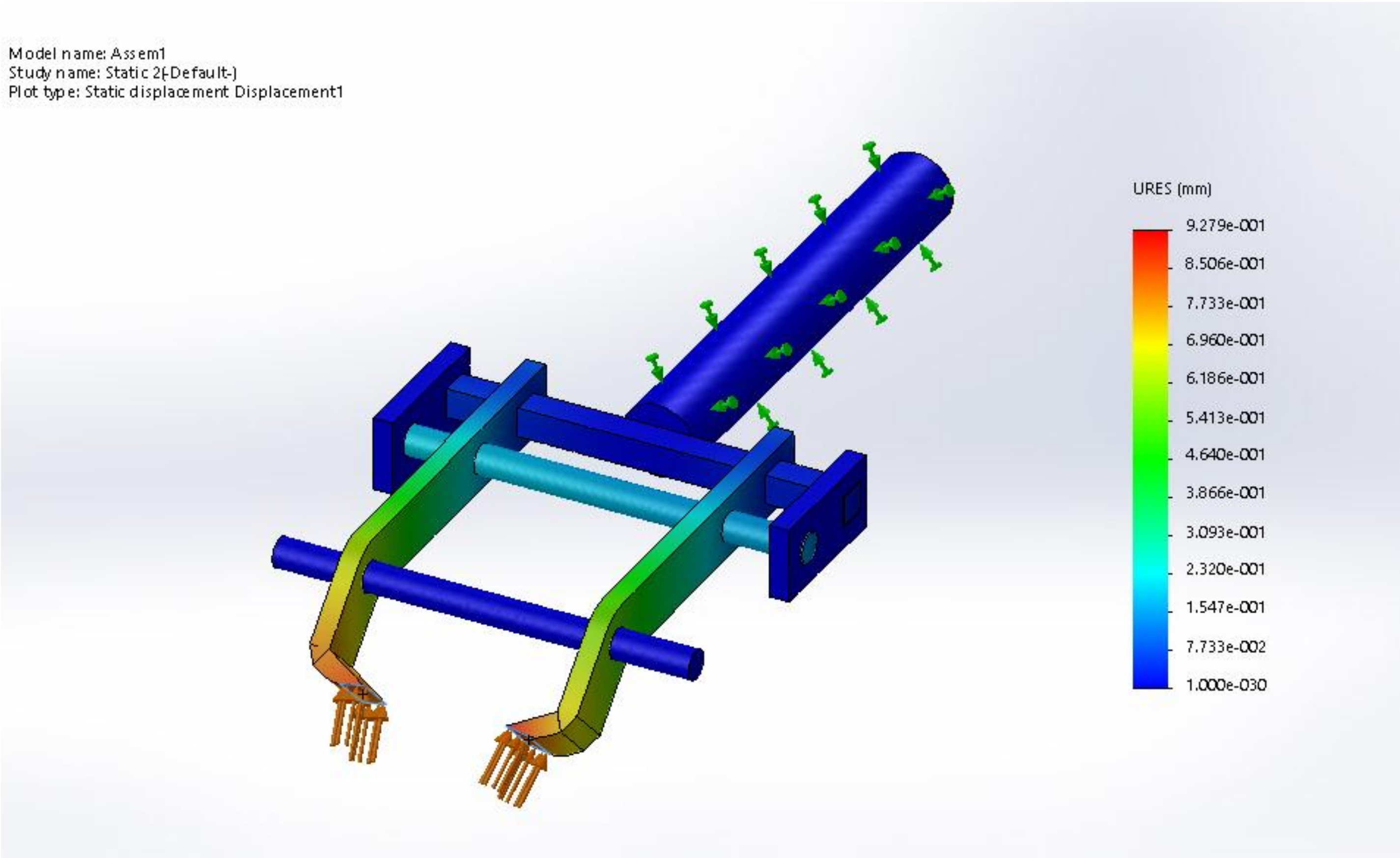


Image-3

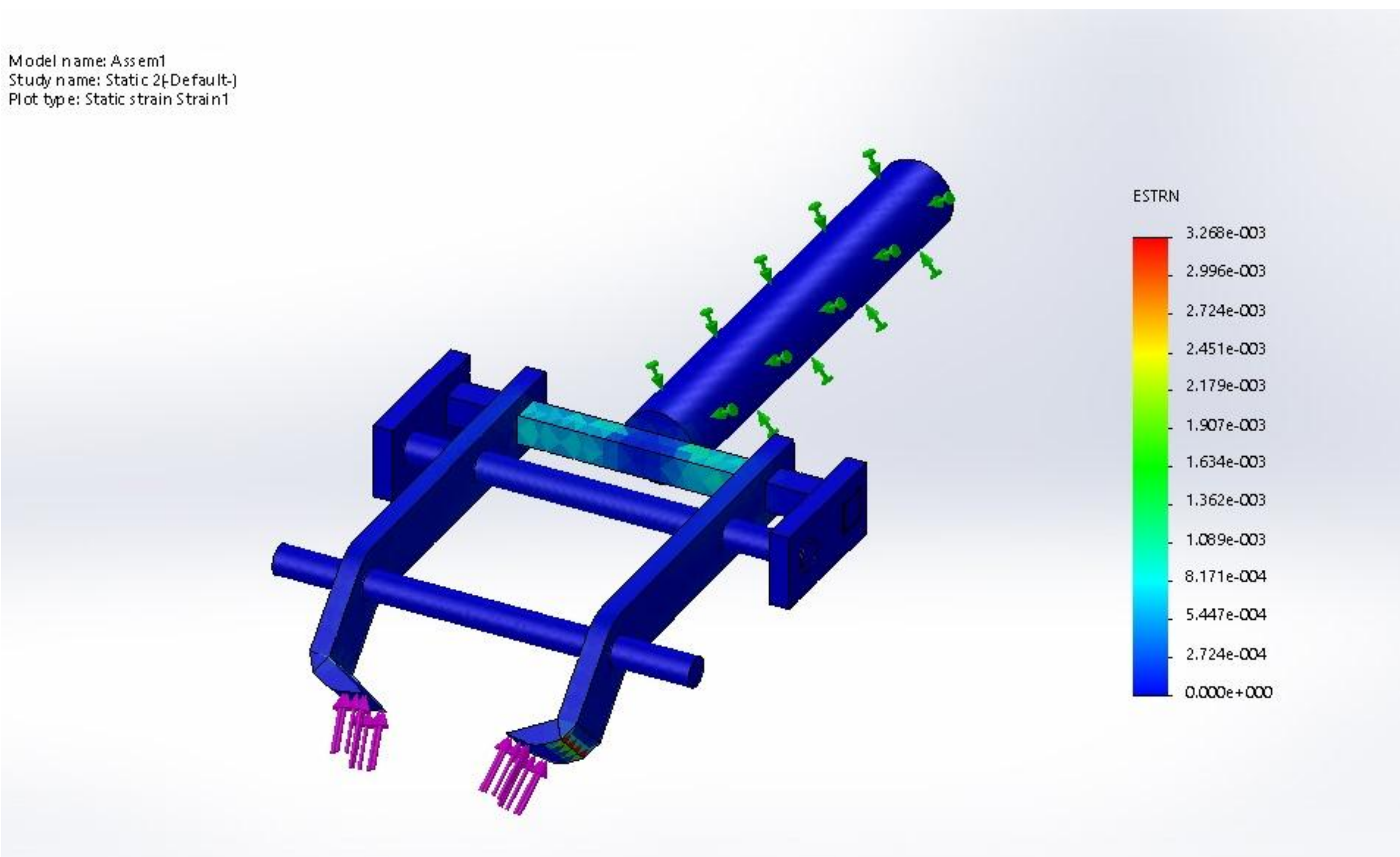


Image-4

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APPENDIX A

Details Drawing of the Developed Cinnamon Peeling Equipment.

APPENDIX B

Stress Analysis Report of the Developed Cinnamon Peeling Equipment.