DESIGN AND ANALYSIS OF RUBBER TAPPING MACHINE USING ANSYS SOFTWARE

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DECLARATION

I hereby declare that the work reported in this thesis is the result of my own investigation and that no part of the thesis has been plagiarized from external sources. Materials taken from other source are duly acknowledgements by giving explicit references.

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LIST OF ABBREVATIONS

Symbol	Description
RTM	Rubber Tapping Machine
CAD	Computer-aided Design
IR	Infrared
IMU	Inertial Measurement Unit
DC	Direct Current
LED	Light Emitting Diode
FSR	Force Sensitive Resistor
POM	Polyoxymethylene
MFI	Melt Flow Index
Pa	Pascal
UV	Ultraviolet
EPDM	Ethylene Propylene Diene Monomer
DIY	Do It Yourself
SPDT	Single Pole Double Throw
PCB	Printed Circuit Board
FFT	Fast Fourier Transform

ABSTRAK

REKAAN DAN ANALISIS MESIN PENOREH GETAH MENGGUNAKAN PERISIAN ANSYS

Produk getah adalah penting terhadap Malaysia dan adalah salah satu eksport utama negara kita. Oleh itu, peningkatan kualiti hasil getah asli adalah penting demi pembangungan dan pengekalan ekonomi Malaysia. Namun, bilangan penoreh getah yang berpengalaman semakin berkurangan dan penggunaan alat menoreh getah tradisional manual yang ada di pasaran tidak mampu mengatasi permintaan getah asli yang tinggi. Dalam kajian ini, sesuatu rekaan mesin penoreh getah telah diperkenalkan untuk menyelesaikan masalah ini. Mesin penoreh getah ini adalah semiautomatik dengan menggunakan alat penoreh putaran dan boleh lakukan penoreh getah dalam 16 saat. Mesin penoreh getah ini berfungsi dengan bantuan minimum pekerja. Pekerja diminta untuk menyesuaikan alat penoreh putaran itu kepada luka menoreh sebelumnya. Selepas itu, butang pelaksanaan haruslah ditekankan untuk menjalankan proses penoreh getah oleh mesin itu. Dengan menggunakan perisian ANSYS, analisis modal, tindak balas kekerapan, fana dan tekan telah dilakukan untuk menganalisis prestasi mesin ini. Berbanding dengan mesin penoreh getah di pasaran, mesin baru ini mudah untuk digunakan oleh pekerja. Seterusnya, kos untuk membina mesin ini dianggap rendah berbanding dengan harga mesin penoreh getah dalam pasaran.

ABSTRACT

DESIGN AND ANALYSIS OF RUBBER TAPPING MACHINE USING ANSYS SOFTWARE

Rubber products are important and took up few percentages of Malaysia's total exports. Due to this, it is necessary to improve the quantity of natural rubber that been produced. However, the number of skilled rubber tappers are getting lower nowadays, and the available manual tools are unable to cope with the high demand of variable products to be produced. In this study, a new design of Rubber Tapping Machine (RTM) is introduced as a solution to this problem. The designed semi-automatic RTM with rotational cutting tool can complete the tapping process in 16 s of time. This tool involved a minimum labour contact, where in they just need to move the cutting tool or the tapping head down by pressing switch until the cutting tool contacted with the previous tapping wound. Then, execution button is used to carry out the whole tapping process. By using ANSYS software, the modal, frequency response, transient and stress analyses are conducted to analyze the performance of the RTM. Compared to the available RTM in the market, this newly designed RTM has an advantage such as convenient to be used. Also, the total estimation cost to build the RTM is considered low compared to the price of other RTMs in the market.

CHAPTER 1

INTRODUCTION

1.1 Background Study

Natural rubber is produced by exudations of certain tropical plants such as Hevea brasiliensis or rubber tree. It is a type of polymer and plays important roles in human society. It is also an essential raw material which can be used to create or manufacture many other products such as tyre, shoes, gloves and many more. It is useful because of elasticity, resilience and toughness characteristics. Since Hevea brasiliensis's efficiency in rubber production is higher than other threes, the rubber plantation only focusing on planting Hevea brasiliensis. (Gent, 2020b)

In modern tapping process, when the bark of the rubber tree is tapped, a milky liquid will flow out from the tree which helps to cover the wound for healing the tree as shown in Figure 1.1a. The milky liquid is called latex where people will collect and further turn it into rubber products. Half of the trunk circumference is tapped to extract the latex. The cut is slanted with 30° from the horizontal, starting from highest point and from left to right diagonally. The tapping is usually started when the tree trunk has 50 cm circumference at 1 m height from the ground (Soumya *et al.*, 2017). The bark is cut about 3 to 5 mm deep into the trunk without damaging the Cambium of the tree with a thickness of 1.5 to 2 mm (Susanto, Ali and Hanif, 2019). The Cambium of the tree is as shown in Figure 1.1b.

(a)

(b)

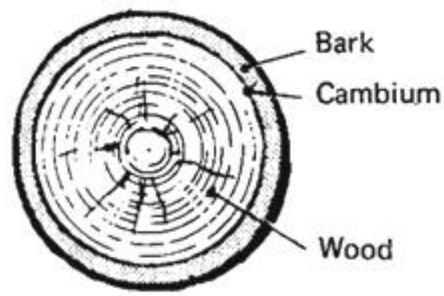

Figure 1.1: (a) Latex being extracted from rubber tree (Gent, 2020a) (b) Cambium of the tree (*the rubber tree*, 2021)

Natural rubber is one of the largest commodities in Malaysia. Malaysia produces almost 20% of the world's natural rubber. More than half of Malaysia's rubber comes from thousands of smallholdings and the rest is owned by various companies. The smallholdings' rubber plantation areas are usually 2 hectares while the large estates will have over thousand hectares. In overall, Malaysia has 1.7 million hectares of rubber plantation area.

According to Malaysian Rubber Board, even though the increasing of world rubber consumption and production, the Malaysia's natural rubber production has been decreasing since year 2006 (Figure 1.2) and the import of natural rubber (Figure 1.3) from other countries has been increasing year by year (*Malaysia Rubber Board - Natural Rubber Statistic*, 2020).

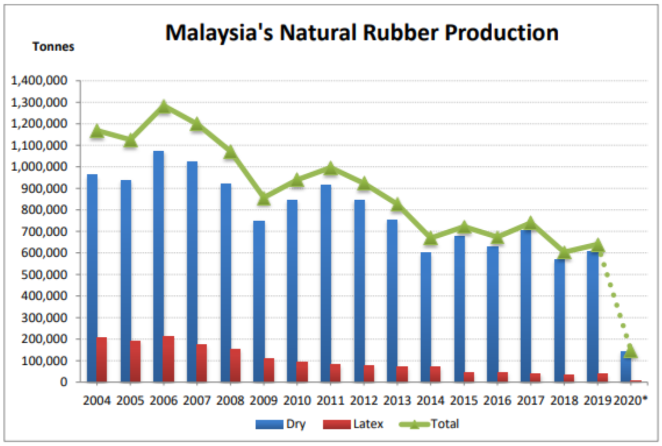

Figure 1.2: Malaysia's natural rubber production (Malaysia Rubber Board - Natural Rubber Statistic, 2020)

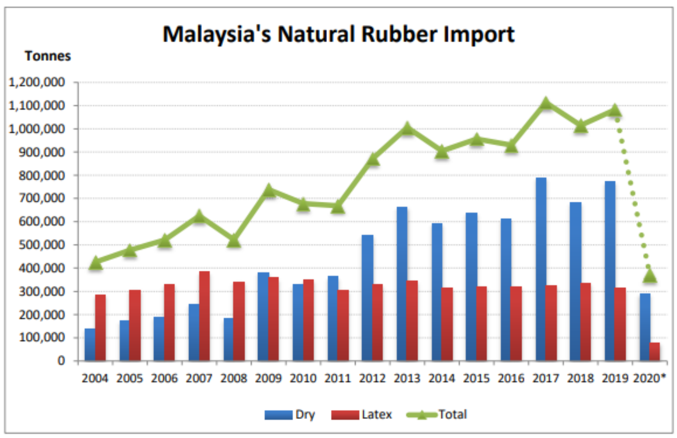

Figure 1.3: Malaysia's natural rubber import (Malaysia Rubber Board - Natural Rubber Statistic, 2020)

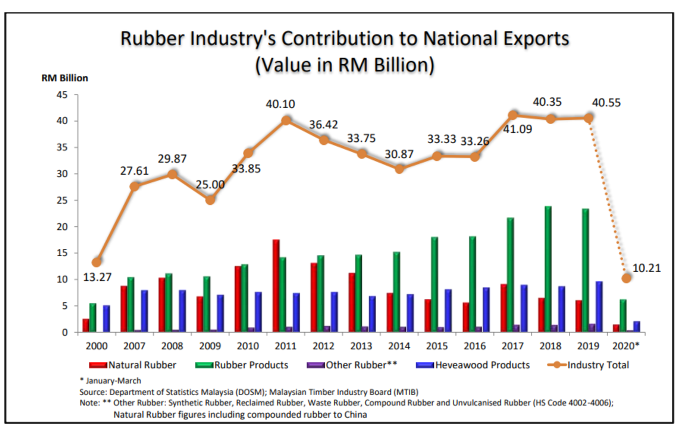

Figure 1.4: Rubber industry's contribution to national exports (Malaysia Rubber Board - Natural Rubber Statistic, 2020)

As shown in Figure 1.4, although the contribution of natural rubber has been decreasing in recent years, the contribution of the export of rubber products is showing an increasing trend. If the production of the natural rubber can be increased, the profit margin from rubber sector can be increase too.

Currently in Malaysia, the rubber tree is tapped using Jebong knife. Similar to other rubber producing countries, Malaysia is facing the problem of insufficient labour for rubber tapping. Rubber tapping is a skill-oriented job which need to be done repetitively and exhausting. Due to the aging of the skilled rubber tapper and not much young generation interested in this, the number of skilled rubber tapper has been decreasing over the years. A solution such as development of automatic or semi-automatic rubber tapping machine (RTM) can solve this problem by decreasing the workload and allows labour without rubber tapping skills to perform the tapping process.

1.2 Problem Statement

In Malaysia, the number of skilled rubber tappers are getting lower. The young generation are not interested in taking the job as a rubber tapper due to low and unstable income with a difficult task. However, rubber products are important and took up few percentages of Malaysia’s total exports. It is necessary to improve the quantity of natural rubber that been produced. The available manual tools are unable to cope with the high demand of variable rubber products and RTM has to be introduced to replace the current method. Hence, this study aims to design a new RTM in order to reduce the effort and time for rubber tapping by allowing unskilled people to do the task efficiently.

1.3 Objective

The following objectives are set to be achieved:

- To design a new concept of RTM using SOLIDWORKS software with detail function.
- To investigate the performance of the RTM in terms of vibration, stress and time of completion
- To compare the cost analysis of RTM with other available products.

1.4 Scope of Work

In this project, the new concept of RTM will be designed and investigated. Firstly, the idea of the machine is collected from the previous machine designs and come out with a new design that collects as much as advantages. SOLIDWORKS software is used for the 3D CAD modelling and the design is then tested using ANSYS software in terms of stress, vibration and functionality. Finally, the cost analysis for the RTM is compared with other available machines.

1.5 Thesis outline

The thesis is subdivided into five chapters which are:

- Chapter 1 – Introduction

This chapter contains of the background study, objectives, problem statement and scope of projects.

- Chapter 2 – Literature Review

This chapter discusses the previously designed RTM, mechanical properties of Hevea brasiliensis and the cutting force.

- Chapter 3 – Methodology

This chapter includes the details of the designed RTM such as design ideas evolution, CAD design, control system design, material and motor used. It also discussed the simulation setup for stress, modal, harmonic response, transient and cutting analyses of the RTM.

- Chapter 4 – Results and Discussion

This chapter discusses the results obtained from ANSYS simulations (stress analysis, modal analysis, harmonic response analysis and transient analysis).

- Chapter 5 – Conclusion

This chapter summarizes the project outcomes. It also mentioned the recommendation for future work’s improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, the following topics will be presented:

- Critical review of past rubber tapper designs
- Rubber tree Hevea brasiliensis
- Cutting force requirement
- Summary

2.2 Critical Review of Past Rubber Tapper Designs

This subchapter will discuss and analyze the past designs of RTM.

2.2.1 "Appuhamy" – The Fully Automatic Rubber Tapping Machine (Yatawara *et al.*, 2019)

a) <u>Introduction</u>

The authors are from Sri Lanka. Natural rubber is a major source of exportation for Sri Lanka and many local industries need natural rubber as raw materials. Compared to the synthetic rubber technologies by western countries, the authors believe that the natural rubber has unique properties that can't be replaced by the synthetic rubber and due to that, Sri Lanka are not capable to compete with the low-cost mass production of synthetic rubber and figured out that they might be able to compete in the market for natural rubber with sufficient involvement of technologies. With technologies, it can make up the low number of labour force present in rubber tapping industry in Sri Lanka. In the study, they designed a fully automated RTM which is able to turn the rubber tapping process into fully automated and required minimum labour force.

b) Summary

The authors reviewed several semi-automated RTM and commented that they still have some disadvantages. The author concluded that the semi-automated RTM required to move from tree to tree by human involvement which is similar to the manual rubber tapping. So, they proposed the fully automated latex tapping machine. It is said to be able to work on its own without the needs to be carried from tree to tree by labour and the tapping process is also automated.

In their machine, it uses camera and multiple sensors such as ultrasonic, moisture, rain and infrared (IR) sensors. The cutting head is able to move in x, y and z direction. With the camera, the rubber tapping path can be captured and the trajectory of the cut can be determined by detecting the previous cut from the tree. With the sensors, it can detect the distance to the tree and control the cutting depth. Other than that, the carriage can move the machine from tree to tree. The RTM moves with the help of two guide wires where they connected to two steel arms which were mounted to the trees. A single controller is used to control the system.

For the tapping head, the authors called it intelligent as it implements machine vision technology. The tapping head is able to take the photo of the trajectory of previous cutting wound on the trees. Further image processing is applied such as binary thresholding and transform it to 2D array data so that the machine can cut according to the previous wound. The tapping head uses rotating cutting force to do the rubber tapping process. It can maintain a 10 degrees slope across the depth of the cut with protruding dot was designed at the cutting head to prevent the cutting blade to move too close to the cambium as shown in Figure 2.1.

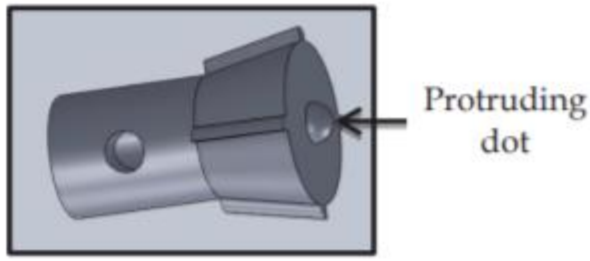

Figure 2.1: Cutting tool for fully automated rubber tapping machine (Yatawara *et al.*, 2019)

As the rubber tree's surface is not flat, the authors proposed a solution with depth detection mechanism using infrared and ultrasonic sensors. It helps to move the cutter with respect to the tree's surface. Besides, the cutter is also able to rotate about the axis of the tree. From this, the cutter head can maintain its position as approximate perpendicular to the tree surface.

In their design, the cutting tool is mounted on a carriage as shown in Figure 2.2a. The carriage carries the cutting tool which can move in x and y-axis in the plane of the main carriage. Another steel ball screw is used to control the z-axis (perpendicular axis from cutting tool to the surface of the tree). The main carriage is used to carry the whole machine from tree to tree. It also has the gripper which hold the machine to the tree when tapping process occurred. In each rubber tree, there are two steel arms mounted, one at above and below. There are cables which connect the steel arms from tree to tree, then, the main carriage will move through the pulley system.

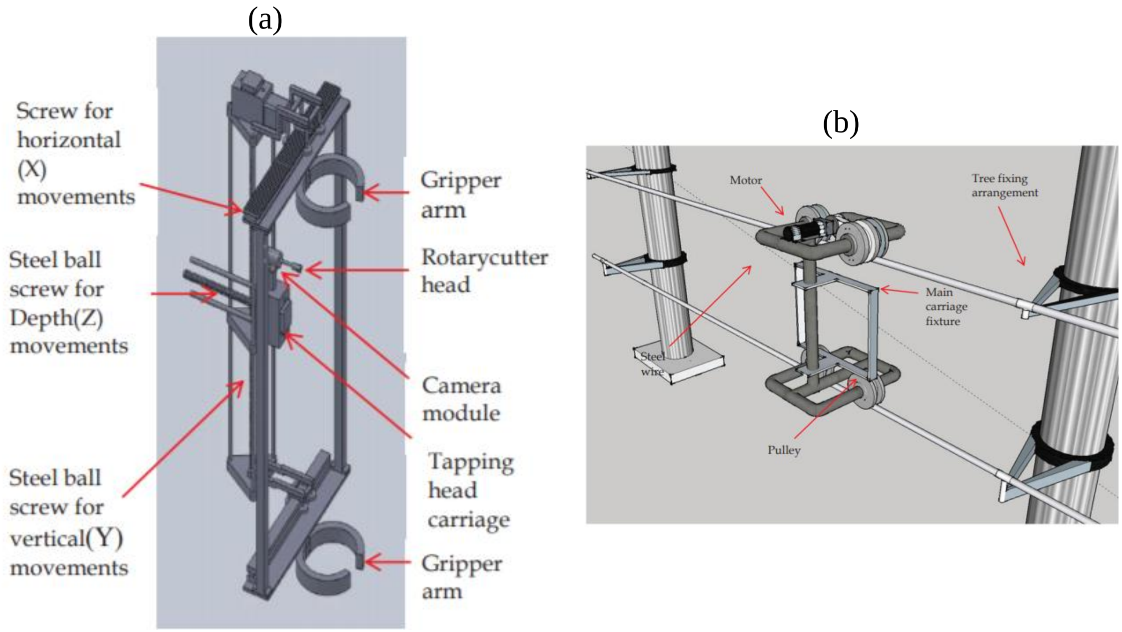

Figure 2.2: (a) Proposed design (b) RTM movement mechanism (Yatawara *et al.*, 2019)

c) <u>Analysis</u>

In their design, the machines can travel from tree to tree by its own as discussed in summary. It can operate using battery for several hours. The controller in this machine is very important which controls the movement of the machines, image processing for the cutting trajectory, identification for tapping and others. The author used Raspberry-pi minicomputer board as their controller. The average tapping time for each tree is around 48 s.

In overall, the whole machine is very huge and heavy. They are carried from tree to tree using two cables as shown in Figure 2.2b which might be not stable when there is a strong wind. Other than that, before the automated machine can be used, two steel arms must be mounted to the rubber tree to connect the cables, which required extra time to work on. This might cause some injuries to the tree as the carriage is heavy. From some research, the average manual tapping time is less than 20 s which is contrast from what the author claimed as their automated machines are quicker in tapping process.

d) Conclusion

The author's machine is great as it is fully automated and performed the tapping process well. Although it is fully automated, but there is still some weakness that can be improved.

2.2.2 **Rubber Tapping Machine** (Prasada, 2020)

a) Introduction

The authors are from India. At first, they discuss on how rubber is important to them. They noted that the prices of natural rubber are affected by the international trade policies, fluctuations in demand and supply of natural rubber, fluctuations in the price of oil and changes of politics. They mentioned that the drop of price of natural rubber affects significantly to the growth of area under production in the producing countries.

In conventional rubber tapping method, a skilled rubber tapper makes an initial cut of 180 degree around the rubber tree and 2 feet down the tree in a spiral shape. They cut 3 to 5 mm deep into the bark to extract the latex without causing damage to the cambium of the rubber tree. After the initial cut, the worker will remove a small thickness of the bark from previous cut every morning to extract more latex. Before removing the bark, coagulated latex is removed by hands to reopen the cut. The rubber tapping process is done in the early morning before the temperature rises so that the latex can drip longer before coagulating.

b) Summary

The authors used CREO software to model the RTM as shown in Figure 2.3.

Figure 2.3: Design of RTM (Prasada, 2020)

The authors carried out experiments and provide the best possible alternative design which can replace the traditional method. This also enable the unskilled worker to carry out the tapping process.

In their machine, the first requirement is to clamp the machine onto the tree. A circular rack and pinion system are used to determine the cutting trajectory. On the rack, a permanent magnet DC motor is mounted, and a knife is fixed on the DC motor. The motor can be controlled to move forward or backward on the axis of the rack. The depth of cutting can be adjusted by changing the bolt and nut arrangement on the knife.

c) Analysis

The authors tested their machine and claimed the tapping process is successful and no harm caused to the rubber tree. They stated that the clamping process of the machine to the tree is a waste of energy and time since after the tapping process, the machine needs to be taken off and put on to a new tree. As they used belt and clamp to do the fixing, it might take some time and effort.

For each tree, they need 15 to 20 seconds to fix the machine on the tree and about another 10 to 15 seconds for the tapping process, which they claim about the same as the conventional methods. The depth of cut is measured to be 3-5mm. The machine can cut a constant depth along the bark. This machine helps in relieving the worker's arm compared to the conventional method as the worker only required to mount and unmount the machine from the tree.

As an opinion, the authors made a machine which can helps the unskilled worker to do the tapping process, which is a huge improve to the conventional method. The depth of cut which is constant throughout the bark is also a good sign. However, depends on trees, if the diameter of the rubber tree is different, the worker has to change the cutting depth or maybe the machine cannot be used due to the size difference. This machine is limited to the rubber tree farm where all the trees are of the same species and same age, so that the diameter of the rubber tree does not vary much. However, there is still a risk where few millimetres differences will cause the knife to cut into the cambium and cause infection to the rubber tree, which eventually broken the tree.

d) Conclusion

The machine can help anyone to do the tapping process in a same speed as the conventional method, but there are a few drawbacks which might cause damage to the tree and need extra time to mount the machine and to change the depth of cut.

2.2.3 Design and Testing of a Semi-automatic Rubber Tree Tapping Machine (Soumya *et al.*, 2017)

a) <u>Introduction</u>

The author mentioned that the rubber tapping is not economical to the local planters as the income is only sufficient to feed the labours and to meet other agriculture expenses. The availability of skilled rubber tappers is also a concern for them. During tapping, latex is extracted from the lactiferous vessels. There is a thin invisible layer called cambium which is very close to the lactiferous vessels and proper care should be taken to avoid the tool from damaging the cambium. Damaging the cambium will results in formation of bulging or the underlying wood layer will be exposed to the microbial attack.

In India, the tapping is usually started when the tree trunk has 50 cm in circumference at 1 m height from the ground. To initiate the tapping process, a pointed tool is used to scribe a helical pattern which is predetermined using a metal ribbon that wound around the tree in a helix angle of 30 degrees at 1 meter from the ground. Then, tapping tool is used to deepen the marking (4 cm) into the wood surface. In India, the tapping tools used are Jabong knife and V groove knife as shown in Figure 2.4.

(a) (b)

Figure 2.4: (a) V groove knife and (b) Jabong knife (Soumya *et al.*, 2017)

The authors mentioned that there are a lot of cheap labour in the state, but they lack experience and skills. Thus, a machine is designed so that the cheap labour is utilised to do the job.

b) Summary

The design from the authors is a semi-automatic machine and battery powered as shown in Figure 2.5. It uses an oscillating power tool with a mechanical guiding structure and sensor-based user assistive system. The cutting blade is specially designed for the tapping process.

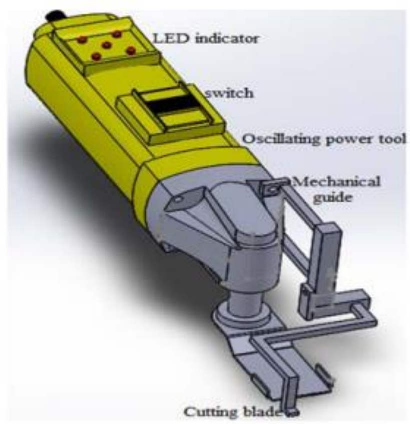

Figure 2.5: 3D model of the semi-automatic rubber tapping machine (Soumya *et al.*, 2017)

The cutting blade design is originated from Jabong knife. It consists of a horizontal and a vertical cutting edge. The horizontal cutting edge has a saw tooth profile which can cut the bark layer when the cutting blade is oscillating on the old cut profile on the tree. The vertical cutting edge will cut the sides of the bark when the horizontal cutting edge is cutting on the tree. A mechanical guiding structure is used to trace the old cutting profile so that the cutting using the machine is based on the existing cut.

Besides, the authors also used Inertial Measurement Unit (IMU) based system which can monitor the orientation of the device. The pitch and roll of the machine are monitored throughout the cutting process and ±5° is allowed for both angles. The machine will communicate with the user using the 5 LED indicator. The user should keep only the LED at the centre on and other LEDs will indicate the disorientation of the machine. If the angle of disorientation exceeds the allowable range, the relay circuit in the machine will cut off the power to prevent undesired cut.

c) <u>Analysis</u>

The machine has been tested in a rubber plantation by an unskilled labour. The test showed that the tapper can performed the tapping process without disorientation using the semi-automatic RTM. Figure 2.6 shows the results of 5 run tests for the pitch and roll of the machine.

(a) (b)

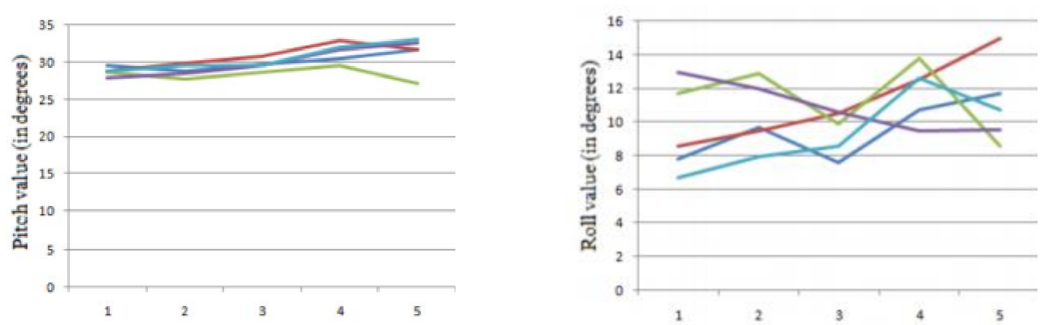

Figure 2.6: (a) Pitch and (b) Roll results (Soumya *et al.*, 2017)

From the cut quality, it can provide a smooth helical cut. The thickness of the bark removed is between 1.5 to 2.0 mm and the length of each chip are between 2.5 to 3.5 cm. It is almost similar to the skilled rubber tapper when they cut using traditional knife.

The author also performed the test using traditional knives and tapping machine by wearing hand gloves with force sensitive resistor (FSR). They found out that the effort of rubber tapping with RTM is lesser compared to the traditional knives. However, the motor used by the authors is normally for the wood and stone cutting which is heavy. They proposed that the motor should be custom made to reduce the weight, battery power and consumption.

d) Conclusion

The proposed design solution by the authors is good as they do not require experienced rubber tapper labours to perform the tasks. In overall, the semi-automatic rubber tapping machine shows a good performance throughout the testing while the motor and battery can be improved to increase the performance of the machine.

2.2.4 The Design of Flexible Rubber Tapping Tool with the Settings of Depth and Thickness Control (Susanto *et al.*, 2019)

a) Introduction

Rubber tree is one of the major economic crops in Indonesia. The authors interviewed several rubber planters and found out that the non-optimal tapping technique is the main obstacles. The depth and thickness of slicing the bark are irregular and the cambium can be damaged during the tapping process. Thus, the authors designed a rubber tapping tool and tested it.

b) Summary

The rubber tapping tool is designed and simulated using AUTOCAD software as shown in Figure 2.7. The tool should tap with depth of 1 to 1.5 mm from cambium, thickness of 1.5 to 2 mm and slope tapping grooves of 30° to 60°. The author mentioned that the older the tree, the deeper the thickness of bark should be removed due to more latex vessels. The device is still work manually by the labour.

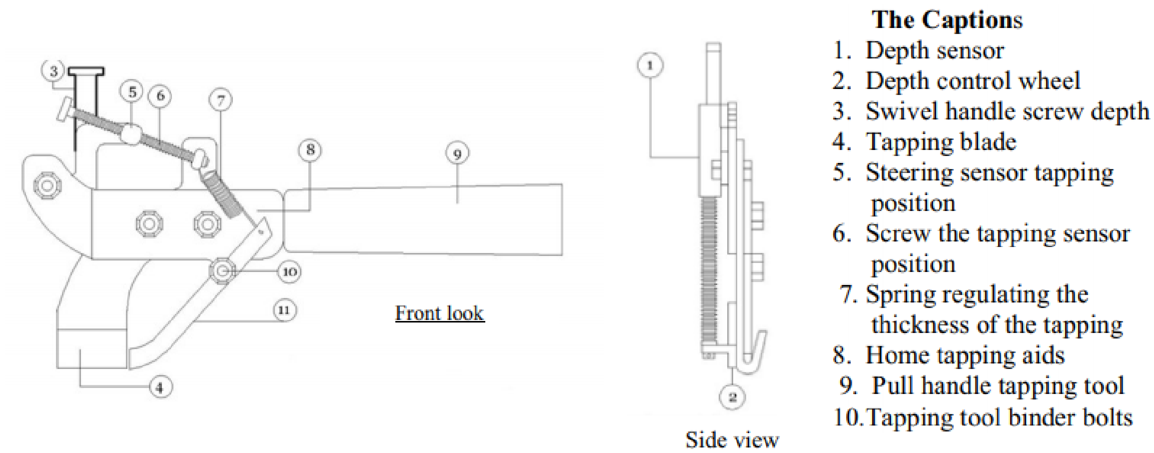

Figure 2.7: Design of the tapping tool (Susanto *et al.*, 2019)

c) Analysis

The authors did not mention on the performance of the rubber tapping tool. However, they focused on how the slope of the tapping angle will affect the weight of latex collection. It shows that as the tapping angle increases, the weight of latex collection will be increased. In conclusion, they stated the rubber tapping capacity is 5 to 6 s which is few seconds faster compared to traditional tapping machine without further discussion.

d) Conclusion

The design can give tapping depth of 1 to 1.5 mm from cambium, tapping thickness of 1.5 to 2 mm, tilt slope of 30 to 60° and perform tapping process faster than traditional tools. However, the author has minimum information for the design and tested data. They also conclude that the increase of tapping angle will increase the weight of latex collection.

2.2.5 Design of Automated Rubber Tapping Mechanism (Kamil *et al.*, 2020)

a) <u>Introduction</u>

The authors pointed out that due to technical difficulties, aging workers and poor working environment, an intelligent RTM is required. Besides, synthetic rubber's properties still could not outstand natural rubber and the demand for natural rubber products are keep increasing. Natural rubber is preferred because of its resistance to aging, low and high temperature and chemical.

From author's study, the bark is usually 6 mm thick and consists of lactiferous vessels, where the latex is produced. Cambium helps to boost the growth of rubber tree and it should be free from damage. In early morning, the bark will have less torque pressure which allows the tapper to tap with smaller force. A tapping panel will be created 1 m above the union and 30 degrees diagonal cut from higher left towards lower right of the bark. The latex will then flow through the path of the diagonal cut and then to the vertical path and into a cup as shown in Figure 2.8.

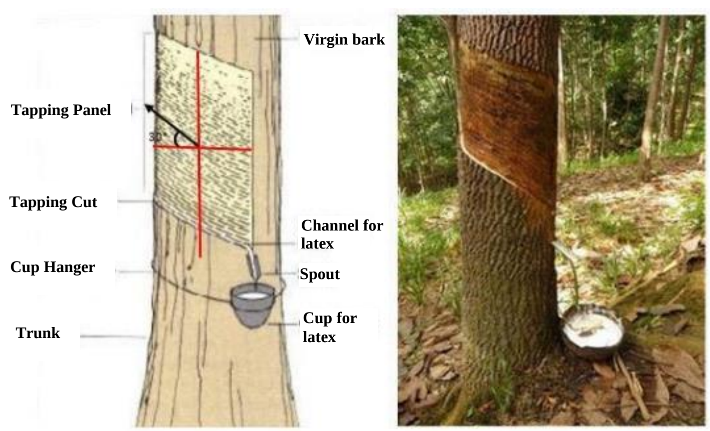

Figure 2.8: Tapped rubber tree (Kamil *et al.*, 2020)

In Malaysia, rubber tree is usually tapped using Jebong knife. It cut the bark without damaging the cambium in the early morning due to high quantity of water in the rubber which leads to the increase of rubber production. The number of workforces required in a rubber tree field is massive. Due to time consuming and exhausting workload, it is hard to find experience tapper in Malaysia. It usually takes three to six months to train a newbie to perform the tapping process. Thus, the author wanted to design an automated RTM to overcome this problem with lesser labour and knowledge required to collect the latex.

b) <u>Summary</u>

In their design, the tapping module system consists of two linear guides, two stepper motors, three infrared and controlled by Arduino Uno sensors as shown in Figure 2.9. The design aimed to mimic manual hand tapping motion and increase latex production. Stepper motors are used in both linear guides. The first linear guide (Linear guide A) performed upward and downward movements and the second linear guide (Linear guide B) performed movements at 30° from the perpendicular of first linear guide. The traditional tapping knife is wielded to the linear guide B and infrared sensors are used to control the movement of the linear guides.

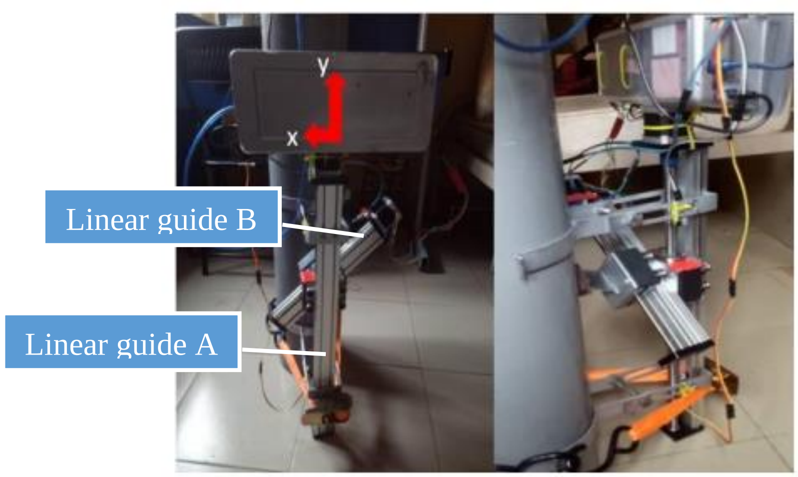

Figure 2.9: Design of the tapping module (Kamil *et al.*, 2020)

c) Analysis

In author's design, the cutting is based on a 2D flat surface which is not realistic as the curve surface of rubber tree. The cutting tool is only based on the linear guide B which the force to cut the bark might not be sufficient. On the real rubber tree, it will have different depth of cut across the circumference of rubber tree. The design is not complete and not been tested on a rubber tree.

d) Conclusion

The system that been designed by the author is not comprehensive. However, the mechanism can be used as a reference.

2.3 Mechanical Properties of Rubberwood Hevea Brasiliensis

From the research done by Humberto, the mechanical characterization of rubberwood was carried out to obtain the properties such as compression, shear, tension and embedding (De *et al.*, 2015). A computer controlled electromechanical testing machine was used to carry out the tests as shown in Table 2.1.

Table 2.1: Physical and mechanical characteristics of rubber tree at 12 % moisture content (De *et al.*, 2015)

Common name	D_b (g cm^{-3})	β_r (%)	β_t (%)	β_v (%)	β_t/β_r (%)	$\sigma_{c\|\|}$ (MPa)	σ_s (MPa)	$\sigma_{t\perp}$ (MPa)
Rubber tree—RRIM 600	0.55	2.5	5.8	9.5	2.3	43.50	9.60	4.00
Rubber tree—GT1	0.54	2.7	5.8	9.3	2.2	49.80	9.90	4.20

$\sigma_{c||}$ = Compression strength parallel

σ_s = Shear strength parallel

$\sigma_{t\perp}$ = Tension strength perpendicular

β = Shrinkage

From the table, two sample trees are being tested, which are RRIM600 and GT1. The samples were originated from the cities of Macaubal and Itajobi, respectively, and both are in Brazil. From Table 2.1, the shear strength of the rubber tree has an average value of 9.75 MPa.

2.4 Cutting Force Requirement

Cutting force is the force required to remove the material from the parent material. The cutting force is also called as shearing force and the magnitude is depending on the cutting area and the mechanical properties of the material to be cut. According to Er. KD Singh, a tool designer, the cutting force can be calculate using the equation below (Singh, 2020):

$$F_{sh} = l \times t \times T_{max} \tag{2.1}$$

Where F_{sh} = Shearing Force (N)

l = length of cut/ perimeter of the component (mm)

t = thickness of material (mm)

T_{max} = Ultimate shear strength of material (N/mm^2)

2.5 Summary

From the literatures, the following summary that related to the RTM can be made:

- The first design (Yatawara *et al.*, 2019) is good where it can travel from tree to tree to perform the rubber tapping, and the control will perform all the work for rubber tapping. However, it is slower compared to manual human tapping and the steel arms are required to mount to the rubber trees so that it can travel from tree to tree.

- In second design (Prasada, 2020), it uses rack and pinion to move the cutter around the tree. It is simple and fixed to the tree. The depth of cutting can be adjusted by changing the bolt and nut arrangement on the knife. However, from the design, the RTM is only able to cut at a fixed trajectory. This is something that required to be improved.
- The third design (Soumya *et al.*, 2017) is a semi-automatic RTM which it requires labour to perform the rubber tapping process. IMU based system is applied, so that the labour can tap with correct orientation. The cutter has horizontal and vertical cutting edge with a mechanical guide to trace the old cutting profile.
- The fourth design (Susanto *et al.*, 2019) is also required labour to work manually and the design is not clearly discussed and presented by the author.
- The fifth (Kamil *et al.*, 2020) design mainly focus on the guides for the cutting tool. One guide is used for vertical movement for the cutting tool, while another guide is used for the movement at 30 degrees from the horizontal.
- In general, Hevea brasiliensis has the shear strength of 9.75 MPa and the cutting force for the tools can be calculated using the Equation (2.1).

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter will discuss the design details of the RTM, from design ideas to the complete design, which includes the material, motor sizing, 3D design and control system design. Methods of the performance analyses of the RTM using ANSYS and cost analysis will also be discussed.

3.2 Conceptual Design of Rubber Tapping Machine (RTM)

In the market, RTM can be categorized into two general type, portable and fixed RTM. Portable RTM is carried by labour to tap around in the rubber tree farm with designs that can assist the labour to do the tapping process. Fixed RTM will be mounted on the rubber tree and will stay on the tree for a period of time. Table 3.1 shows the options for the design of RTM. The RTM is powered by battery either it is semi-automated or fully automated and will be used outdoor. The battery can be placed on the RTM, or it can be carried by labour to power up the RTM. Besides, tapping tool is an important part of the RTM and it can be reciprocating or rotating cutting tool. Other than that, a RTM can be designed to be semi-automatic or fully automatic machine. A semi-automatic RTM will need the help of labour for daily tapping while a fully automatic RTM will only need labour for maintenance. In exchange of that, the cost of building a fully automatic RTM is higher than the semi-automatic RTM.