Rubber tapping machine performance and procedure

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Abstract. Rubber tapping is a rubber latex extraction process which has to be done early morning in order to satisfy cool climate for latex flow. It is a tedious process which takes great work force and man-hour it has to be done with great accuracy. It is a great necessity for an automated or mechanized tapping to cope with the market requirement. So it is required to design a Rubber tapping machine which should be affordable to small planters.

Keywords: Rubber tapping, Cutting tool, Latex, Optimization, Depth control, Guide ways

1. Introduction

The process by which latex is obtained from rubber tree is called Rubber tapping[39,20]. To perform this process we do incision into the bark of the tree this tends to lead us to cut the latex vessels in the tree from which then the product sieves out. To optimize the yield the timing of the incision needs to be set within the planting cycle. Each night or early morning a rubber taper must be utilized to remove a thin layer of bark along the lower spiral half of the specified tree trunk. After this the opposite side would be tapped thus allowing this side to heal[21,23]. A spiral cut in this case tends to help in letting the latex to run down to a collecting cup. This process is carried out either at early morning or in late night as this time the temperature is low thus helping to allow the latex to flow for longer duration before it getting coagulated and the cut getting sealed. Depending on what final product we require with regards to the end product with add chemicals as well as coagulant[24,27]. We get technically specified rubber which is end product after processing the naturally coagulated latex which is also referred as cup lump. The left over latex coagulation is rich in quebrachitol, a cyclitol or cyclic polyol[31, 37].

There is huge demand for rubber in India which is used to manufacture many product. To get latex a helical cut is made in the tree at a distance of around 4 feet from ground level and this should cover half of the tree by circling around it[28, 35]. The biggest problem which is faced by workers is that due diligence needs to be there so that the trees are not damaged. To perform these duties generally a worker is trained in proper technique for approx 6 months as poor technique can kill valuable tree. As well as it is very physically taxing task as we are cutting hundreds of trees manually[33]. This leads to a void for new design in the market to match the demand in the market by tapping more trees. A new design is proposed in this research paper along with its characteristics. Parameter influencing the problem are Material of frame, Shape of cutting tool, Tool material and dimension, Type of clamping used, Clamping material, Cutting speed, Shape of cut, Depth of cut, Durability, Ease of use, Cost effective and Strength of structure.[25]
2. Methodology

In this design we are using guide ways for the movement of the cutting tool in helical direction as shown in fig 1 and fig 2. A rubber pad is used to adjust the size and to mount it to the tree. Lead screw is used for the size adjustment. As a rigid structure is used for holding the cutting tool it gives more rigidity and strength to the machine. Reduce the total weight and manufacturing time.\(^{(38)}\)

![Solidworks model of rubber tapping machine](image)

**Figure 1.** Solidworks model of rubber tapping machine

![2D drawing of model](image)

**Figure 2.** 2D drawing of model

2.1. By performing ANSYS analysis

Found that the stress concentration is very less on the frame. By optimizing the frame into a semi-circular frame we can reduce the use of material by nearly 40% in the frame. Reduced material results in reduced mass which increase ease of use and low cost. We can use a low strength material as shown in fig 3 and 4.\(^{(1,8,10)}\)
3. Optimization

3.1. Geometry optimization with regards to energy minimization

In computational chemistry, energy optimization is a process using which we tend to find the arrangement in space, where there is a collection of atoms. Here we find computational model of chemical bonding along with net interatomic forces on each atom.\(^{(6,8,11)}\) Here we see that the acceptable value is closer to zero and position on the potential energy system is nearing zero. Along with this we see that a molecule is made up of a collection of atoms, condensed phases, ions, transition state or even a collection of these. Special emphasis was placed on minimizing the weight to reduce the weight as well as the cost.\(^{(22,26,32)}\)

The system was geometrically optimized to obtain a optimized structure which is found in nature by mimicking naturally obtainable design as this design can be used both for theoretical and experimental setup taking into account spectroscopy, chemical kinetics and thermodynamics.

3.2. Contact generation

Here we model various contacts in the model along with its contact conditions as shown in Fig 5.\(^{(2,3)}\)
3.3. Force generation

The tool has both push and pull force of magnitude 2N each as shown in Fig 6. This model shows force generation diagram with regards to the rubber tapping machine.\(^{4,12}\)

![Figure 6. Force Generation of the rubber tapping machine](image)

3.4. Meshing

The resultant force acts on the tip of the tool and the complex geometric components requires a fine mesh (large number of elements) for more accurate results. Whereas the other regions are normally meshed as shown in fig 7.\(^{5,13}\)

![Figure 7. Mesh generated on machine](image)
4. Model after optimization
After the analysis it is found that the design is stable and also provides simple design helpful in manufacturing the product. By the analysis it is found to be a better solution as shown in fig 8 and 9.\(^{(7,19)}\)

![Figure 8. Total Deformation of the machine](image1)
![Figure 9. Equivalent stress on the machine](image2)

5. Tool optimization
The fig 10 shows the CAD model of the tool on which all the simulation takes place. The large deformation in tool is observed to be \(9.537 \times 10^{-9}\) m as shown in figure 11. The initial stress on the tool is 51634 Pa as shown in fig 12. This makes it prominent that the tool needs redesigning.\(^{(18,36)}\)

![Figure 10. CAD model of cutting tool](image3)
6. Redesigned Tool
The fig 13 shows the CAD model of the tool on which all the simulation takes place. The large deformation in tool is observed to be $3.2618 \times 10^{-9}$ m as shown in figure 14. The initial stress on the tool is 51634 Pa as shown in fig 15. This makes its prominent that the tool needs redesigning. The redesigned model has less stress concentration and deformation, by decreasing the cutting angle and increasing the thickness of the blade and diameter of angle.

Figure 11. Deformation of cutting tool

Figure 12. Equivalent stress of cutting tool

Figure 13. Redesigned model of cutting tool
7. Fatigue analysis of cutting tool

This cutting tool works for infinite life as shown in fig 16. The equivalent stress of the redesigned model of cutting tool in fatigue analysis is 16221 Pa as shown in fig 17. The safety factor for the redesigned model of cutting tool is 15 as shown in fig 18. The damage on the machine is 1000 as shown in fig 19. The tool has a high life cycle, which avoids frequent replacement and grinding and it is less prone to damage gives us details about various characteristic of tool under fatigue analysis.
Figure 17. Stress of Redesigned model of cutting tool under fatigue

Figure 18. Safety factor of Redesigned model of cutting tool under fatigue

Figure 19. Damage of Redesigned model of cutting tool under fatigue
8. Material optimization and properties
From ANSYS it is found that the total weight of the machine has been reduced from 10.05Kg using structural steel for frame to 4.17kg by using aluminium alloy. Here stainless steel is used for cutting tool as shown in fig 20 and 21 as well as table 1. The reduced mass helps in easy carrying and increase the efficiency of working

\[16,30]\]

![Figure 20. Structural steel frame](image)

![Figure 21. Aluminium Frame](image)

| Parts   | Materials   | Density (gm/cm³) | Young’s modulus (Gpa) | Poisson’s ratio |
|---------|-------------|------------------|-----------------------|---------------|
| Frame   | Aluminium alloy | 2.7              | 70                    | 0.35          |
| Rubber pad | Aluminium alloy | 2.7              | 70                    | 0.35          |
| Support | Stainless steel | 8.05             | 190                   | 0.265         |
| Tool    | Stainless steel | 8.05             | 190                   | 0.265         |
| Bolt    | Stainless steel | 8.05             | 190                   | 0.265         |

9. Results and conclusion
- Reduced total mass of the machine by half that is from 10KG to 4.6KG, by changing the material from structural steel to aluminium alloy.
- Reduced the total cost by redesigning the model such that it uses less material and uses less mechanical components.
- Modified the cutting tool such that it has less deformation and stress acting on the contact point.
- Increase the tool life.
10. References

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