AN APPROPRIATE TECHNOLOGY APPROACH TO MECHANISATION OF COCONUT HARVESTING

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Summary

An inexpensive mechanical drive system for climbing tall monocot trees such as the coconut palm is proposed. The main features of the proposed system are:

(i) a novel self-gripping tree-climber mechanism designed to carry the operator with it,
(ii) a counter-weight assembly centrally located in the coconut field, and
(iii) a cable linking the counter-weight to the climber mechanism.

The operator exercises control over the speed of climbing by supplementing the pull of the counter-weight whenever the speed is too low, and by applying a partial brake whenever the speed is too high.

1. INTRODUCTION

The coconut palm[1] thrives in the moister regions of the tropics — along the banks of backwaters, lagoons and estuaries, and close to the water's edge on sandy sea beaches. The palm yields many products of use to the human race such as oil, fibre, sugar and alcohol. The nuts will be of a better quality if harvested long before they appear dead ripe and start to drop of themselves from the tree.

To the author's knowledge no satisfactory method has been developed to date for harvesting coconuts on a large scale. In the traditional societies of south and south-east Asia, human labour has been used, but climbing tall trees is a difficult and hazardous task and skilled climbers are becoming scarce. Thus, there exists a pressing need to develop a machine which will make the climbing operation safer, easier and faster.

Mobile cranes are not suitable for the difficult terrains in which coconut palms are commonly found. What seems more appropriate is a machine which grips quite readily and runs up and down the tree at the operator's command. The machine should be designed to carry the operator with it.

The trees to be climbed could be as high as 15m. The trunk in most cases is upright and has a rough surface texture. The cross-section is approximately circular with a diameter in the range of 0.2 to 0.3m.

From a theoretical viewpoint, the net mechanical work done during the entire operation is zero. During the ascent, work is done to increase the potential energy. This energy is dissipated during the descent. If one considers the potential energy of the harvested coconuts, there will be more energy to be dissipated during descent than the energy supplied during the ascent. A machine system designed to recover and store the released energy will not require substantial extra energy input except for the initial energisation of the storage medium.

2. THE BASIC MECHANISM

The schematic diagram of the mechanism is shown in Figure 1. The main frame is formed by two identical bars ABCD and A'B'C'D' bent to an inverted 'V' shape. These are held together by cross bars CC' and DD'. Bars CC' and DD' in turn support two identical wheels W_1 and W_2 on frictionless bearings. The third wheel W_3 is also supported on frictionless bearings, but in this case, the bearings are carried on a slider S which moves smoothly along the inclined legs AB and A'B'. Initially, the slider and the wheel attachments are taken out and the machine is positioned with the tree inside the two bars ABCD and A'B'C'D'. The slider attachments are then put back onto the legs AB and A'B' and pushed up against the tree. All the three wheels have V-grooves to provide a better grip of the tree. As wheel W_3 is turned clockwise, it grips the tree automatically provided that the angle of inclination of AB and A'B' to CD and C'D' is less than a critical value as shown in the Appendix. When this condition is satisfied, the machine will move up the tree as wheel W_3 is turned clockwise. For a controlled descent the wheel should be released slowly.

3. THE DRIVE SYSTEM

The wheel W_3 is driven by a cable. The end of the cable is held firmly on a large drum attached to the axle of wheel W_3. The cable is wound on this drum and then passed over a pulley supported at a suitable location on the main frame. The cable is passed round this pulley a few times so that the tension in the cable can be boosted, if required, by applying a torque to the pulley (by means of a handle fitted to the pulley). As the cable is pulled down it unwinds from the drum and turns wheel W_3 clockwise. When the cable is released slowly, wheel W_3 turns counterclockwise and the cable rewinds onto the drum.

The counterweight system is centrally located in the coconut field so that it is accessible to all the surrounding trees. The counterweight is hung from two neighbouring coconut trees by a differential pulley and cable arrangement as shown in Figure 2. The cable from the climber mechanism is passed round a pulley supported at ground level on a self-aligning arm which is free to swing about a vertical axis. The cable is then reeved over the differential pulleys and its end is fixed to either of the two links supporting the pulleys. The arrangement enables the counterweight to exert a varying pull on the climber mechanism via the cable. Maximum pull is exerted when the counterweight is at its highest point and the climber mechanism at the ground level. The pull gradually decreases as the counterweight descends and the climber mechanism ascends. The counterweight together with the climber mechanism constitutes a single degree of freedom system undergoing free oscillations under the influence of gravity when set free. The system starts from rest, accelerates with decreasing magnitude for part of the climb and then decelerates with increasing magnitude for the rest of the climb. Similarly during the descent the system accelerates with decreasing magnitude and decelerates with increasing magnitude afterwards. The system will traverse the middle portion of the tree at high speed but the speed will be low at the two extreme positions. This enables the operator to closely control the stopping positions quite easily by either supplementing the pull of the counterweight or by applying the brake.

The counterweight will have to be locked in its position whenever a changeover of the climber mechanism from one tree to the next is made. This could possibly be done by means of a cable lock placed alongside the self aligning pulley.

4. CONCLUSIONS

Mechanisation of the coconut industry is the key to improved productivity in this sector. While mechanisation of dehusking and other downstream processes have been investigated before[2,3], no attempt has been made to date to mechanise the harvesting of the coconuts. As these devices are required in the developing countries, it is essential to keep down the cost of mechanisation.

In this paper, an appropriate technology solution to the mechanisation of the harvesting process is proposed. Two persons will be required to operate the system, one to go up the tree with the climber mechanism and the other to carry supervisory function on the ground. A cable and counter weight system is used for the drive system, but alternative drive systems such as electric and hydraulic motors can also be used. Consideration should also be given to the possibility of eliminating the need for a person to go with the machine by developing a remotely controlled robotic manipulator arm to pluck the coconuts.

REFERENCES

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2. DENNIS, R.A. & NARAYAN, C.V., "Design and Development of a Coconut Dehusker", WEST INDIAN JOURNAL OF ENGINEERING, Vol. 4, No. 2, p. 33.
3. SANKAT, C.K. & NARAYAN, C.V., "A Coconut Meat Extraction System for Copra Production", Paper presented at the 1979 summer Meeting of ASAE and CSAE, University of Manitoba, Winnipeg, June 24-27, 1979.

APPENDIX

Static force Analysis

For ease of analysis, the contacting surface of the tree is considered to be perfectly vertical. In Figure 3 is shown all the external forces acting on the mechanism. The tension in the cable is T and it is pulled down from the ground at an angle θ to the vertical. The normal reactions at the contact points of the wheels are R_1, R_2 and R_3 as shown. F_3 is the frictional force at the contact point of the wheel W_3. The frictional forces at the other two wheels are both zero since the wheels are on frictionless bearings and they are not subjected to any external torque. The combined weight of the system including the operator is Mg and it acts at the center of mass G. By considering the forces in the vertical direction, it is seen that for the machine to climb up,

$$F_3 > Mg + T \cos\theta \qquad \text{.......... (1)}$$

Torque balance on the wheel W_3 and the cable drum gives the following relationship between the frictional force F_3 and the cable tension T,

$$F_3 = n\,T \qquad \text{.......... (2)}$$

where n is the ratio of the cable drum radius to the wheel radius.

The free body diagram for the slider S, cable drum, and the wheel W_3 all considered together, is given in Figure 4. Q is the normal reaction between the slider and the legs AB and A'B'. F_4 is the frictional force between the sliding surfaces and mg is the weight of the slider and its attachment. β is the angle the cable (as it comes out of the cable drum) makes with AB. α is the angle between AB and CD. For the wheel to grip the tree firmly, the following condition should be satisfied:

$$T \cos\beta + F_3 \cos\alpha > R_3 \sin\alpha + mg \cos\alpha + F_4 \qquad \text{.......... (3)}$$

Resolution of the forces perpendicular to AB gives,

$$Q + T \sin\beta - F_3 \sin\alpha - R_3 \cos\alpha + mg \sin\alpha = 0 \qquad \text{.......... (4)}$$

$$\text{In the limit } \frac{F_3}{R_3} = \mu_e = \tan\lambda \qquad \text{.......... (5)}$$

where μ_e is the effective coefficient of friction, and λ is the effective friction angle.

$$\text{Also, } \frac{F_4}{Q} = \mu' = \tan\lambda \qquad \text{.......... (6)}$$

where μ' is the coefficient of friction between the slider S and the legs AB and A'B' and λ' is the corresponding angle of friction.

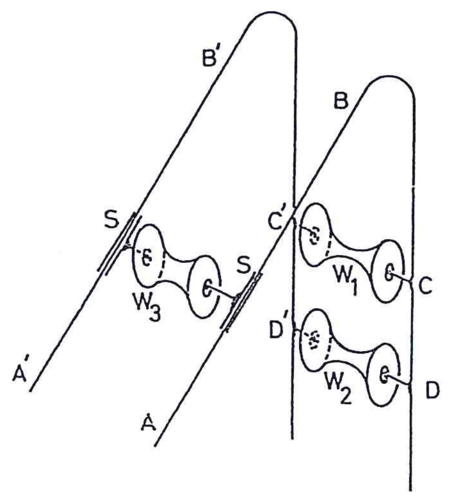
Note that for a V-grooved wheel $\mu_e = \frac{\mu}{\operatorname{Cosec}\psi}$ where μ is the actual coefficient of friction for the two contacting surfaces and ψ is the semi-groove angle of the wheel. By combining the above equations it can be shown that for self gripping t take place:

$$\tan\lambda > \frac{(\sin\alpha + \cos\alpha \tan\lambda')}{(\cos\alpha - \sin\alpha \tan\lambda') + \frac{(\cos\beta + \tan\lambda' \sin\beta)}{n} + \frac{mg}{nT}(\sin\alpha \tan\lambda' - \cos\alpha)} \qquad \text{........... (7)}$$

When the above inequality is satisfied, the wheel will not slip on the tree. When the torque on the cable drum is increased by increasing the cable tension T, the forces Q, R_3 and F_3 all increase proportionally until

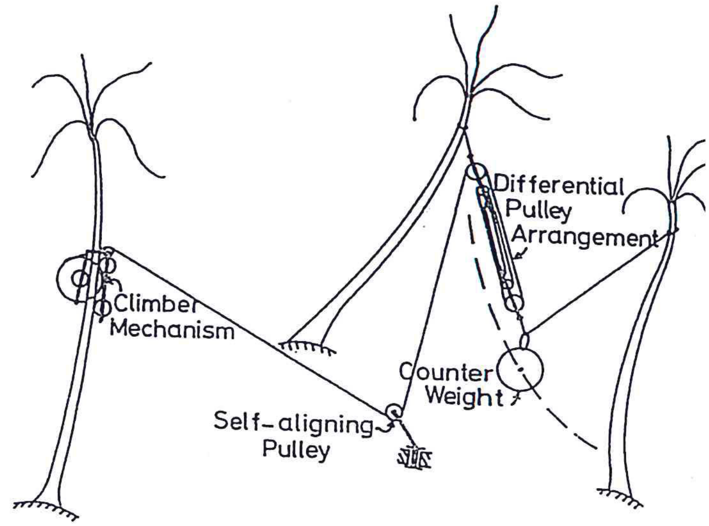
$$F_3 = Mg + T \cos\theta$$

At this point the machine begins to move up the tree.



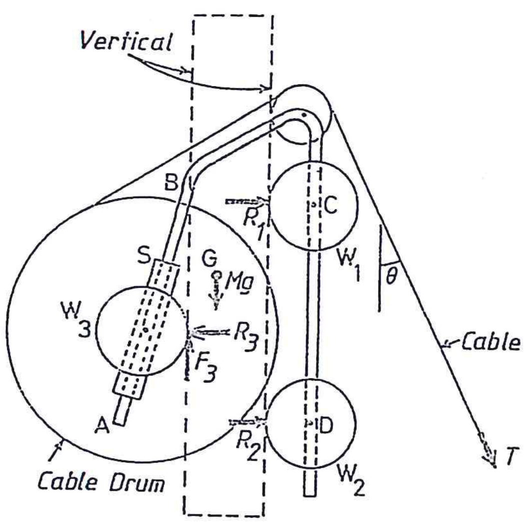
Schematic diagram of the basic mechanism

FIGURE 1



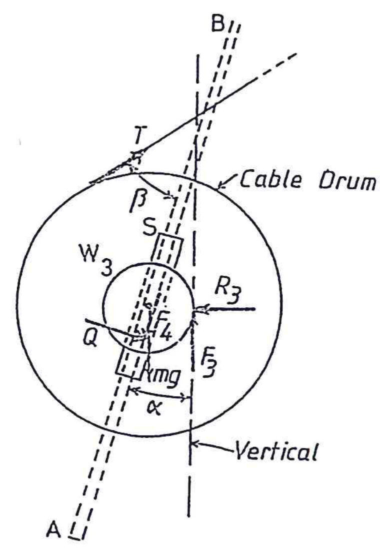
The cable drive system

FIGURE 2



External forces acting on the mechanism

FIGURE 3



Free body diagram of the slider and its attachments

FIGURE 4