Proposed Lifting Model for Gripper Date Palm Service Machines

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ABSTRACT

Many of the cultural operations of date palm tree require the man to climb the tree and work at a considerable height above the ground. This is a dangerous and slow operation further compounded by a severe labor shortage. The objective of this study is to propose an innovative gripper service machine in order to climb the tree and do special operations at the top. Gripper date palm service machine is a machine which connects to the tree trunk and uses it as support. It causes to reduce size and weight of this machine in order to utilize in date palm gardens which has no special planting pattern and palm is cultivated with other trees. This work demonstrates how a gripper climber machine can be applied to service palm trees with the aim of reducing the size, weight and cost. The proposed machine was designed in Solidworks computer software. Finally the maximum weight which the tree can suffer was estimated. According to the results of maximum load which the tree can suffer and safety of the occupant, it is recommended to use this machine as a remote control machine and without occupant.

Keywords: Date palm, lifting, climbing, lifter, climber, gripper, service machine, Iran

1. INTRODUCTION

The growth habit of date palm (*Phoenix dactylifera* L.) is a cylindrical, no branching stem, and relatively tall trunk. The trunk of date palm is composed of vascular bundles held together with connective tissues. Towards the periphery, where the leaf bases are embedded, the tissue tends to become more lignified and tough (Barreveld, 1993). The date palm tree commonly grows to a height of about 10 to 15m and features a slender trunk of more or less constant diameter from the base to the crown. Each year the old leaves are cut off at the base of the leaf stem. If the bases of the leaves are cut off, the trunk becomes smooth, much smaller in diameter, and more difficult to climb (Al-Suhaibani et al., 1988). Overall length of date palm depends on variety and region. In some cases as Shahani variety in Jahrom, the tree becomes 20 meters and more (Hashempour, 1999).

Many of date palm operations such as dethorning, pollination, thinning, bagging, pruning, harvesting and spraying for insect control require the man to climb the tree and work at a considerable height above the ground. Many of the difficulties arose from the cultural practices of random planting and intercropping with forage crops and fruit trees. The other major problem for the machines was crossing the irrigation canals and ditches. For attempts of mechanization of crown-related operations to be viable, the proposed machinery must be able to serve the orchards as they exist, without requiring any modification to the tree population, density or varieties, the irrigation network, and the cropping patterns (Al-Suhaibani et al., 1988). The proposed

machinery must also be affordable (Ali and Akyurt, 1998). A suitable machine can improve the productivity of the indigenous farmer, and hence the quality of the product, better timeliness and less dirt contamination and be considerably safer than climbing trees freehand or with a belt (Al-Suhaibani et al., 1988).

Al-Suhaibani et al. (1992) designed and evaluated a date service machine which uses the ground as support. Shamsi (1998) developed and tested a climbing machine to harvest and service date palm trees. This machine has three wheels which use the tree trunk as support. Ali and Akyurt (1998) presented several designs for machine systems that enable the undertaking of crown-related operations. Sclater and Chironis (2001) presented three griper designs for gripper robots. They introduced a reciprocating lever mechanism which opens and closes the jaws of a gripper robot and permitting it to grasp and release objects.

In this study, an innovative machine is proposed which is able to connect to the tree trunk and uses it as a support in order to climb any tall palm trees and do special operations at the top. No detailed literatures were found on gripper date palm service machines up to now. This work demonstrates how a gripper climbing model can be applied to service palm trees.

2. MATERIALS AND METHODS

A number of factors should be considered during selection the type of gripper. The gripper must clamp on the trunk firmly and yet not damage the trunk. It is further desirable to have a grip that makes use of force intensification techniques for the purpose of securing reliable grips. Based on Keramat Jahromi et al. (2007) reports, the maximum circumference of trunk is 215.00 cm at down of trunk and its minimum is 134.20 at the top for different ranges of tree age. Therefore the designed grips should have the capability of opening and closing in trunk diameter confine and math themselves with its variations. Fig.1 shows one of the designed grips for this mean. The reciprocating lever mechanism which introduced by Sclater and Chironis (2001) was the base for this design.

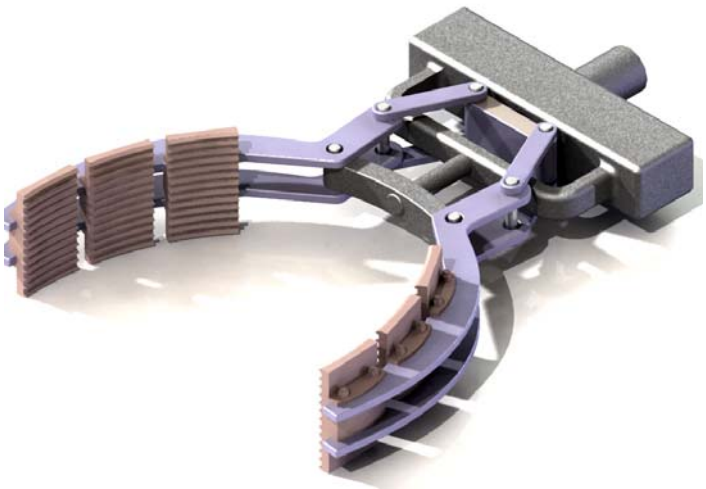

Fig.1. The designed gripper

This machine has four grips which are located in two sections. Each grip has a hydraulic jack which control its opening and closing. Two of the grips (bottom grips) are connected to the frame directly and the others (top grips) are able to move up and down with the connective jacks. The machine has three hydraulic connective jacks. Grips provide the machine connection to the tree and the connective jacks provide inconstant motion of this machine. All the grips and connective jacks are powered by hydraulic system for convenience and safety. The grip force on tree trunk is controlled by electro hydraulic load sensing system. This type of system gives very smooth control with very precisely controlled positioning. Also hydraulic sensors are used to regulate grips force on tree trunk with variation in trunk diameter due to different ingredients like soil, climate conditions and farming practices, particularly irrigation in different years. This system helps the machine to work on different groups of tree trunk diameters, too. The connective jacks have adjustable ramp functions to control the speed. The controls can be done by wire or wireless (remote) control in machines without occupant or by the probable occupant who is seated on the machine and has all the controls to hand. The designed machine in Solidworks computer software is shown in Fig.2.

Fig.2. The designed gripper date palm service machine

The working principals of gripper date palm service machine are as follows: The jointed arms are open when the machine is connected to the tree, to allow the trunk enter the frame among the grips. All the grips are open and the connective jacks are closed at this time. Then the jointed arms will be closed to confine the machine move only along the tree direction during its upward and downward motion and provide it from throwing out of tree. The grips embrace the trunk at

their center. There is a roller mechanism with spring pressure on each jointed arm which presses the trunk and helps the machine regulate its equilibrium, increase the contacting area with the trunk and finally reduce the pressure on the trunk. The bottom grips which are jointed to the frame are tightened firmly around the trunk to hold it in position and top grips are open. The connective jacks start to open and move the top grips (which are connected to them) up along the trunk. Hear top grips are close to hold the trunk and the bottom grips are released. Finally the connective jacks will be closed and allow the machine to lift up. At this time the only contact areas of machine with tree are the upper grips jaws (bottom grippers are open). Closing the connective jacks will cause to machine move up. This cycle will be repeated until the machine reach at the ideal height of tree. In order to descend the machine, these operations will be repeated controversy as following. The upper grips are locked to the tree and the bottom grips are open, opening jacks will cause to machine lift down. At this moment the only contact areas of machine with tree are the bottom grips jaws (the top grippers are open). Opening the connective jacks will cause to move the frame down and totally the machine move downward. Timing sequence stages of machine is controlled by microcontroller system.

One of the most important requirements of a date palm service machine is to ensure the safety of the probable operator and provide easy access to the crown of the tree. Keramat Jahromi et al. (2007) found that the average elevation of palm trees (cv. Shahani) is 10.32 m for trees with 45 years old. According to reports on a life of one hundred years old and more which resulted in higher elevation of these trees, it is necessary to consider special mechanisms for safety of climber machine. There are a number of safety features to protect the machine and the probable operator safety. The first safety mechanism should be considered to hold all over the tree trunk and confine the machine to move only along the tree direction during upward and its downward motion. If the grips don't work correctly, this mechanism will prevent the machine to throw out of the tree and it causes to reduce the damage to the machine and its operator. Another mechanism was used to lock the machine on trunk when the grips don’t work correctly in order to prevent machine throw. Also this mechanism is used during the period that machine is stop on the trunk at the top, in order to service the tree. The distance between the lowest green leave and fruits is varies between 0.62-2.14 m based on Kerramat Jahromi et al. (2007) research. View point to maximum movement of this machine below the lowest leaves, then a mechanism should be considered in order to access the fruits in harvesting purposes.

A garden tractor is considered in order to transport the machine in the garden. Also it provides the power requirement of the hydraulic pumps. Considering a combustion engine on this machine will cause to machine got very heavy.

In order to calculating the maximum weight of this machine and the fact that if this machine can be utilized by an occupant or not, it is necessary to know the maximum applied load which the tree can suffer. According to date palm variation in variety, the physical and mechanical properties of various varieties are different. The selected cultivar for determining the critical weight was Shahani Jahrom with the measured data which Keramat Jahromi (2007), Keramat Jahromi et al. (2007) and Keramat Jahromi et al. (2008) obtained for this variety. Shahani is one of the most important and also one of the highest varieties of date palm trees in Iran.

3. RESULTS AND DISCUSSION

Critical mass of machine due to bending and axial compressive strength of trunk, critical mass due to buckling, the maximum applicable force on each grip and the grips number due to climber weight are some of the designing aspects in designing this machine which should be calculated accurately considering appropriate safety factors for a practical prototype machine. Critical mass of machine is the only factor which is calculated here considering only one safety factor.

Because of high cost of manufacturing, it is important to determine the maximum weight of machine or the axial supposed load before manufacturing. The maximum axial load is sum of crown, occupant, machine and equipment like a saw, fruit shaker or the harvested fruits weights. It supposed that the load is applied along the longitudinal axes of the tree.

Stress due to bending and axial compressive strength is lower than stress due to buckling. Then buckling is the confident factor in determining weight of this machine. Calculating the trunk height to its radius showed that palm tree can be supposed as a tall column (for the mentioned trunk height). The maximum applied load in tall columns is calculated using Euler relation (equation 1 for columns with one side connection) with safety factor as F_s(=2.74) (Beer and Johnston, 1925) which was rewrite as equation 2:

$$P_{max} = \frac{\pi^2 E_c I}{4L^2} \qquad (1)$$

$$M_{max} = \frac{\pi^3 E_c D^4}{701.44 L^2} \qquad (2)$$

where P_{max}, M_{max}, E_c, I , L and D are the maximum load (N), critical mass of machine (Kg), compressive module of elasticity along the trunk fibers (Pa), the area momentum of trunk (mm^4), the tree trunk height (m) and the trunk diameter (m), respectively.

According to equation 4, the critical mass of machine was determined for trunk height ranges between 10-15 meters and five groups of trunk diameters as 0.40, 0.45, 0.50, 0.55 and 0.60 meters. The critical mass (which is written on the curves based on Kg) versus tree height (m) with safety factor of 2.74 is shown in Fig. 3.

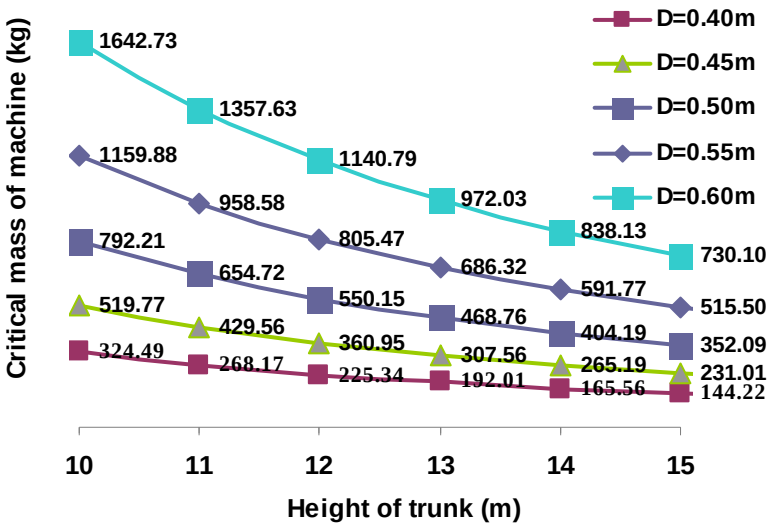

Fig.3- The critical mass of machine (Kg) versus tree (cv. Shahani) height (m)

Results show that the critical mass of machine decreases nonlinearly versus age in trees with same diameter. The critical load which the tree can suffer ranges between 144.22 and 730.10 Kg for trees with 0.40 and 0.60m in diameter, respectively. This range show that the variations in critical load respect to age and trunk diameter is very high. This critical load is sum of crown and fruit weight, the machine weight, the probable occupant weight and the required equipment weight for different operations. The machine weight designed by Shamsi (1998) was 150 kg which could carry a payload of 100kg. Totally he considered a maximum mass of 250 Kg for the machine weight.

In order to use this machine (without occupant) it is necessary to define a range of tree height and diameter which the machine can be utilized without damaging to trees. The safe estimated weight for the designed date palm lifter machine depends on height and diameter of trees. Considering average weight of 250 Kg for the crown, trees with height less than 15 m and diameter more than 0.50 m, prepare safe condition for using this machine with estimated weight of 100 Kg.

Safety is the most important instances which confine using of this machine with occupant. In addition to tree endurance and safety, there are some another unknown factors which are affective in determining the critical mass and are ignore in these calculations, like the strength of tree roots against the applied load and hurricane. The some other factors which confined using these machines with an occupant are difficulties of moving of this machine from tree to tree and not maneuverable enough between the trees.

Finally it is recommended to employ the grips in three different sections instead of placing them in two sections (which in one section the grips are fixed to the frame and in another section, grips are able to move) to prepare longitudinal equilibrium of machine around the trunk properly.

Since using the tree trunk as support will causes to reduce the size and weight of this machine, enable these machine to be cheaper than the machines which use the ground as support, and enable using this machine in date palm gardens which has no special planting pattern which palm is cultivated in combination with other trees, it is recommended to use this machine without occupant and as a remote control machine. The best way to use an occupant for servicing date palm trees considering safety, is utilizing the machines which use the ground as support. Using these machines requires certain changes in tradition gardens, for example, modification of the tree spacing and possibly the irrigation systems to permit easy and rapid access of the new machinery. These machines meet both of the requirements as well as the additional criteria of safety, practicality, and robustness.

4. CONCLUSIONS

1. Using the tree trunk as support will cause to reduce the size and weight of the proposed machine and enable this machine to be cheaper than the machines which use the ground as support. Also reducing size and weight enable using this machine in palm gardens which has no special planting pattern.
2. According to the critical mass results due to buckling, the critical mass which the tree can suffer ranges between 144.22 and 730.10 Kg for trees with 0.40 and 0.60m in diameter, respectively. The critical mass of machine decreases nonlinearly versus age in trees with same diameter. Buckling is the confident factor in determining weight of machine. Stress due to bending and axial compressive strength is lower than stress due to buckling.
3. In order to use this machine, it is necessary to define a range of tree height and diameter which the machine can be utilized without damaging to trees. It is recommended to use this machine without occupant and as a remote control machine.
4. Considering average weight of 250 Kg for the tree crown, trees with height less than 15 m and diameter more than 0.50 m prepare safe condition for using this machine with estimated machine weight of 100 Kg.
5. Remotely controlled tree climbing machine has the potential solution to the problems of harvesting and servicing date palm trees.

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