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Slow Tree Climbing Robot Analysis of Performance

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Abstract - ***This paper focuses on testing and performance analysis of an anthropomorphic tree climbing robot. The first part of the research consisted of design and development of an anthropomorphic tree climbing robot. This paper presents the second part of the research which consists of velocity, acceleration and torque analysis of robot and its effects on the performance. Performance measures like speed of climbing, distance covered per cycle of climbing are discussed. The robot specifications like the battery capacity required, range of size of tree stem the robot can climb are discussed. The performance of the robot is tested and the dynamic problems that occurred are analysed and the necessary modifications and additions in the design of the robot are presented in this paper. ADAMS View software is used for the velocity, acceleration and torque analysis.***

Key Words: *Tree climbing robot, ADAMS view, Torque, anthropomorphic.*

1. INTRODUCTION

Many researchers all around the world have worked on climbing robots most of these climbing robots are capable of climbing regular structures like poles, walls, domes etc but a very few are capable of climbing trees, main reason being irregular surface and variation of diameter with length .It also requires greater agility and high manoeuvrability to be used as a product. Also the bark of some trees may not be strong enough to bear the weight of the climbing device, hence conventional climbing robots cannot be used for tree climbing applications. Many trees like coconut tree, areca nut tree, and palm trees are so tall that climbing them becomes risky. Hence harvesting fruits and nuts and maintaining them becomes difficult. So development of a unique tree climbing mechanism is necessary which may be used for maintaining and harvesting applications. In olden days most of the activities were done manually. Gradually many equipments were developed to ease human activities, thus to lessen the human efforts to do the things. Presently most of the activities which included human efforts are either replaced or automated by the use of machines or other kind of equipments. Due to the height and lack of branches, it is very difficult to climb on coconut trees. A professional climber with proper training only could able to climb coconut tree. Due to the risk involved very less people are coming forward to climb on coconut trees. Due to the lack of professional climbers, the existing professionals may charge more from the owners, moreover as the educational background of Indian youth is increasing most of the people may hesitate to come in this type of profession. Considering this scenario, a device which will help the user to climb coconut tree easily will be useful for the people who are having coconut cultivation. It's very hard to learn the necessary skills to climb coconut trees. The few first times, people barely managed to get a few feet off the ground. In addition to fear, the soft skin on the palms of hands and soles of feet made climbing difficult. During the initial climbing the skin of palm, chest and foot skin may be disturbed. Climbing person's feet and toes, walk up alternating moving feet and hands. Technically it seems to be the easiest to learn but requires good balance and arm strength. [8]

2. VELOCITY AND ACCELERATION ANALYSIS

In this study changes in velocity and acceleration of each link is analysed for 3 cycles of climbing. Graphs of velocity and acceleration vs. time are plotted for each link. The graphs plotted for the arms indicate that velocity and hence acceleration is zero at the time when the arms are gripped to the stem of the tree. Thus there is no force of gripping. The gripping is achieved completely due to the friction between the arms and the stem.

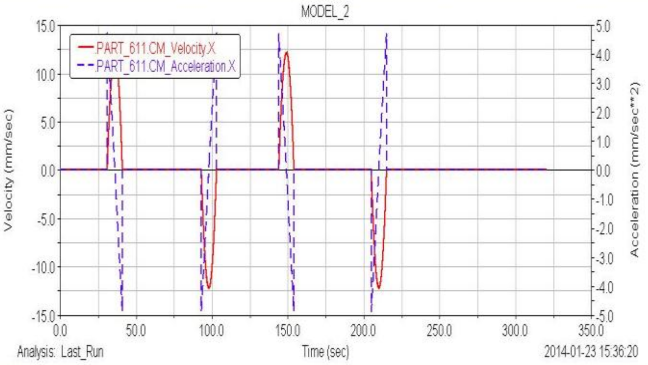


Fig 1: Velocity and acceleration vs. time for lower left arm

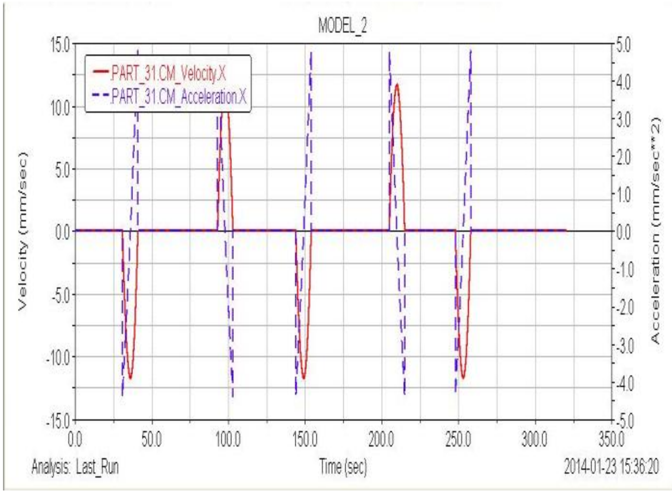


Fig 2:Velocity and acceleration vs. time for lower right arm

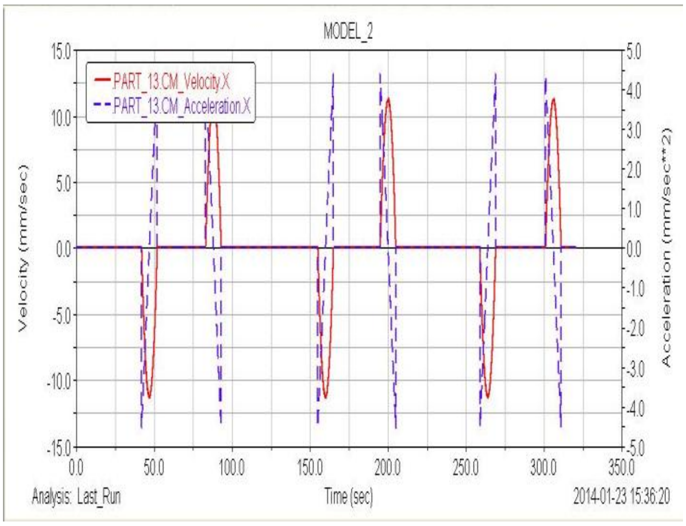


Fig 3: Velocity and acceleration vs. time for upper left arm

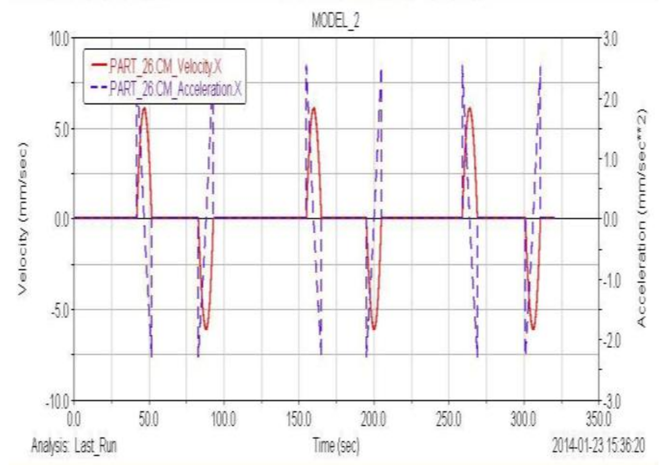


Fig 4: Velocity and acceleration vs. time for upper right arm

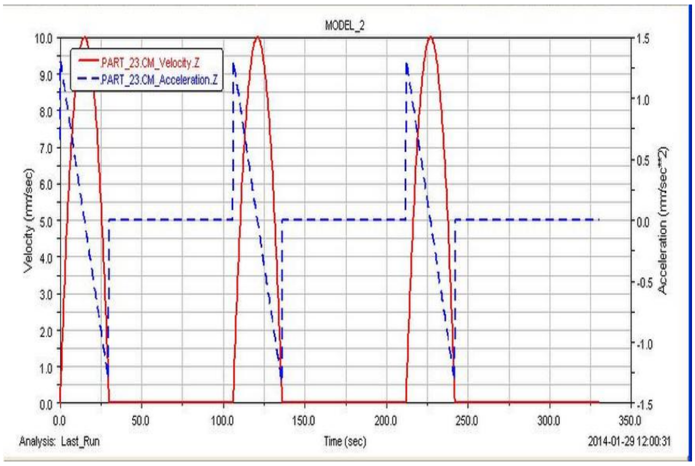


Fig 5: Velocity and acceleration vs. time for lower body

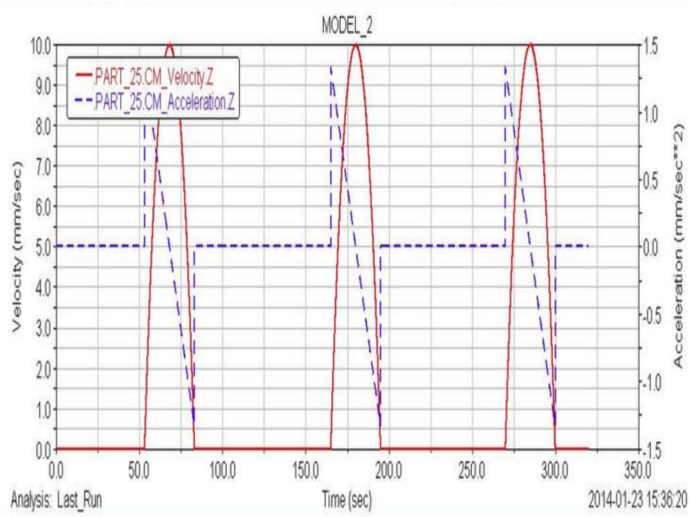


Fig 6: Velocity and acceleration vs. time for upper body

3. TORQUES AT THE JOINTS

Simulation results showed that there should be torque (force) to grip the arms firmly to the stem. Initially in the research this point was not considered. If this force is not present, the arms will not be able to grip the stem firmly and may slip down because in the gripped condition the whole weight of the robot has to be supported by the contact between the arms and the tree stem. When the motors are in locked position they only hold the self-weight of the arms but no additional force is exerted to grip the arms to the tree stem. To provide this additional force changes have to be made in the gripping mechanism.

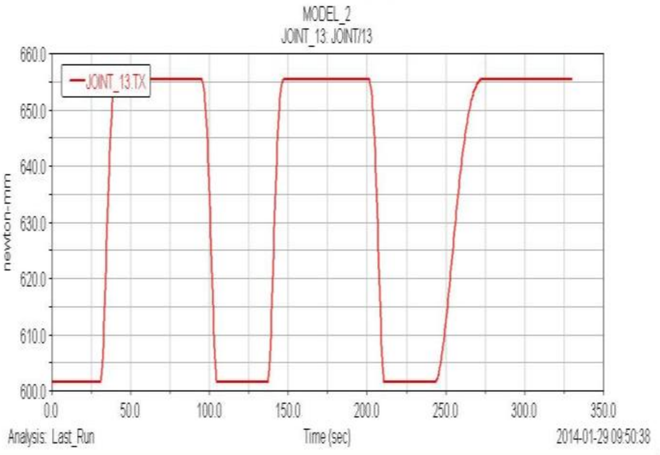


Fig 7: Torque vs. time for lower arm joint

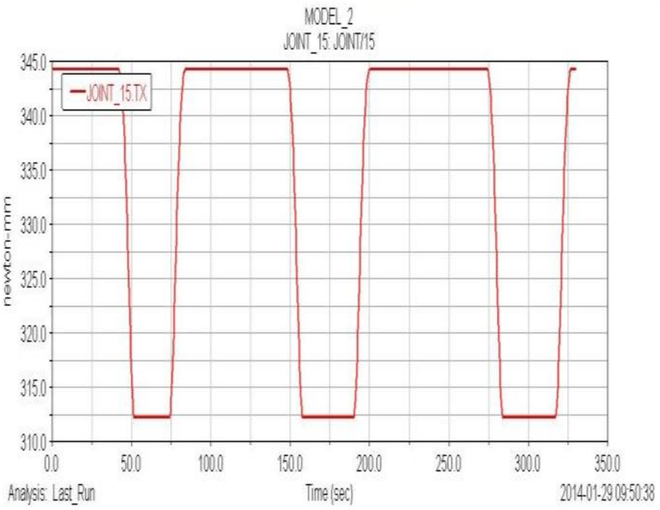


Fig 8: Torque vs. time for upper arm joint

4. PERFORMANCE OF THE TREE CLIMBING ROBOT

Experiments were conducted to test the performance of the robot based on the pre-defined performance parameters such as speed of operation, ranges of diameters of the tree stem the robot can climb and the distance covered per cycle of climbing.

4.1 SPEED OF OPERATION In this study the experiments were conducted to determine the speed of operation of the robot by measuring the time taken by the robot to complete 1 cycle of climbing. These results were compared with the results of simulation conducted in the ADAMS VIEW software. The speed of operation was found to be lesser compared to the speed of operation in the simulation. It is found that more time is taken in firmly gripping the arms to the tree stem due to the absence of the additional force in the locked condition of the motor. Below table shows the comparison between the experimental results and the results of simulation

Table1: Speed of operation

Description of the step	Experimental results (Time taken in seconds)	Simulation results (Time taken in seconds)
Step 1	10	10
Step 2	32	30
Step3	30	10
Step4	10	10
Step5	32	30
Step6	28	10
Total time taken	142	100

4.2 DISTANCE COVERED PER CYCLE OF CLIMBING

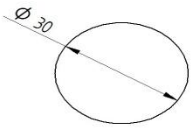
In this study experiments were conducted to determine the maximum distance the robot can climb per cycle with maintaining dynamic stability. The robot could not achieve the designed length of traverse per cycle of climbing. When the robot was made to cover the designed length of traverse the dynamic stability of the robot was getting affected.

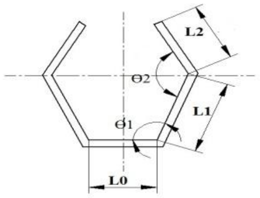
Table2: Distance covered per cycle

Description	Experimental results (distance in mm)	Designed length of traverse (distance in mm)
Distance traversed	240 mm	400mm

4.3 RANGE OF DIAMETERS OF THE TREE STEM

The range of diameters of the tree stem that robot can climb depends on the length of the link on which the arms are mounted (L0) and the length of the arms (L1 and L2).





The minimum diameter of the tree stem = L0=150 mm

The maximum diameter of the tree stem=2*L0=300 mm

4.4 BATTERY CAPACITY

There are totally 5 motors used in this robot. 4 motors are used to actuate the arms and 1 motor is used to actuate the rack and pinion. 2 motors operate at a time to open or close the arms and 1 motor operates independently to actuate rack and pinion and vertical movement of the robot.

Motors to actuate arms

Power of motor= P = 2*π*N*T/60
= 0.10788 watts
Maximum current drawn by the motor= P/V
= 0.10788/12
I= 8.99 mA
Total time for which the motor is operating= 40 seconds
Capacity of battery= I*t
= 8.99 ma * 40
= 0.3596 As
Total no of motors= 4
Capacity of the battery= 4* 0.3596
= 1.4384 As

Motors to actuate rack and pinion

Power of the motor =P= 2*π*N*T/60
= 0513717 watts
Maximum current drawn by the motor= P/V
I= 42.80 mA
Total time for which the motor is operating= 64
Capacity of battery= 64* 42.80
= 2.7392 As
Total capacity required per cycle= 4.1776 As
= 1.160 *10-3 Ah
Length of the tree= L
Length traversed in 1 cycle= 0.4 m
No of cycles required to climb= (L/0.4)*2
Total capacity of the battery= ((L/0.4)*2*1.160)/1000
Ah

Hence the capacity of the battery is directly proportional to the length of the tree to be climbed.

Fig 9: Experimentation

Fig 10: Experimentation

Fig 11: Experimentation

Fig 12: Experimentation

Fig 13: Experimentation

5. CONCLUSION

From the results of the experiments and the simulations the following conclusions are made.

- The anthropomorphic tree climbing robot has a simple configuration which has resulted in simple design and reduced complexity of control compared to the existing tree climbing robots. It mimics the manual tree climbing method which makes it simple.
- The dynamic stability is a concern, due to the variation of centre of gravity (or ZMO-Zero moment point) as the robot climbs up the tree instability tends to occur. Further work has to be done in this regard to make the robot dynamically stable so that it covers the complete length in one cycle. Presently it is not able to cover complete designed distance of 0.4 m in 1 cycle of climbing
- From the velocity, acceleration and torque plots it is evident that an additional force is required to grip the arms firmly to the tree stem. The locked position of the motor does not provide that additional force to grip firmly. Due to this the robot is able to climb only one cycle successfully and after that it is slipping down.
- From the experimental and simulation results it is found that the cycle time of the robot is lesser than the cycle time of simulation. More time is consumed in gripping the arms to the tree as the additional force required to grip the arms of the robot to the tree stem is absent.
- The battery capacity required is directly proportional to the length of the tree to be climbed and it is given by the equation

$$C= ((L/0.4)*2*1.160)/1000 \text{ Ah}$$

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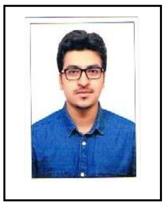
Author Profile



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