

## Research Article

### Dynamic Simulation Analysis of Forest-fruit Vibratory Harvester Arm

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**Abstract:** For obtaining excellent properties of vibration type picking machine of oil tea fruit, two and three dimensional virtual prototype of forest-fruit vibratory harvester was established by CAD and Pro/E software, then the dynamic prototype was converted and the dynamics simulation was worked out by the Adams system simulation software for the arm. The mechanical characteristics of arm were measured during positioning and vibrating the end of arm and they provide a theoretical references to optimize the physical prototype.

**Keywords:** ADAMS, dynamic simulation, forest-fruit harvester, virtual prototype

#### INTRODUCTION

Recently, harvesting fruit industry has become the core which improves the modernization of rural economic in China and the mechanization is the key to realize the improvement. In the area of the harvesting, vibrating-style fruit harvester is the most popular prospects for improvement, it suits to the large style and high rapid harvesting. But the traditional fruit vibrating-style harvester have many defaults while facing to the different environments (Chen *et al.*, 2011), there have some ways to be industrialization. The article built the dynamics model using the technology of virtual prototype and simulating analysis according to the all kinds situation, it could find and solve the problems in the practice, also could provide the theory references for the physical harvester (Yinhui, 2012), so as to accelerate the speed of the design and developing of the harvester.

In order to adopt the outdoor picking situation which was hilly and mountain area where were planted fruit trees, vibrating-style fruit harvester was designed to use track-style chassis device and picking arm to grasp and vibrate tree trunk, so as to assure that the harvester whole construction was compact, the chassis turning radius was small, the operation was flexible and the machine run the trees smoothly (Changqin, 2012). The harvester whole construction mainly includes: controlling system, chassis, picking arms, visual capture system, excitation mechanism, the clamping mechanism, picking up device, controlling system, the harvester virtual prototype model was built by CAD and Pro/E, which can prepare for the continue dynamic analysis.

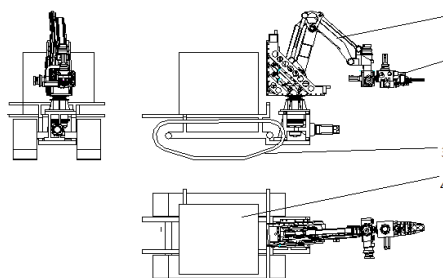


Fig. 1: Model of forest-fruit vibratory harvester

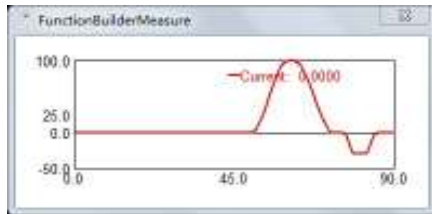
Firstly, general models of every part were built and then the parts' details were corrected. After two or three dimensional models of every parts were built, characteristics of different parts were identified and the assembly property was determined, virtual assembling was produced, there would be some problems (Horvath and Sitkei, 2005), such as interference, not enough space, unreasonable assembling, etc., which needed checking, through several times correcting of the model, the final assembly model was shown as Fig. 1. The objective of study can serve the excellent design for vibration type picking machine of oil tea fruit, thus it could help the machine manufactured in the reality successfully.

#### MATERIALS AND METHODS

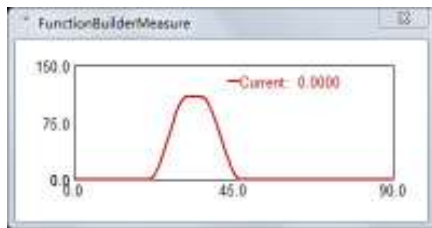
**Inputting model:** The studied vibrating style fruit harvester model was more complex, it didn't suit to build dynamic model directly, so the three dimensional model of virtual prototype of vibrating style fruit harvester general machine built by Pro/E was input into ADAMS. The software's Pro/ENGINEER 5.0 and

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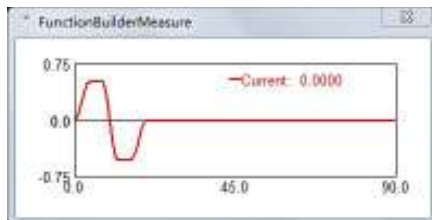
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(a) Rotary drive



(b) Horizontal moving driving



(c) Lifting mobile drive

Fig. 2: Drive function curves

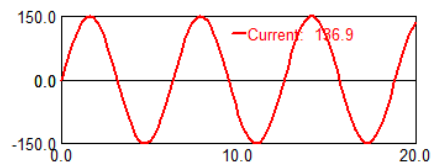


Fig. 3: Curve of vibrating harmonic force

ADAMS2012 were adopted in the article, \*.asm format model file in Pro/E could be input into ADAMS directly.

**Editing dynamic physical property model:** Relative parts were jointed together by Bule operation simply after the files were input into ADAMS, dynamic property of model was restricted, such as gravity set, correcting rigid quality property and simplifying virtual prototype model, other operation etc. and the simulation analysis was assured.

**Adding kinematic pair:** In the premise of not affecting the normal movement of the mechanical arm model, part's motion relationship was set. The process of building models needed to choose the bound carefully, it could avoid model causing over-binding phenomenon (Castro-García *et al.*, 2007). The corresponding pairs

were added after analysis of the movement relation between each member, then relative constraint was input after model testing, if there was any problem of over-constraint, basic side or side assembly would be adopted to replace the low side or the high side so as to avoid the over-constraint. Through the study of the mechanism, low side inline constraint could replace rotating pair to solve the over-constraint problem of vibration picking machine with three parallelogram structures, thus the model construction was completed and the simulation process was insured smoothly.

**Applying the drive:** During the picking operation of camellia fruit, the one situation was how to locate the picking head, it was as follows: picking arm base rotating; controlling the picking arm range; the main spindle of picking arm moving horizontally, controlling the distance between picking head and trunk; the main shaft of picking arm lifting up and down, controlling the picking head height relating to tree base; picking head rotating so as to aim at the trunk. This study mainly analyzed the part movement of the picking arm and adding corresponding drive of the picking arm.

Picking arm rotating drive function: STEP (time, 0.0, 0.0d, 4.0, 30.0d) + STEP (time, 8.0, 30d, 12.0, -30d) + STEP (time, 16.0, -30d, 20.0, 0d)

The main arm horizontal moving drive function: STEP (time, 21.0, 0.0, 32.0, 0.110) + STEP (time, 36.0, 0, 47, -0.110) + STEP (time, 48.0, 0.0, 49.0, 0.0)

The main arm lifting up and down drive function: STEP (time, 50.0, 0.0, 60.0, 0.100) + STEP (time, 62.0, 0, 73.0, -0.100) + STEP (time, 76.0, 0, 79.0, -0.030) + STEP (time, 82.0, 0, 85.0, 0.030) + STEP (time, 86.0, 0, 88.0, 0)

The drive function curves were shown in Fig. 2: While 0-20 sec, picking arm base was rotating; While 21-49 sec, level movement of picking arm 0 mm; While 50-86 sec, picking arm lifting up and down.

**Applying friction and working load:** In order to get the simulation data more accurate, friction was added in each moving pair. The two vibration conditions were analyzed in the process: the anti-force which trees applied to picking machine was changeable and more complex. On the basis of neglecting the torque size, it was considered as the harmonic force. According to the theory of value  $F = F_0 A \sin(2\pi ft)$ , also from experiment, the function curve was shown as Fig. 3.

**Model checking:** To complete the steps, dynamic simulation model of vibration type of fruit picking machine working device had been set up, finally the proving information of parameterized model was shown as Fig. 4.

After completing prototype model, the test needed model test to ensure the accuracy of the model, which displayed part numbers, quantity and degree of freedom of motion and indicated the correct inspection information.

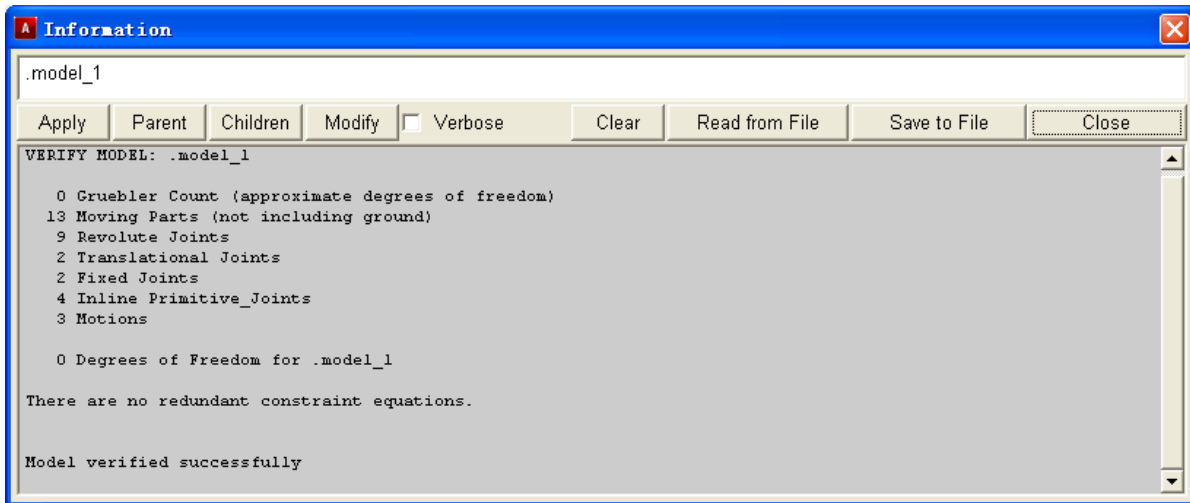


Fig. 4: Proving information of parameterized model

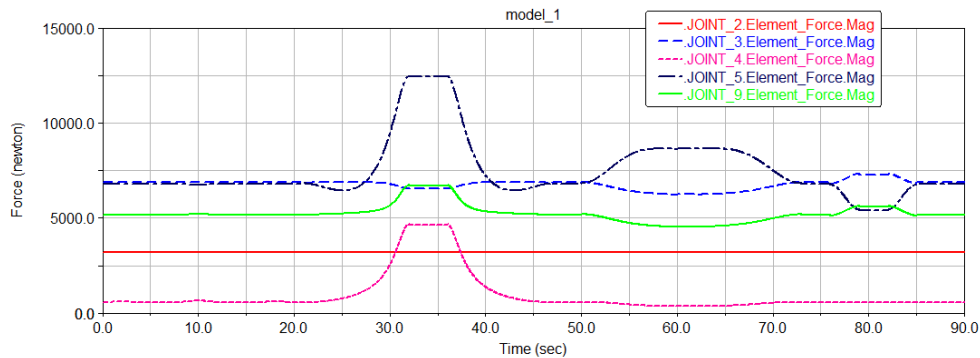


Fig. 5: Mechanical characteristics of motion joint

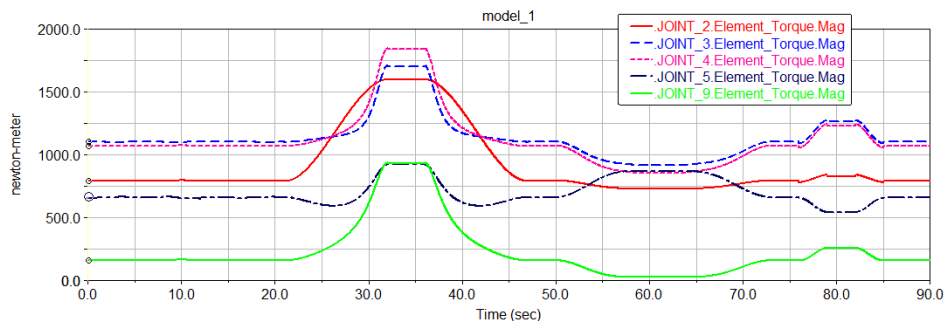


Fig. 6: Torque characteristics of motion joint

## RESULTS AND DISCUSSION

After model had been established, then all moving parts relation was determined and a virtual prototype simulation could be calculated (Castro-Garcia *et al.*, 2008). The calculate of interactive control simulation was used in this study, setting the simulation time was 90s, the simulation step number was set as the 4000 steps and the main motion joint and driving mechanical characteristics of two cases were analyzed.

**Mechanical analysis of the process of locating the picking head position:** The main kinematic pair: rotating pair JOINT\_2 of picking arm bottom, the horizontal movement of the sliding side JOINT\_3, sliding side JOINT\_4 lifting up and down, the main arm 1 connecting with the rotating side JOINT\_5, the main arm 2 connecting with the rotating side JOINT\_9. Combining the ADMAS/Processor module, force and moment values of the main parts could be obtained, as shown in Fig. 5 and 6.

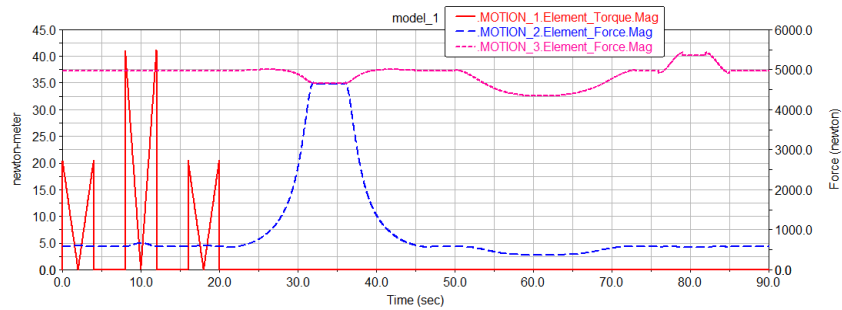


Fig. 7: Mechanical characteristics of drive

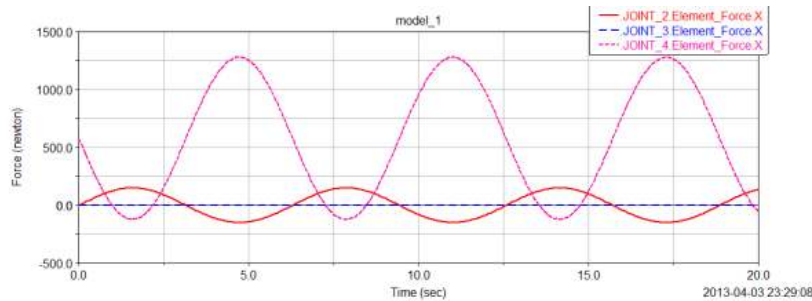


Fig. 8: Mechanical characteristics of main joint of picking arm

From the above, Fig. 5 and 6 could show, in the process of adjustment of picking arm position, force and moment values were changing with movement, the change values were larger sometimes; While the mechanical arm just started and stopped, force and torque both had peaks, so peak sizes were related to the member inertia and driving function set (Polat *et al.*, 2007). The overall trend of each joint motion measurement curves were close, the maximum force and torque of each joint were measured as follows: in the whole picking process, the rotary joint JOINT\_2 force was uniform, its' value was 3202.58 N, the maximum torque was 1597.97 N\*M; The maximum force of translational motion joint JOINT\_3 in the picking arm horizontal movement was 7340.43 N, torque was 1708.72 N\*M; Maximum force of lifting movement joint JOINT\_4 was 4682.81 N, torque was 1845.29 N\*M; The main arm joints JOINT\_5 and side arm movable joint force of JOINT\_9 were relatively small.

**Measurement of driving force:** Three drives of picking arm part were considered, they were the rotary drive, horizontal moving drive and lifting drive, the mechanical characteristics of drives were shown in Fig. 7.

According to the analysis of simulation curve, the maximum torque of rotating movement was 41.14 N\*M, the maximum drive forces of horizontal and lifting movement were 4681.92 and 5426.56 N. According to the simulation of the force and torque peak, the servomotor selection could be guided.

**Mechanics analysis of vibration harvesting process:**

In the vibration process of vibration head, picking head movement was predetermined to a certain location; picking arm was relatively stable, under the action of the exciting force, picking head part and the trees connected to form a resonance. The effect of vibration on picking arm was shown in Fig. 8.

Picking arm was studied as a rigid body, after anti-vibrating harmonic force applied, the whole movement of picking arm could not be caused, but the picking arm would be affected by the harmonic force. Because the exciter and picking head were connected with a damping spring, the affecting force of trees and picking arm would decrease relatively. From the simulation analysis, the biggest impact was counterforce for the picking arm on the vertical rail, the maximum was 1279.48 N. Force was relatively small; the picking arm strength design can meet the requirements.

**CONCLUSION**

- Virtual prototype model of vibration type fruit picking machine was constructed by Pro/E three-dimensional mapping software and picking dynamic model was calculated by the virtual prototype analysis of software ADAMS, it would provide reference for the virtual prototyping technology to further study on other specific fruit picking machine.
- Picking arm force value of vibration-type fruit picking machine was larger at the beginning and stopping or changing of exercise or exercise, it was

mainly related to inertia of rod and picking head. The picking arm and picking head quality should be minimized in optimization design.

- During working process of the vibration-type fruit picking machine, reaction force holding trunk by the picking arm was larger in vibration operating. The corresponding measures of reducing physical prototype vibration should be designed to decrease the influence of picking machine on the fuselage in the vibration process.

#### **ACKNOWLEDGMENT**

The authors thank the Key Project of Science and Technology Department of Hunan Province of China (2011GK 2012), Project of Science and Technology Department of Hunan Province of China (201104090), Open Lab Project of Centre South University of Forestry and Technology of China (KFXM 2012029).

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