

1. Establishment of finite element model of hippophae rhamnoides pruning

1.1 Characteristics of pruning and fruit of hippophae rhamnoides

After artificial pruning and natural growth, the branching pattern of Hippophae rhamnoides L. is axisymmetric, and the basic growth pattern of Hippophae rhamnoides L. is a main branch-primary branch-secondary branch-tertiary branch-tender branch, the main fruiting branches are tertiary branches and some small lateral branches growing on them. The local farmer pruned and harvested the secondary branches of the tertiary branches of the main pruning band, as shown in Figure 1.

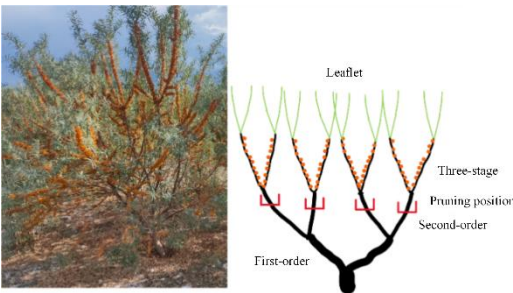


Figure 1. Diagram of growth and the sea buckthorn tree.

Table 1. Size of pruning branches of hippophae rhamnoides.

Se- rial No.	Secondary branch			Tertiary branch				Twig			
	Ini- tial Di- am- eter	End Di- am- eter	lengt h	Initial Di- ame- ter	End Di- ameter	leng th	Nu mbe r	Ini- tial Di- am- eter	End Di- am- eter	leng th	Nu mbe r
1	23	19	227	11~1 4	5~7	915 ~10 69	3	5~6	4~6	64~ 120	14
2	25	20	219	12~1 4	5	882 ~11 04	4	5~6	4~6	57~ 109	13
3	22	19	197	10~1 2	6	843 ~97 7	2	4~6	4~5	63~ 138	8
4	28	22	238	13~1 5	1	101 5~1 174	5	5~7	4~6	71~ 127	17
5	22	18	186	10~1 3	7	958 ~11 44	3	5~6	4~6	51~ 112	12
6	27	23	215	13~1 5	2	998 ~11 16	3	5~7	4~6	68~ 131	15

Using a vernier caliper, tape measure, and high precision electronic scale to measure the length of secondary and tertiary branches, branch diameter, stalk diameter, and fruit quality. The binding force between hippophae rhamnoides fruit and stalk was measured by Edberg digital display push-pull tester (Model HP-10, range 0 ~ 10N, accuracy: 0.001N). Take the cut branches of 6 different sea buckthorn trees as the measurement object, and obtain 6 groups of test data, as shown in Table 1.

1.2. A three-dimensional model of hippophae rhamnoides pruning were established

The three-dimensional solid model of sea buckthorn pruning is shown in Figure 2.

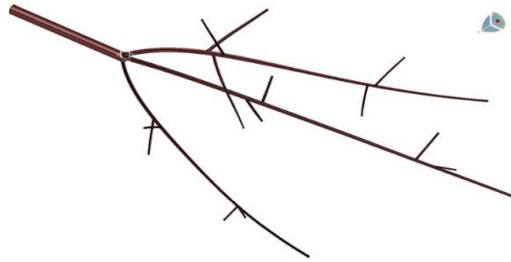


Figure 2. CATIA 3D model of hippophae rhamnoides cutting a branch.

2. Finite element simulation analysis

In Abaqus, the modal superposition method is used to analyze the harmonic response, and nine key points are selected on the three branches of the pruning model and digitally labeled 1-9, as shown in Figure 3.

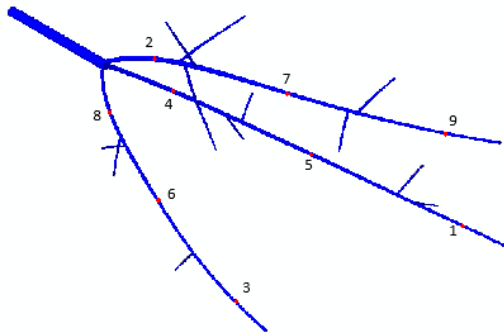


Figure 3. Nine marked points on the model.

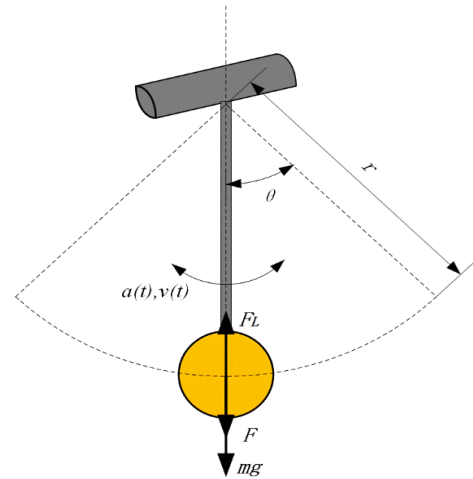


Figure 4. Schematic diagram of fruit pendulum motion

The short fruit stalk can be assumed to do simple pendulum motion in the vibration process, as shown in Figure 4.

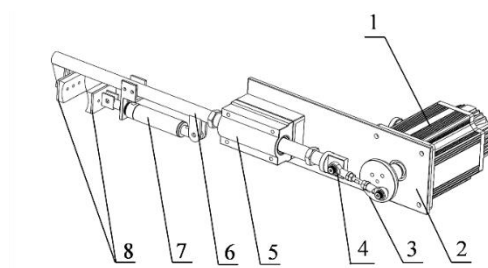
3. Dynamic Model of Prune-Device

3.1. The structure and work principle of that vibrating fruit thresh device

The vibration fruit threshing device mainly comprises a servo motor, a crank disc, a connecting rod, a vibration arm, a hydraulic cylinder, a clamping piece, a linear bearing, and a

supporting base, as shown in Figure 5. The linear bearing and the supporting base are used for restraining and supporting the vibration arm; the vibrating arm is guided by the linear bearing to do linear reciprocating motion; the hydraulic cylinder controls the movement of the clamping piece to lead the clamping piece to clamp the branch; The crank disc is provided with connecting holes with different sizes to adjust the amplitude.

When the clamping device works, hydraulic oil is controlled to enter the hydraulic cylinder from the hydraulic pump through the oil-pressing pipe to drive the lower clamping piece on the piston rod, so that the upper clamping piece and the lower clamping piece clamp the seabuckthorn pruning branches; When the excitation device works, the servo motor provides power, and the vibration arm linearly reciprocates through the crank connecting rod mechanism, so that clamped pruning generates forced vibration; and when the stress generated by the vibration branch at the connection point of the seabuckthorn fruit and the fruit branch is greater than the minimum stress for separating the fruit from the fruit branch, the seabuckthorn fruit falls off.

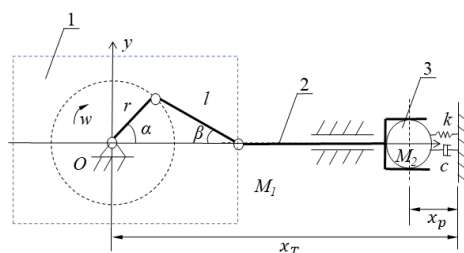


1. Servo motor 2. Support base 3. Crank disc 4. Connecting rod 5. Linear bearing 6. Vibration arm
7. Hydraulic cylinder 8. Upper and lower clamping pieces

Figure 5. Schematic diagram of vibration device.

3.2. Establishment of a Dynamic Model of Fixture-Pruning

Build the device-pruning dynamic model, which can be simplified to a single-degree-of-freedom equal-stroke mass-spring-damping vibration system, as shown in Figure 8. During the analysis, the following assumptions are made: The vibration damping of the vibration device is neglected, the vibration arm is regarded as a pure equivalent mass, and the elasticity and damping are neglected; the vibration device is in rigid contact with the hippophae rhamnoides fruit-carrying pruning; The mechanical properties of the pruning with the fruit of Hippophae rhamnoides L. are expressed by an equivalent elastic coefficient and damping coefficient.



1. Crank excitation device 2. Vibration arm 3. Hippophae rhamnoides with fruit pruning.

Figure 6. Device-cutting branch dynamic model.