DEVELOPMENT OF A PERSIMMON HARVESTING SYSTEM

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ABSTRACT

A persimmon harvesting vehicle that can be operated in hilly orchards as well as a manipulator that can be used to harvest persimmons located in remote positions in the trees were designed and developed. The vehicle could be operated with keeping balanced position in an inclined field and its working platform could be moved up and down easy to approach fruits in a remote region with the aids of a hydraulic and a electrical and electronics systems. The weight of the vehicle was 927 kg and the center of gravity was located at 427 mm to the inner side from the center of a right driving caterpillar, 607 mm to a rear axle from the center of a front axle, and 562 mm to upward from ground. The automatic level control sensor for leveling the working platform was activated within 14.5 ~ 16.5 degrees of slope variation. The total length of the manipulator was 1.39 m and weight is 975 g. It was powered by a 12 V geared motor to detach persimmon fruits with a rotational force. The gripper was made of plastic and rubber to increase a frictional force.

In a performance evaluation test, static tipping angle, dynamic tipping angle toward front side when the vehicle was moving downward, climbing angle, driving speed of the vehicle were measured or calculated. In persimmon harvesting tests 24.9% of yield was increased by hand picking with the aid of the vehicle and additional 7% of yield were increased when the manipulator was used. Therefore, 99% of total possible yield was achievable when both of the vehicle and the manipulator were used for the manual persimmon harvesting. Increase in 22.5% of total yield was achieved with the manipulator only.

Key Word: Persimmon, Harvesting, Vehicle, Manipulator, Automatic Level Control

INTRODUCTION

Persimmon is a fruit of a perennial arbor whose habitat is temperate and sub-tropical zones. It is produced in the southern part of a Korean peninsular. There are two types of persimmon, sweet persimmon that has high sugar content and firm flesh and bitter persimmon that is inedible due to its bitterness right after they are harvested. Persimmon is usually harvested by hands. However, harvesting is very difficult because over 70 % of persimmon trees are planted in hilly orchard. Also, the branches of persimmon trees are very weak to climb up, which make it difficult to hand-pick the persimmons located in the higher portions of trees (Lee et al. 1998). So persimmons in a hard-to-reach area are harvested using a ladder, which requires a very dangerous and hard work.

The persimmon is the second largest among all the fruits produced in Korea in terms of growing areas. Its production mainly relies on human labor and partially relies on power units. Sweet persimmons are usually grown by full-time farmers and guarantee high income. The most advanced nation in developing sweet persimmon varieties and production skill in the world is Japan. Like other agricultural products, Korean sweet persimmon growers are highly dependent on Japanese practices. Recently the market price of persimmon decreased because its domestic production increased and its export is relatively reduced. Its price competitiveness in an international market is decreased because persimmon market has been opened like other agricultural products and production labor cost becomes higher. Its price competitiveness will be decreased more if the current practice in production and use of power units is limited. Production of high quality products and mechanization to reduce production cost are the only ways for the Korean persimmon growers to survive in a current situation.

Persimmon harvesting is the most labor-intensive process, which takes up 20% of whole labor power for persimmon production. The second labor-intensive process is sorting and packaging, which take up 10% of whole labor power. Currently mechanical sorting machines, usually sort persimmons based on their weight, are popular in Korea. However, packaging and harvesting are totally done manually. Mechanization of harvesting process is difficult in most fruit harvesting. Especially, "Fuju" persimmon harvesting is very difficult even it is done manually by handpicking because persimmon trees are planted in hilly areas and in a dense form, which makes it more difficult to harvest fruits by hands. In addition the trees are quite high. So usually 10 % of total persimmon fruits are abandoned because of these difficulties in harvesting.

The objectives of this study were to develop a vehicle for persimmon harvesting which can keep balanced position automatically on slopes within about 15 degrees of inclination, to develop a portable manipulator for harvesting persimmon positioned in a hard-to-reach position, and to carry out performance test of the developed vehicle and manipulator.

PROCEDURES

Development of a prototype persimmon harvesting vehicle

A prototype persimmon harvesting vehicle, which could automatically control the level of working platform, was designed and developed. Figure 1 shows a side-view of the vehicle when a working platform is fully elevated. The vehicle was powered by a 16 horsepower gasoline engine to drive a hydraulic motor and was equipped with rubber caterpillars. Electronic level control system combined with hydraulic control system was used to control the position of working platform within 15 degrees of slope variation. A hydraulic pump was used to control the level of working platform of the vehicle. Figure 2 shows a schematic diagram of the vehicle. The elevation control of the working platform was performed only when the vehicle was stopped and the total moving distance and maximum height of working platform were 1 m and 2 m, respectively. Table 1 shows specifications of the vehicle.

The vehicle developed could be used in harvesting other fruits growing both in inclined and in plain regions. Also the vehicle could be used as a power unit that supplies power to other field machinery.

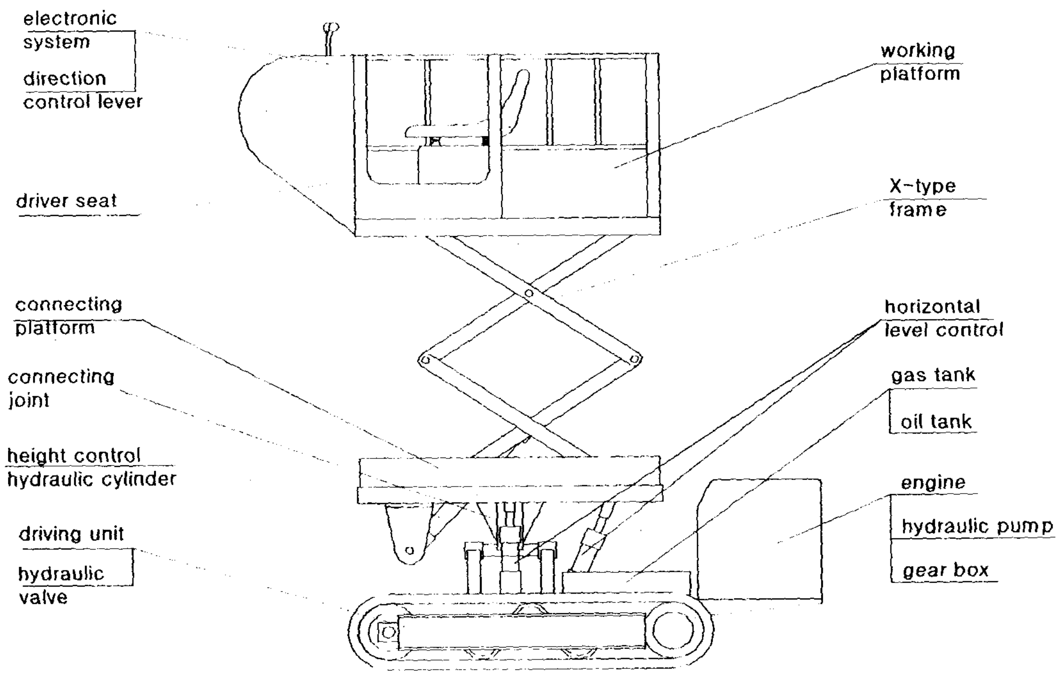


Figure 1. Side-view of prototype vehicle.

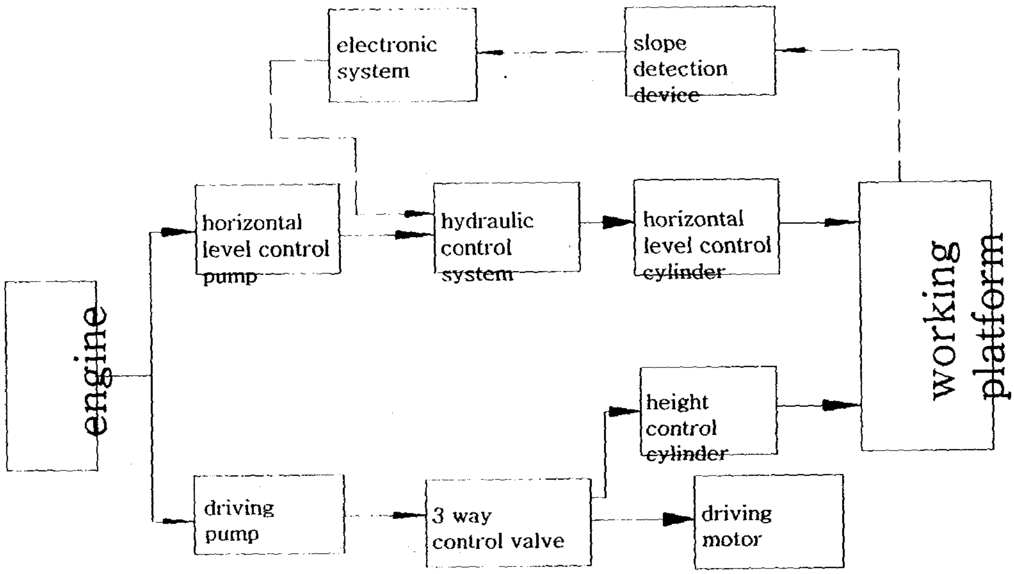


Figure 2. Schematic diagram of prototype vehicle.

Table 1. Specifications of prototype persimmon harvesting vehicle.

Vehicle body		length: 227.5 cm, width: 114.0 cm
		height: 285.0 cm (max.), 185.0 cm (min.)
Driving unit	engine	gasoline 16 ps
	gear driver	engine speed: driving pump ε=1, level control pump ε=0.5
	caterpillar	material: rubber, width: 24.0 cm
	driving pump	248 kg_f/cm^2, 6.10 cc/rev
	driving motor	160 kg_f/cm^2, 291 cm^3/rev, 598.4 N•m
Control system	hydraulic & electronic system, operating mode: manual, automatic	
	level control pump	248 kg_f/cm^2, 2.00 cc/rev
	horizontal level control sensor	4 proximity sensors
	control degree	15.5 deg.(leftward), 15.5 deg.(rightward) 16.5 deg.(forward), 14.5 deg.(backward),
Working platform		height: 200.0 cm (max.), 100.0 cm (min.)

Development of a prototype persimmon harvesting manipulator

A portable prototype manipulator was designed and developed. The total length of the manipulator is 1.39 m and weight is 975 g. A 12 V geared motor to detach persimmon fruits by a rotational force powered the manipulator. The gripper was made of plastic and rubber to increase the frictional force. Figure 3 shows the head part of the manipulator.

The developed manipulator for harvesting persimmons is small, light, and portable that can be used to increase the harvesting yield. Also the manipulator can be used to harvest other fruits.

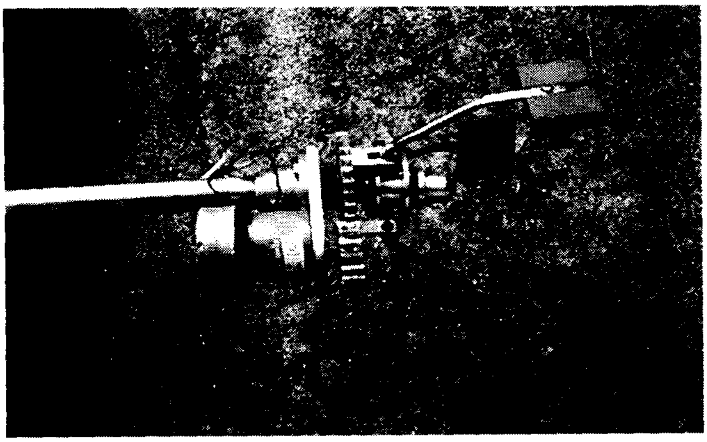
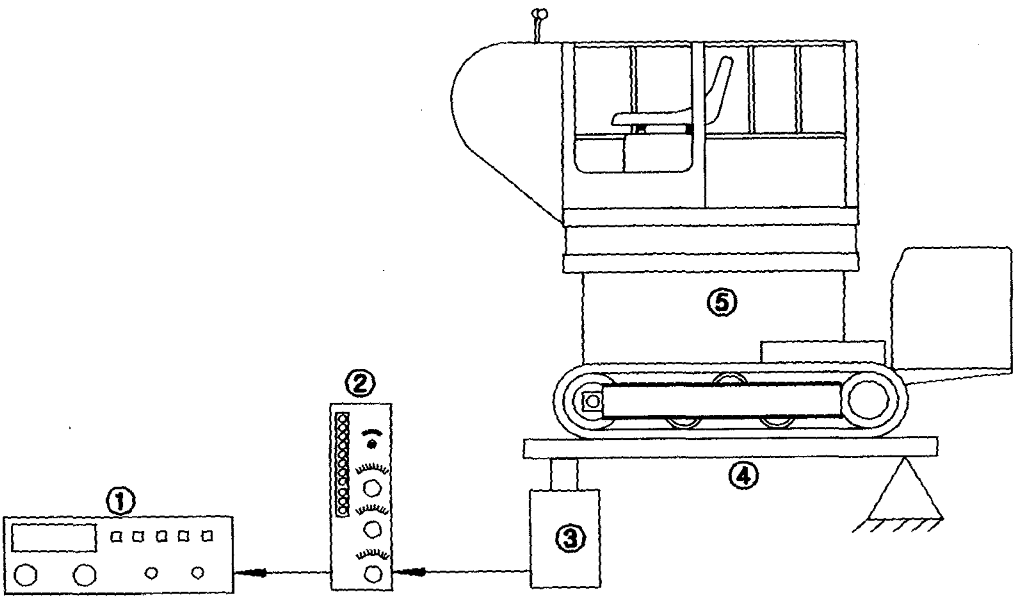


Figure 3. Gripper and driving motor of the manipulator.

Performance test

Several performance tests were done to determine the efficiency of the developed vehicle and manipulator. Measurements of weight and center of gravity, static overturning angle, driving speed at level ground and sloped field were done with the vehicle. Dynamic overturning angle and climbing angle of the vehicle were calculated. Also horizontal level controllability and persimmon harvesting tests were performed. Figure 4 shows an experimental setup for measuring the weight of the vehicle.



1. multimeter 2. strainmeter 3. load cell 4. steel plate 5. vehicle

Figure 4. Experimental setup for measuring the weight of the vehicle.

RESULTS AND DISCUSSION

Measurement of weight and center of gravity

The weight and the center of gravity of the vehicle were measured using an experimental setup shown in figure 4 and related moment equations. Total weight of the vehicle was 927 kg. The center of gravity of the vehicle was located at 427 mm apart from the center of a right driving wheel to a left driving wheel, 607 mm apart from the center of a front driving axle to a rear driving axle, and 562 mm apart from a ground contacting point to upward.

Calculation of dynamic overturning angle

When a vehicle is moving downward on inclined road, there is a possibility of forward overturning of a vehicle when a vehicle is stopped suddenly. To calculate a dynamic overturning angle at this situation, some assumptions were made. These assumptions were that vehicle weight was 927 kg, driving speed of a vehicle was 0.78 m/s, height of the center of gravity from ground was 0.56 m, and the distance between a front wheel axle and the center of gravity was 0.6 m. From a moment equation, a forward dynamic overturning angle was calculated. Determined forward dynamic overturning angle was over 30 degree when vehicle-stopping time was over 0.2 second.

Measurement of static overturning angle

Static overturning angle was investigated on two cases. One situation was when working platform was parallel to vehicle body without an automatic platform level control (in a manual mode) and the other situation was when working platform was inclined with an automatic platform level control (in an automatic mode). Measured static overturning angle was over 46 degree at manual mode and over 49 degree at automatic mode (refer table 2). Considering average slope of 25 degree in persimmon harvesting fields in Korea, the vehicle will be stable against a static overturning on fields.

Table 2. Measurement of static overturning angle at different operating modes.

Situation	When working platform is parallel to vehicle body				When working platform is inclined (automatically balanced)			
Direction	F	B	L	R	F	B	L	R
Overturning angle (deg.)	59.7	53.7	46.2	46.3	61.0	55.3	48.8	49.5

where F: forward, B: backward, L: leftward, and R: rightward

Calculation of climbing angle

Theoretical climbing angle of the vehicle was calculated. The assumptions were the weight of the vehicle was 927 kg, the weight of a driver was 65 kg, torque of driving hydraulic motor was 61 kg•m, radius of driving wheel was 0.16 m, and there was no rolling resistance. Under these assumptions, calculated climbing angle was 36 degree when the vehicle was loaded with a 300 kg weight.

Horizontal level controllability test

Horizontal level controllability test on control range, control starting angle, and control ending angle was repeated three times. Horizontal level control of working platform ranged from 14.5 degree to 16.5 degree (refer table 3). The automatic level control was started within 4 degree and ended within –2.5 degree.

Table 3. Results of horizontal level controllability test of working platform.

Control direction	Control range (deg.)	Control starting angle (deg.)	Control ending angle (deg.)
Forward	16.5	1.67	-2.50
Backward	14.5	2.83	-1.00
Leftward	15.5	2.17	1.5 0
Rightward	15.5	3.83	0.83

Measurement of driving speed at level ground

The driving speeds of the vehicle were measured on 20 m long level ground. The measurements were repeated 6 times and the average value was used as a driving speed. The driving speed was defined as the speed when accelerator of the vehicle was fully throttled. The speed was 2.83 km/h at level ground and 2.14 km/h on inclined road of 6.33-degree slope.

Measurement of driving speed at sloping field

Field driving speed of the vehicle was measured on winded 510 m long road in persimmon orchard in southern part of Korea (refer figure 5). Measured optimal field driving speed was 1.87 km/h when average slope was 6.33 degree.

Figure 5. Photograph of field driving test showing the vehicle and road condition.

Harvesting test

Field harvesting test was performed by using four different methods and the results were compared and analyzed. These methods were as follows; harvesting from ground with a manipulator, harvesting with a vehicle with/without using a manipulator (refer fig. 6), and conventional harvesting. Harvesting efficiency was improved about 20% compared to conventional manual harvesting and the ratio of unharvested fruits reduced to about 1 %. (refer table 4)

Figure 6. Photograph of persimmon harvesting on working platform with a manipulator.

Table 4. Harvesting efficiency on different methods.

Harvesting method	Harvesting efficiency (ea./min)	Ratio of unharvested fruit (%)	Remarks
Harvesting from ground with a manipulator	7.3	10.4	Not using a vehicle
Harvesting with a vehicle	8.7	8.0	Not using a manipulator
	8.1	1.0	Using a manipulator
Conventional harvesting	7.1	10.0	Climbing up to trees

CONCLUSIONS

A prototype persimmon harvesting vehicle, which could automatically control the level of working platform, and a portable prototype persimmon harvesting manipulator were designed, developed, and tested. Total weight of the vehicle was 927 kg.

Performance test results were as follows:

1. Static overturning angle was over 46 degree when working platform was parallel to vehicle body and over 49 degree when working platform was inclined (automatic platform level control)
2. Forward dynamic overturning angle was over 30 degree when the vehicle stopping time was over 0.2 second.
3. Calculated climbing angle was 36 degree when vehicle was loaded with a 300 kg weight.
4. Horizontal level control of working platform ranged from 14.5 degree to 16.5 degree.
5. Maximum driving speed of the vehicle was 2.83 km/hour at level ground.
6. Optimal field driving speed of the vehicle was 1.87 km/hour when average slope of field was 6.33 degree.
7. About 99% of fruits were harvested with the combined use of vehicle, manipulator, and hand picking.

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