DESIGN AND PERFORMANCE EVALUATION OF A CABBAGE LOADER

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ABSTRACT

Cabbage is the most important vegetables in korea. The cabbage production was based on arduous human labor. A comprehensive research for substituting the human work by machines has been performed at present.

In general, cabbage is cultivated on hillside in korea. The harvested cabbage in a field and carrying it to a vehicle for transportation are very laborious work. Hand labor in cabbage transportation to the market damages the quality of cabbage and is also a cause to increase the cost of cabbage production. This study was to design and evaluate a prototype cabbage loader for deserving efficient and safe transportation of cabbage.

The developed cabbage loader was a semi-tracked vehicle operated by a hydraulic system, allowing the safe transporting and the loading of cabbage in a steep field. The maximum loading capacity of the loader was 1.0 ton. By using safety devices attached to the loader, the static slopes were 34.0% and 37.4% for the left and the rear roll-over, respectively. The maximum field speed was about 6km/hr with two cabbage pallets of 750kg at a 25% inclined field. The field capacity was about 35 pallets/hr in case of picking up, carrying and unloading two cabbage pallets. The field efficiency of the loader was analyzed to be more than 8 times in comparison of the conventional human labor.

The developed loader would be applied for loading and carrying the other vegetables due to the similarity of operations. The study suggested a standard approach to the design of field machines operated in a steep field.

Key Word : Cabbage Loader, Semi-tracked Vehicle, Hydraulic System, Fork Lifter, Steep field, Safety Device

INTRODUCTION

Cabbage is the most important vegetables in korea. The production of the vegetables has been based on human labor. In particular, picking up the harvested cabbage in a field and carrying it to a vehicle on the road for transportation are very arduous work since cabbage is generally cultivated on hillside. Hand labor in cabbage transportation to the market damages the quality of cabbage. The operation is also a cause to increase the cost of cabbage production. According to the result of field tests, using cabbage pallets could save the transportation cost of about 28% in comparison of the conventional method by human labor.

A comprehensive research for substituting the human work in cabbage production by machines has been performed at present. In this study, a cabbage loader was designed and evaluated as a part of the research on the basis of the conventional operation. The operation efficiency and the safety of a loader on carrying cabbage by pallets in an inclined field were taken into account in the study. The function of the prototype loader includes to pick up the cabbage pallets in a field, and to carry and unload them to a vehicle for transportation.

MATERIALS AND METHODS

Basic Consideration on Design of a Cabbage Loader

Cabbage is conventionally transported by 5-ton trucks from the cabbage field to the market. On considering the carrying capacity and the size of 5-ton truck, a cabbage pallet would be 1.1m x 1.1m x 1.1m in size and the truck can carry 16 pallets by two layers of 8 pallets.

The maximum weight of a pallet carried with 100 roots of cabbage was about 350kg based on the result of measuring the maximum size and weight of cabbage. Therefore, the loading capacity of a cabbage loader should be more than 700kg with two pallets. In the study, the maximum loading capacity of the loader was determined to be 1.0 ton with a loading allowance.

The loader should have a function to carry cabbage pallets from a steep field to a vehicle on the road for transportation. The loader was designed as a semi-tracked vehicle in order to minimize a slip and secure the machine maneuverability in the field.

Design of a Cabbage Loader

The chassis of loader was a rectangular frame of horizontal structure on which a fork lifter operated by a hydraulic system was placed. Figure 1 and 2 shows the schematic diagram and the prototype of the loader, respectively. The overall dimensions were 2,6m x 1.2m x 2.1m(length x width x height). A box-type safety cab was designed for operator's safety.

The power train consisted of a 2-cylinder 18 HP gasoline engine, driving a transmission of high and low, two forward and one rearward speeds and a 9cc/rev hydraulic pump. The loader equipped with two operator consoles could be operated forward and rearward by turning the operator seat. The hydraulic system consisted of a 30ℓ hydraulic oil tank, 5 hydraulic

levers(longitudinal movement of lifter, lifting of forks, operation of side arms, operation of safety devices and tilting of forks), 12 cylinders and 4 flow-rate control valves. Table 1 shows the specification of hydraulic cylinders.

The maximum lifting height of forks was 2.5m from the ground considering the case that the loader would unload two cabbage pallets one by one on a vehicle for transportation. The lifter could move up to 1.1m inward of the loader from the position of picking up the pallets on the ground, so that the pallets could be placed on close to the weight center of loader for safe carrying. The forks could tilt by 10o horizontally for safe carrying.

The lifter was equipped with a set of side arms to prevent the cabbage pallets carried in an inclined field from slipping or rolling over. Figure 3 shows the side arms of loader. The operation of the side arms was consisted of combinations of a 90o rotation and a 60cm linear stroke. When picking up pallets, the side arms rotated first followed by a linear contraction for holding them tight while carrying. When unloading the pallets, they were extracted outward followed by a rotation. Such combinations were performed by a two-position hydraulic valve and four flow-rate control valves.

Two sets of safety devices were designed to avoid the roll-over of the loader in a steep field. The overall width between front wheels was extended up to 50cm by expanding two hydraulic cylinders in both sides. Two safety wheels attached above the rear side of rubber track were rotated to the ground, so that the overall length of loader could be extended by 40cm rearward. Figure 4 shows the rear safety wheels of loader. The rear safety wheels had the function to prevent the rear roll-over of the loader when picking up and unloading heavy pallets.

RESULTS AND DISCUSSION

Static Roll-over Slope of The Cabbage Loader

The static roll-over angles of the developed cabbage loader were analyzed by the mass simulation program of AutoCAD 14. The program could find the weight center of loader given the properties of each part on a 3-dimensional AutoCAD drawing, and analyze the static roll-over slopes with a functional script file.

Table 2 shows the static roll-over slopes of the loader. The reference in the weight center was the rear and middle point of the loader on the ground. The overall weight of two pallets filled with cabbage was assumed to be 750kg. Without pallets and safety devices, the static slopes were 91.6% and 58.5% for the left and the rear roll-over of the loader, respectively. On carrying two pallets without the safety devices, the slopes were reduced to 27.4% and 24.4%. By using safety devices, however, they were increased to 34.0% and 37.4%, respectively, for the corresponding roll-overs.

When picking up or unloading two pallets of full weight, the loader rolled over rearward because the weight center was extremely located on the rear of the loader. Figure 5 shows a schematic diagram of unloading two pallets with using the safety devices. Figure 6 shows the change in rear roll-over slopes with ballast weights when unloading two pallets at the lifting height of 1.5m from the ground. It was assumed in the figure that the ballast was equipped in

front of the loader with using the safety devices. The figure shows that picking up or unloading pallets was relatively stable at an inclined field by using ballast. Considering that most slopes of road be less than 10%, the ballast of about 120kg could remove the possibility of the roll-over in unloading pallets on a vehicle for transportation.

Performance Evaluation of The Cabbage Loader

Figure 7 and 8 show that the loader was carrying cabbage pallets in an inclined field and unloading them on a truck. The maneuverability of the loader was very excellent even in a steep field.

The maximum field speed of loader was about 6km/hr with two cabbage pallets at a 25% inclined field. The field capacity of loader was about 35 pallets/hr including picking up, carrying and unloading two cabbage pallets. Though depending on an operator's expertness, the operation efficiency of the loader was analyzed to be more than 8 times in comparison of the conventional human labor.

The developed loader would be applied for loading and carrying the other vegetables due to the similarity of the operations.

CONCLUSIONS

This study was to design and evaluate an efficient cabbage loader which could pick up, carry and unload cabbage pallets in an inclined field. The developed loader was a semi-tracked vehicle with a hydraulic system.

The loader had five hydraulic levers by which an operator could perform the work very efficiently in a field. The safe devices made it possible for the loader to be operated in most of inclined cabbage fields in korea. The high field capacity of the loader could reduce the production cost of cabbage.

The developed loader could be applied for loading and carrying the other vegetables due to the similarity of the operation, The study suggested a standard approach to the design of field machines operated in a steep field.

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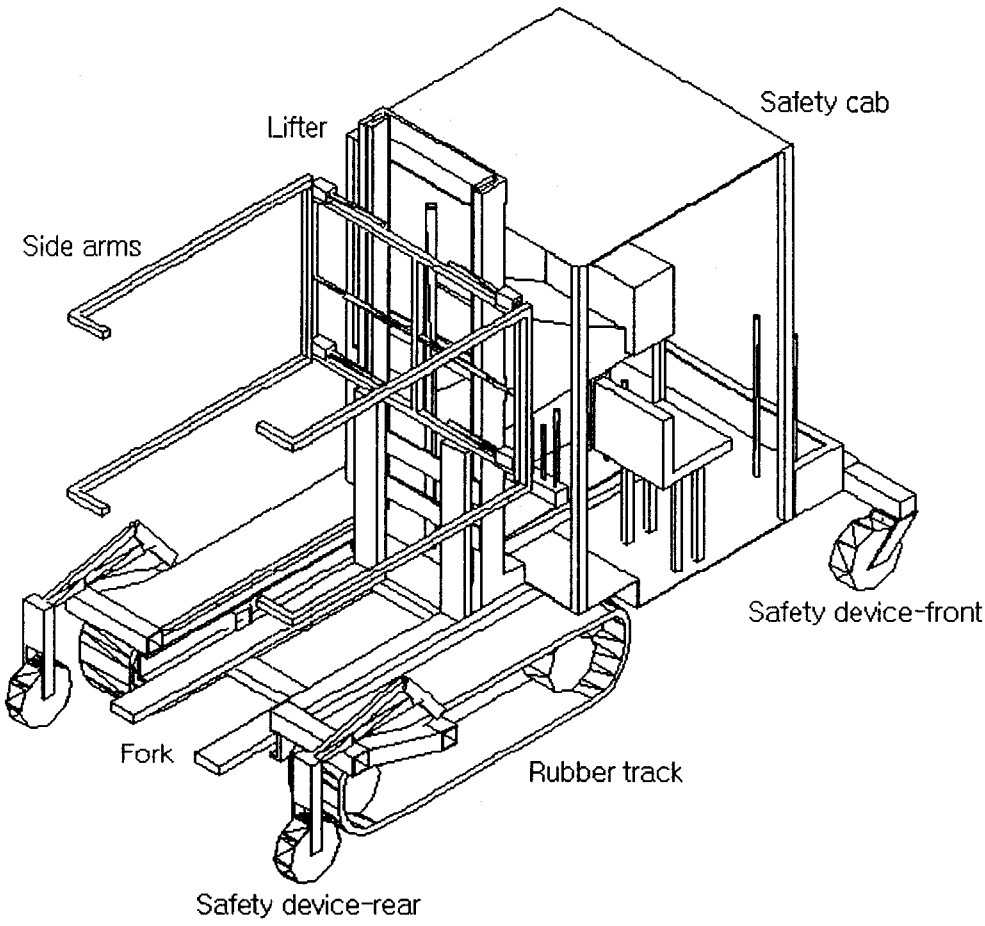

Fig. 1 The schematic diagram of the loader in the study.

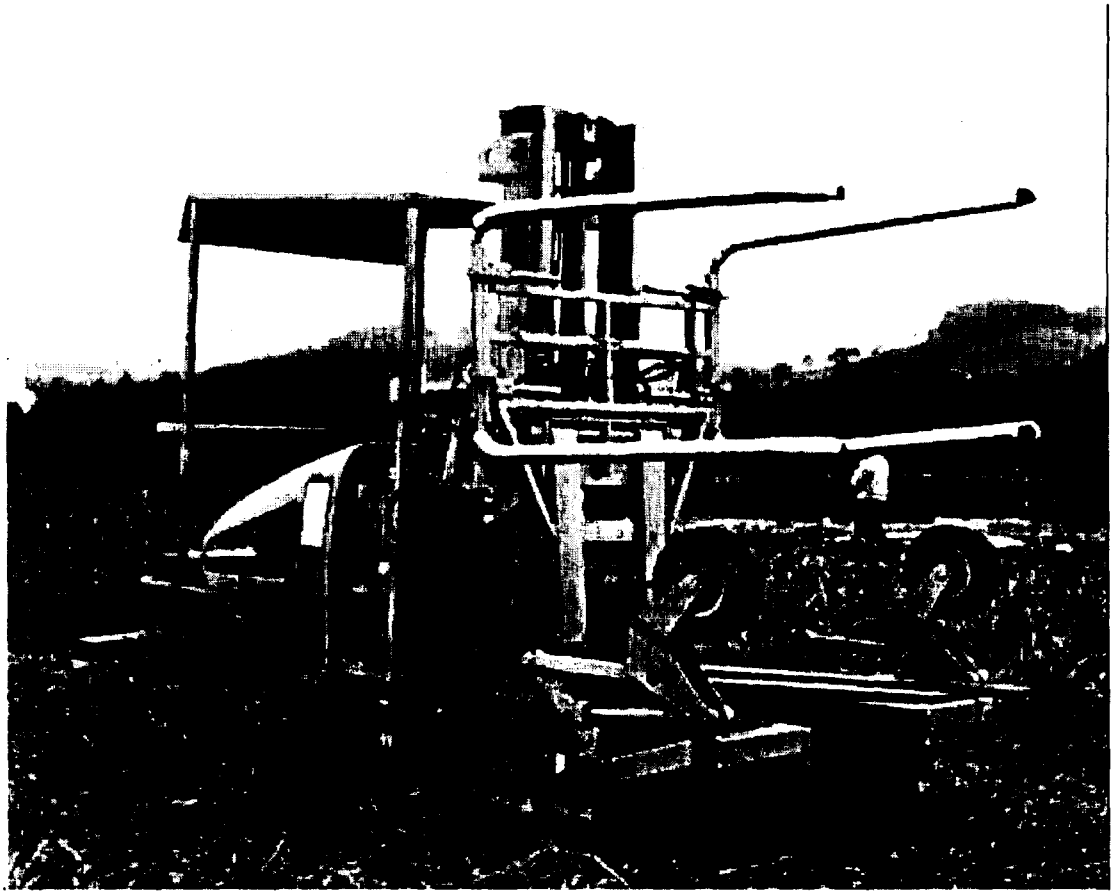

Fig. 2 The prototype of the loader in the study

Table 2. The static roll-over slopes of the loader. (The origin of the weight center : the rear and middle point of the loader on the ground)

Function of cylinder	Number of cylincer	Overall length (mm)	Stroke (mm)	Outer diameter (mm)	Inner diameter (mm)	Remark
Longitudinal movement of lifter	1	1,170	1,100	85	47	
Lifting of forks	1	1,600	1,250	75	47	Overall lifting 2500mm
Rotation of side arms	2	170	120	45	15	Overall 90o rotation
Linear stroke of side arms	2	355	300	45	20	
Linear stroke of front safety device	2	300	250	45	20	side expansion

Rotation of rear safety device	2	230	135	55	30	rear expansion
Tilting of forks	2	110	70	60	25	

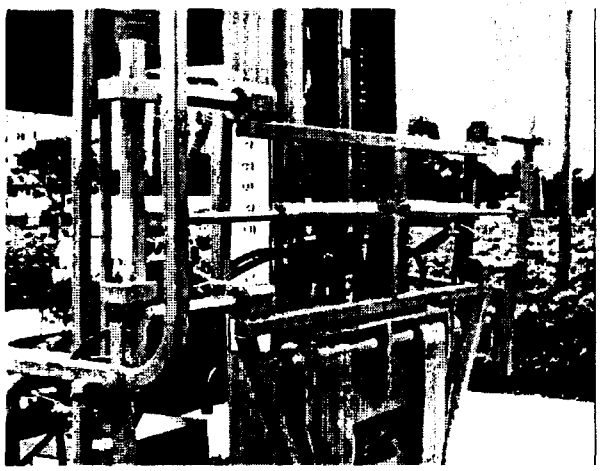

Fig. 3 The side arms of loader.

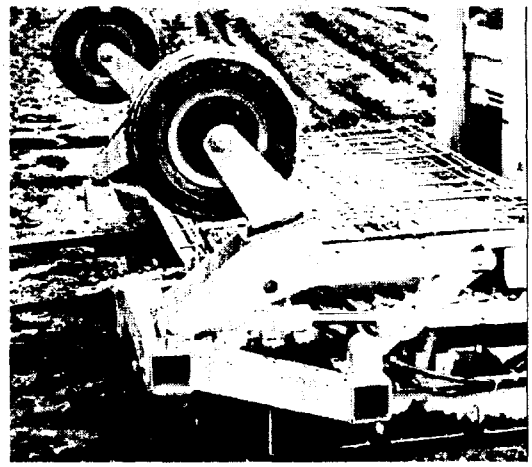

Fig. 4 The rear safety wheels of loader.

Table 2. The static roll-over slopes of the loader. (The origin of the weight center : the rear and middle point of the loader on the ground)

Function of cylinder	Weight center of loader (x, y, z) in mm	Static slope of roll-over (%)		Remark
		Lateral	Longitudinal	
Loader movement w/o pallets	(1038, -49, 583)	91.6	58.5	Without safety devices
Carrying two pallets	(939, 25, 1080)	27.4	24.4	Without safety devices
Carrying two pallets	(939, 25, 1080)	34.0	37.4	With safety devices

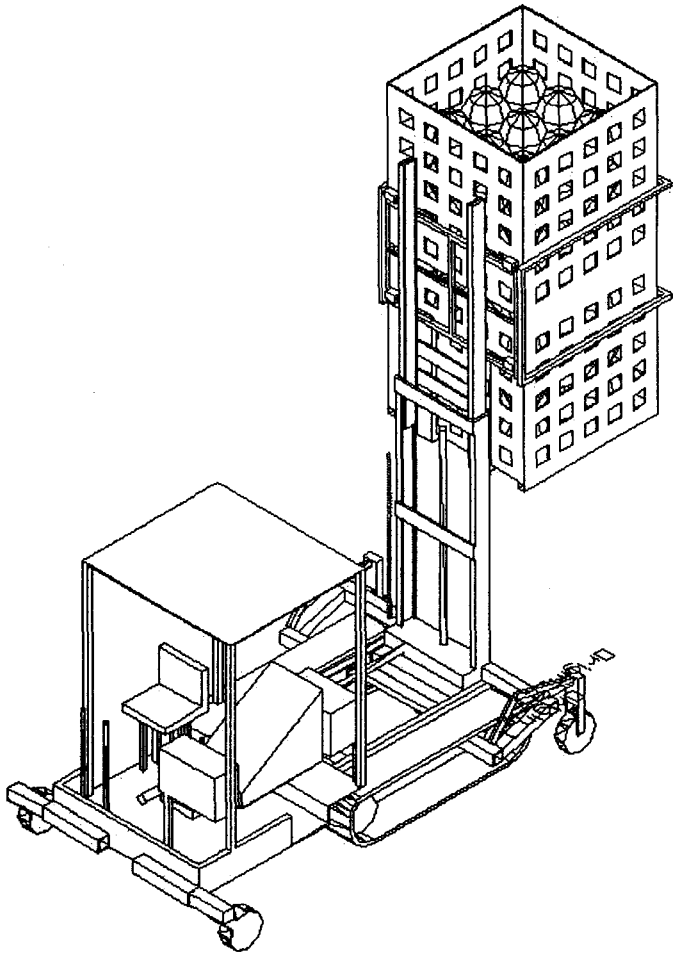

Fig. 5 A schematic diagram of unloading two pallets with using the safety devices

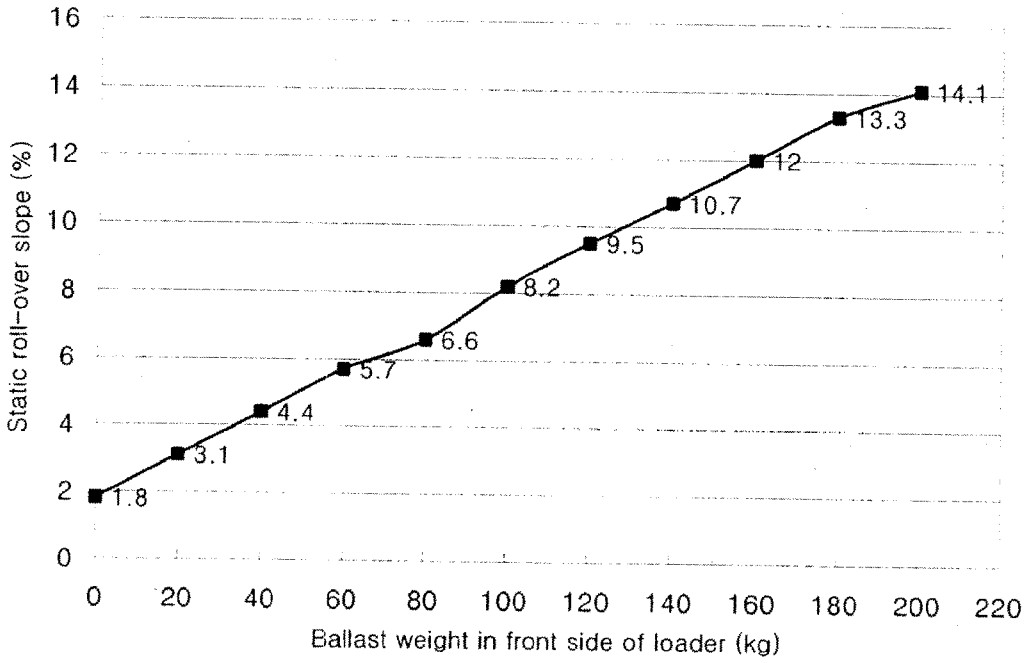

Fig. 6 The change in rear roll-over slopes with ballast weights when unloading two pallets at the lifting height of 1.5m from the ground.

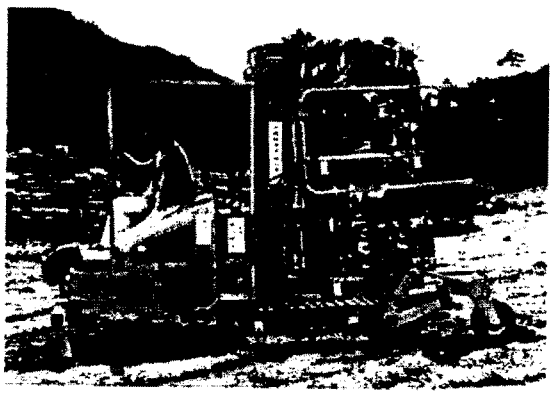

Fig. 7 Carrying cabbage pallets in an inclined field.

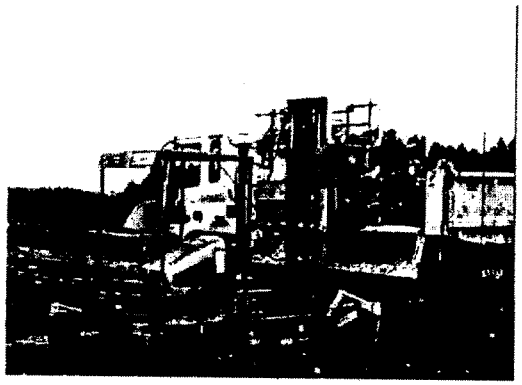

Fig. 8 Unloading cabbage pallets on a truck for transportation.