Agri. & Biosys. Eng. Vol. 3(2):73-78(2002)

Development of a Cabbage Loader

Y. C. Chang, S. I. Cho, J. G. Park, W. Y. Yeo

Abstract: Cabbage is one of the most important vegetable in Korea. The cabbage production was mainly based on human labor. A comprehensive research for substituting the human labor by machines has been performed until now.

In general, cabbage is cultivated on hillside in Korea. Picking up the harvested cabbages in field and carrying to a vehicle for transportation are very laborious work. Manual transportation of cabbage is likely to damage the quality and is also a cause to increase the cost of cabbage production. This study was to develop and evaluate a prototype cabbage loader for efficient and safe transportation of cabbage.

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

The developed loader could be used for loading and carrying the other vegetables. The study suggested a possible approach for designing the field machines operated on hillside.

Keywords: Cabbage Loader, Semi-tracked Vehicle, Hydraulic System, Fork Lifter, Inclined Field, Safety Device

Introduction

Cabbage is one of the most important vegetable in Korea. The cabbage production has been mainly on human labor. In particular, picking up the harvested cabbage in a field and carrying to a vehicle on the road for transportation are very arduous and, sometimes, even dangerous work since cabbage is generally cultivated on hillside. In addition, manual transportation of cabbage to the vehicle used to damage the quality of cabbage.

A comprehensive research for substituting the human work by machines in farming cabbage has been performed until now. As a part of the research, this study was to design and evaluate a prototype cabbage loader for efficient and safe transportation of cabbage from the field to the vehicle transporting the cabbage to the market.

The loading mechanism of the loader developed in this study was based on the conventional harvesting method. The loader was developed as a semi-tracked vehicle operated with a hydraulic system in order to prevent the slip and the rollover in inclined field. The loader could pick up the cabbage pallets in the field, transport, and unload them to a truck on the road. The static rollover analysis was performed and the performance of the cabbage loader was evaluated in the study.

This study was conducted by the research fund supported by Department of Agriculture and Forestry, Korea in 2000. The authors are **Y. C. Chang**, Research Specialist, Seoul National University, **S. I. Cho**, Associate Professor, Seoul National University, **J. G. Park**, Professor, Konkuk University, and **W. Y. Yeo**, Research Assistant, Seoul National University.

Corresponding author : Young-Chang Chang, Research Specialist, Institute of Agricultural Science and Development, Seoul National University, Kwonsun-ku, Suwon, 441-744, Korea. E-mail: ycchang02@kornet.net

Materials and Methods

Basic Consideration on Design of a Cabbage Loader

Cabbage is, conventionally, put in a plastic box with capacity of 18kg, six heads and transported to an agricultural truck near the field after harvesting. Then the truck carries the boxes to a 5-ton truck on the road. The cabbage is unloaded on the truck head by

head with human labor. In this study, it was suggested that pallets should be used in transporting the cabbage from the field to the road in order to increase the transportation efficiency.

On considering the loading capacity and size of 5-ton truck, the size of a cabbage pallet was determined to be 1.1m × 1.1m × 1.1m. Then the truck can carry 16 pallets by two layers of 8 pallets. A pallet can carry 100 heads of cabbage and the maximum weight of the pallet was about 350kg based on the result of measuring the maximum size and weight of a cabbage. Therefore, the minimum loading capacity of the loader should be more than 700kg when assuming that it carry two pallets of full load at a time. In this study, the maximum loading capacity of the loader was determined to be 1.0 ton with considering a loading tolerance.

In addition, the loader should have a function to carry cabbage pallets in a steep slope without any rollover. Thus 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. Fig. 1 shows the schematic diagram of the loader in this study. The overall dimensions were 2.6m × 1.2m × 2.1m (length × width × height). A box-type safety cab was designed for operator's safety. Fig. 2 through Fig. 5 show the specific dimensions of the cabbage loader in the study.

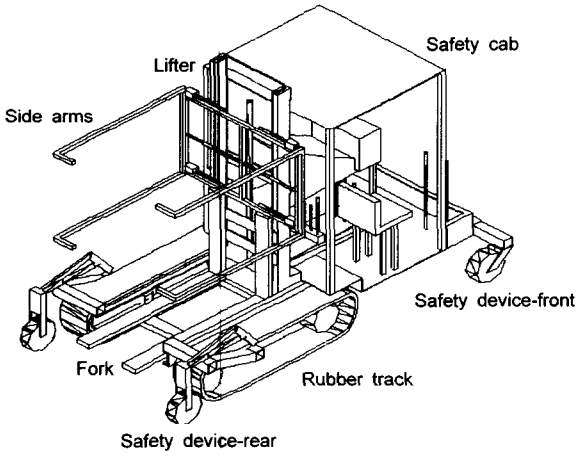

Fig. 1 The schematic diagram of the cabbage loader.

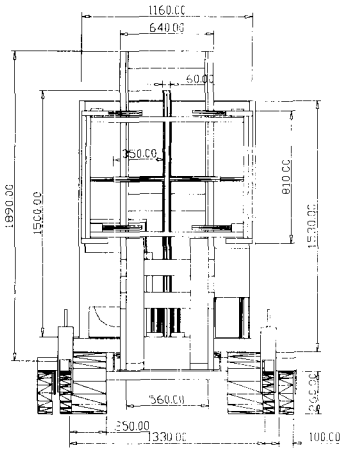

Fig. 2 The specific rear dimensions of the cabbage loader.

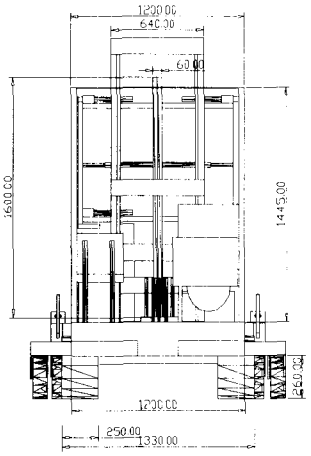

Fig. 3 The specific front dimensions of the cabbage loader.

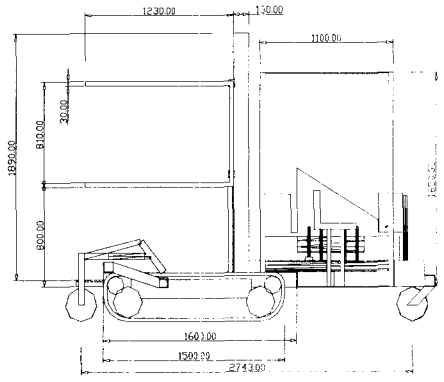

Fig. 4 The specific side dimensions of the cabbage loader.

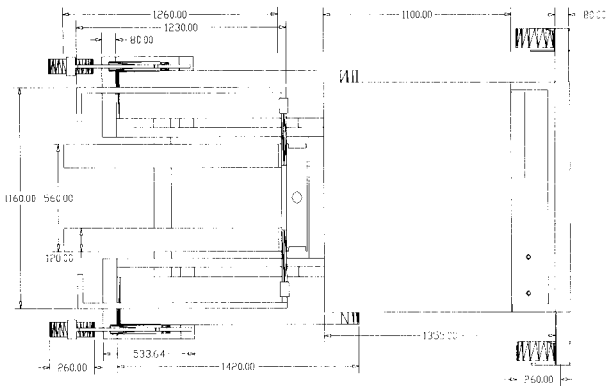

Fig. 5 The specific top dimensions of the cabbage loader.

The power train consisted of a 2-cylinder 18 HP gasoline engine, driving a transmission with high and low selection, 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 30 ℓ hydraulic oil tank, 5 hydraulic levers which control longitudinal movement of lifter, lifting of forks, operation of side arms, operation of safety devices and tilting of forks along with 12 hydraulic cylinders and 4 flow 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 5-ton truck. The lifter could move inward of the loader up to 1.1m 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. Also, the forks could tilt by 10° horizontally to that purpose.

The lifter was equipped with a set of two side arms to prevent the carried cabbage pallets from slipping or rolling over on hillside. The operation of the side arms was consisted of combinations of 90° rotation and 60cm linear motion. When picking up the pallets, the side arms were rotated first and then closed by linear contraction for holding them tight while carrying. When unloading the pallets, they were opened outward by linear expansion and rotated. Such combinations were performed by a two-directional hydraulic control valve and four flow 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.

Table 1 The specification of hydraulic cylinders of the cabbage loader

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 2,500mm
Rotation of side arms	2	170	120	45	15	Overall 90° 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. 6 shows the prototype of the loader developed in the study. Fig. 7 and 8 show the side arms and the rear safety wheels of loader, respectively. The rear safety wheels had the function to prevent the rear rollover of the loader when picking up and unloading heavy pallets.

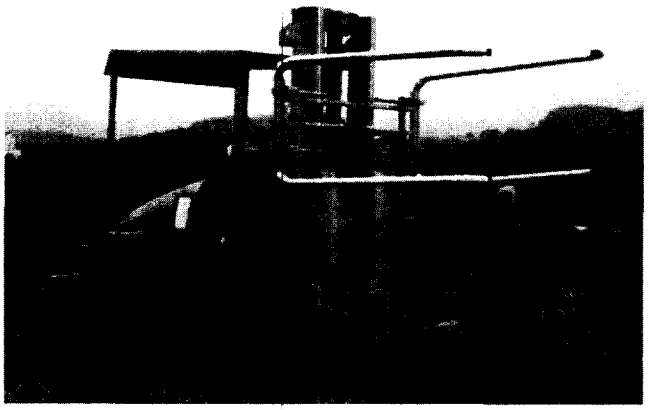

Fig. 6 The prototype of the loader in the study.

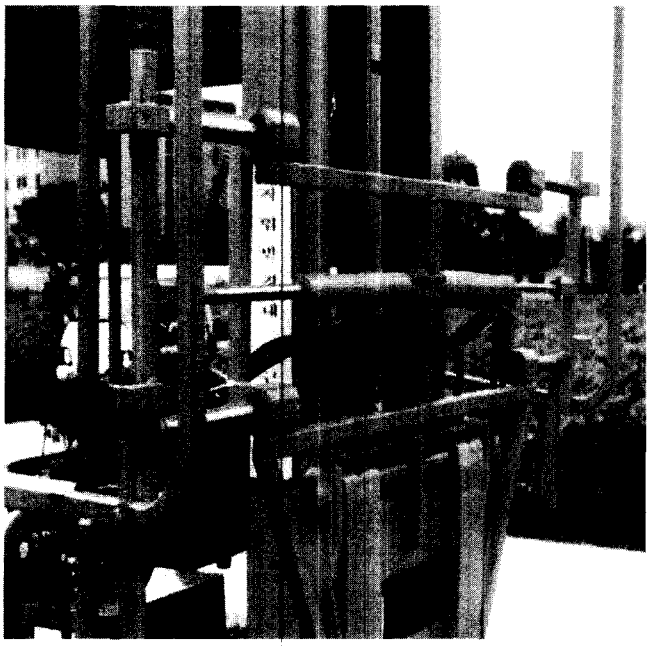

Fig. 7 The side arms of loader.

Results and Discussion

Static Roll-over Slope of The Cabbage Loader

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

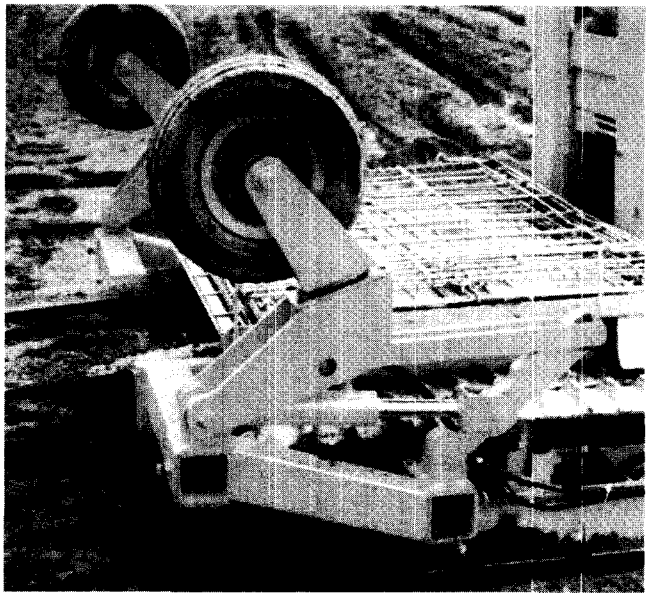

Fig. 8 The rear safety wheels of loader.

Table 2 shows the static roll-over slopes of the loader. The reference to 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 rollover 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 rollovers.

Unlike carrying the pallets, when picking up or unloading two pallets of full weight, the loader was likely to roll over rearward because the weight center was extremely moved to the rear of the loader. Also the weight of loader was lighter in comparison to that of two pallets. Fig. 9 shows a schematic diagram of unloading two pallets along with using the safety devices. Fig. 10 shows the change in rear rollover slopes with ballast 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 by using the ballast at an inclined field. Considering that the slope of road be less than 10%, the ballast of about 120kg could remove the possibility of the rollover when unloading two pallets

Table 2 The static rollover 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

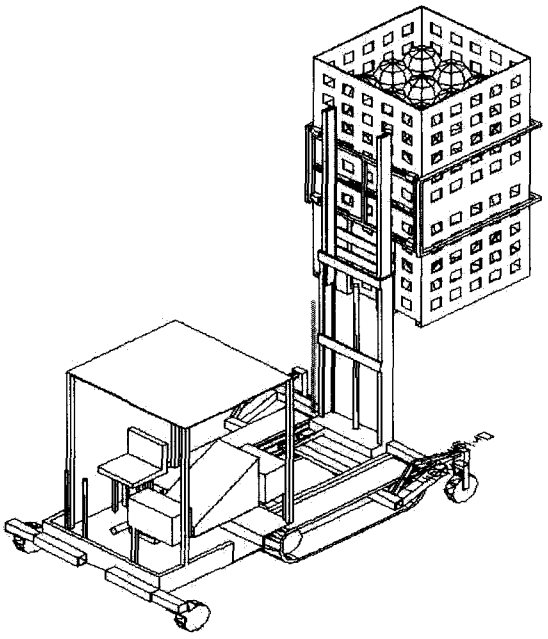

Fig. 9 A schematic diagram of the loader unloading two pallets with safety devices.

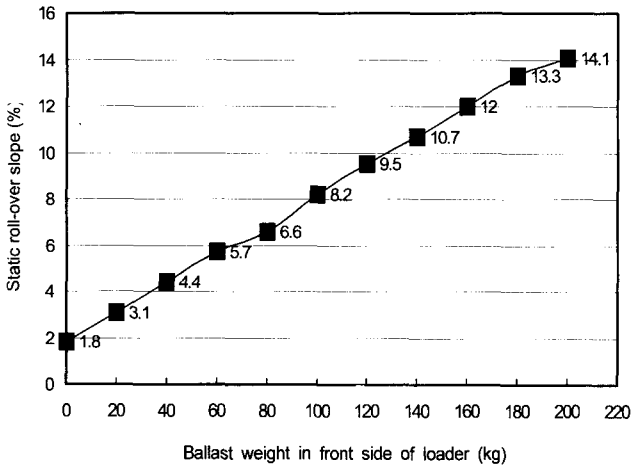

Fig. 10 The change in rear roll-over slopes with ballast weights when unloading two pallets at the lifting height of 1.5m from the ground.

on the truck for transportation.

Performance Evaluation of the Cabbage Loader

Fig. 11 and 12 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 slope.

The maximum field speed of loader was about 6km/hr with two cabbage pallets at a 25% inclined field. The maximum speed was almost uniform as the slope of field and the weight of two pallets changed because the power of engine was enough to support the total weight of two pallets filled with cabbage.

The performance of the loader was evaluated under

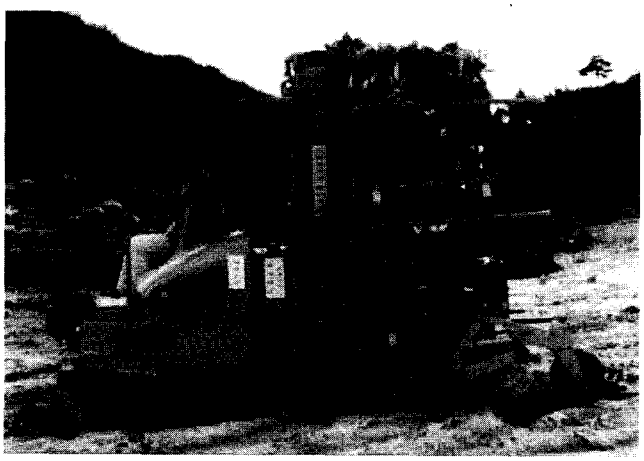

Fig. 11 View of carrying cabbage pallets in inclined field.

the assumption that the loader carry two pallets of full weight on the distance of 50m from the field of 25% slope to the road. The loading operation included

Fig. 12 View of unloading cabbage pallets for transportation.

picking up two pallets, carrying and unloading on a truck. The time that the loader took for one operation was approximately 3.5 minutes. Based on the result, the loading capacity of loader was analyzed to be about 35 pallets/hr which is approximately equivalent to the total cabbage weight of 9.0 ton. Though depending on an operator's expertness, the capacity was estimated to be more than 8 times in comparison of the conventional human labor of less than 1.0 ton/hr.

The developed loader could be used for loading and carrying the other vegetables because of the similarity of loading operations.

Summary and Conclusions

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

The loader had five hydraulic operation levers by which an operator could perform the work very efficiently in fields. The safe devices made it possible for the loader to be operated in inclined cabbage fields of about 30% slope in Korea. The high loading capacity of the loader of 9.0 ton/hr could reduce the production cost of cabbage in comparison with the conventional human labor of less than 1.0 ton/hr.

The developed loader could be applied for loading and carrying the other vegetables because of the similarity of the loading operations. The study suggested a possible approach for designing the field machines operated on steep hillside.

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