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Development of an Electric Powered Tiller for House Gardening

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Abstract

This report describes the design, manufacturing, analysis, control, and experimental activities in which a student conducted for a motor-powered tiller for house gardening work. In Japan, the engagement in agricultural business was decreased to 50% during the past 20 years, and labor-saving and efficiency has been demanded. Besides, the elderly engagements are about 50 %. In this research, a student in the Kochi University of Technology, a former graduate student, selected the development of an electric powered tiller, since he is concerned with ecology, agriculture, and engineering. Engineering education for mechanical engineering needs the practical design and manufacturing, since design and manufacturing is the key of engineering. The first objective is the design and manufacturing of a tiller which elderly engagement can easily handle by a rotary body part and going up and down mechanical part of nails. The second is stress analysis, control experimental confirmation of the tiller. In this project, I would report the activity of the design, manufacturing, analysis, control, and experimental work, which is thought to be an appropriate engineering education.

Keywords

electric vehicle, motor-powered tiller, agricultural business, house gardening, elderly engagement

1. INTRODUCTION

The Kochi University of Technology has been trying to develop new engineering educational curricula such as first year seminars using real products [Sakamoto et al., 1997] experimental courses using vehicles [Sakamoto, 2001], computer assisted English education [Greene, 2001, Hunter, 2001], and so on. Among them, the author thinks that the design education is of great importance, as Fargason [Fargason, translated by Fujiwawa and Sunada, 1995] mentioned that design is engineering synthesis. As design practices, electric vehicles can be good targets to start.

One graduate student selected the development of an electric tiller, which does not use a gasoline-powered internal combustion engine, and elderly people can easily operate. In order to design and develop such an engineering machine by a student, knowledge and experience on 3D-CAD, basic engineering dynamics such as mechanics of material, and so on will be required. Especially, design education is synthetic one, and the author takes charge of 3D-CAD lecture for 3rd year grade students using a text [Power Co., 1991] and of a lecture on mechanics of material. During the past 7 years, electric vehicles have been designed and manufactured mainly in our laboratory.

Electric tiller was proposed by a graduate student, who was interested in environmental issue, aging society, agricultural business, and design and manufacturing. Figure 1 shows the trend of population in agricultural business and elderly people among them. As is clear in Figure 1, the population of engagement in agricultural business decreased year by year, and the rate of elderly people increased. Although typical agricultural works have been modified by labor-saving tools such as tractors or tillers, human work is still needed. Fore example, when the work is conducted in a narrow area like the

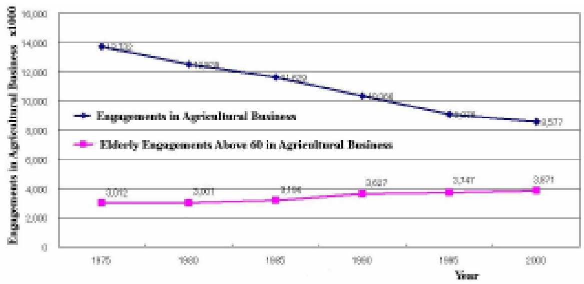

Fig. 1 Trend of population in agricultural business and elderly people among them

Fig. 2 Typical tractor (left) and tiller (right) used in local area for agricultural works

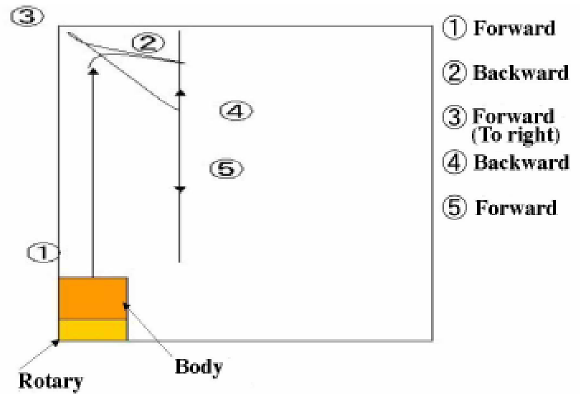

Fig. 3 How the conventional tiller change the diction

one in Japan, the turn action is hard. As shown in Figure 3, the directional change needs to make the tools move as a case in Figure 3. If the turn can be conducted at the same position by using a rotary mechanical part as is described in the later chapter, the work can be easier even for elderly people.

The first objective of an electric tiller is the design and manufacture, which is from the idea of environmental consideration and easy handling for elderly people. Such easy handling is to be conducted by focusing on tight turn around the same position and on up and down mechanism of rotary parts. The second is the control and confirmation of the function by experimental works. This reports the procedure of design, manufacture, control, and experimental works.

2. DESIGN AND MANUFACTURE OF ELECTRIC TILLER

2.1 Engineering and design aspects

The small-sized electric motor-powered tiller was designed and produced in 2005 [Sakamoto and Tsuneishi, 2005]. It was the first tiller which is manually operated, and is shown in Figure 4. The whole parts and assembly of the tiller were made by hands because it was a small-sized one, and wheels were not used. This time, the student tried to develop the one which can be used in a real industry.

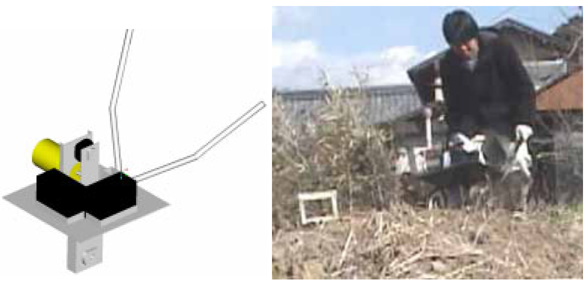

Fig. 4 Previously produced manually operated tiller

Items to be considered this time are as follows,

(1) Forwardly moving electric tiller by driving motor
(2) Tight turn at the same position and up and down mechanism of rotary parts
(3) The control is conducted by wired signal.
(4) Light-weight frame and designed by 3D-CAD

2.2 Specification and produced tiller

The tiller we aimed is forwarding moving rotary-type one by wheel-drive, which is operated by motors and batteries. The tiller can make a tight turn at the same position by controlling the rotation of two wheels. This can be done by possessing up and down mechanism in the main body. The operation is conducted by a wired joystick. The idea of the mechanical system is that the tiller can be worked without a lot of rotational and steering movement by human. The specification to be designed was decided as in Table 1. The specification was decided from the information of an existing engine displacement of 60cc.

Table 1 Specification of the tiller

Flame	650×750×450 (mm) 650×700(mm)
Weight	80(kg)
Input	24(V)
Output	400(W)
Torque	8.5(N·m)
Rpm	300(rpm)
Width for rotation	600(mm)

Figure 5 shows the produced tiller. Left figure is how it cultivates, and right figure is how it rotates. The vehicle can cultivate and rotate by controlling the vehicle position by a control unit, and inside the house garden area it can be cultivated by small human power with the motored electric power. By using the electric motor, exhaust fume does not exist and the maintenance expected to be easier.

Fig. 5 Electric power tiller for house gardening, tiller work (left) and turning (right)

2.3 Design of motor-powered tiller

The driving mechanism to be designed is in the following. Two independently controlled wheels are placing parallel to each other. The driving shaft is connected to each 125W DC motor. By driving each wheel in a different rotation, it can be possible to turn at the same position. Moreover, in order to smoothly make the turn, the tiller size is designed within a cultivating circle.

Figure 6 shows the roughly designed tiller. The rotary part is center drive method consisting of a 400 DC motor, sprockets, and a chain. The rotational velocity of the rotary shaft when cultivating is generally 200-400rpm. In this report, the rotary shaft rotational velocity of 2000rpm and torque of 14 N·m are used . The velocity is reduced by sprockets, and the gear ration is 6.25: 1 . The obtained velocity is 300rpm, and the torque is 8.5 N·m. The batteries used for the rotary motor are four of 12V-7.2 Ah, and the one for driving used are two of 12V-13Ah.

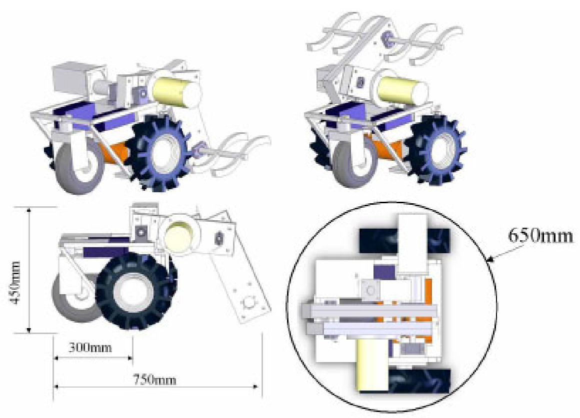

Fig. 6 3D-CAD of electric power tiller for house gardening

The design of rotary up and down mechanical part is conducted.

The part is two links one as is shown in Figure 7, and the power (driving) transmission mechanical one consists of sprockets and a chain. The rotary part contains a DC

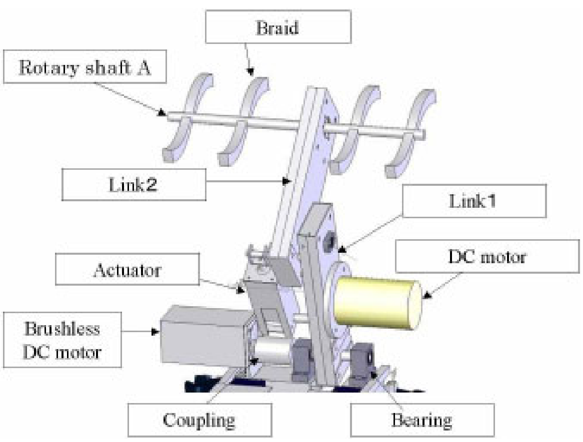

Fig. 7 Rotary going up and down mechanics

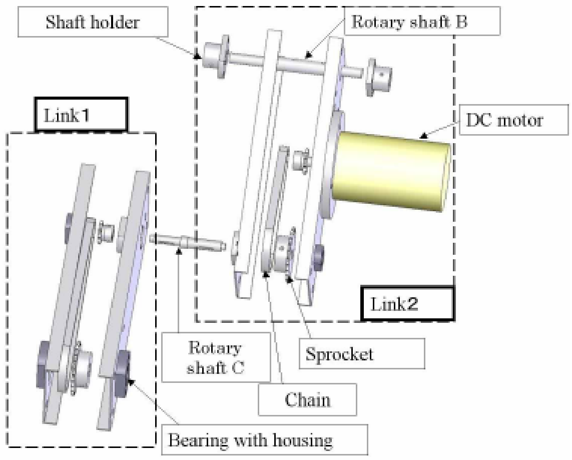

Fig. 8 Structure of rotary going up and down mechanics (1)

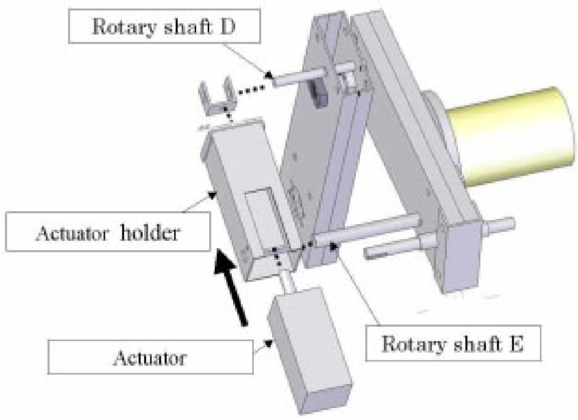

Fig. 9 Structure of rotary going up and down mechanics (2)

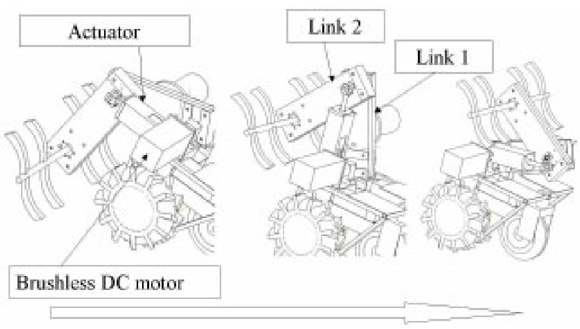

Fig. 10 Movement of rotary going up and down mechanics

brush-less motor and an actuator (stepping motor) of 50mm stroke. The frame was designed in a manner that the rotary up and down mechanical part and the cultivating nail does not interfere each other. When the turn is conducted, the stroke of the actuator is extended, and the tiller is turned by rotating the brush-less motor. Figure 10 shows the movement of the rotary.

After the tentative design was finalized, the stress analysis was conducted. The frame material is SS400 (Japanese steel standard of structural steel of 400MPa tensile strength), and hollow square tubes of 16 mm x 16mm and 1.6mm thickness are used. The design was conducted by a 3D-CAD software of Solid Works, by which the mechanics simulation can be conducted as well as stress analysis. After the design was decided, the stress was estimated. The frame configuration is shown in Figure 11 left. The stress analysis was performed by Cosmos/works, which is a part of Solid Works. The analytical condition is as follows. The location where the wheels and motor are equipped is fixed. The weight of batteries, motor, and rotary up and down mechanical part is loaded on the frame. Figure 11 right shows the result of stress analysis. The frame is going to be fabricated by welding, and the stress concentration at the corresponding location was considered. The stress concentration factor is assumed to be 1.5. The maximum stress calculated is 113MPs at the bottom portion of the frame. The valuating loading by tiller movement of 0.3g and the fatigue strength of 45% tensile strength are assumed. The resulting safety factors for tensile, yielding and fatigue are 2.4, 1.3, and 3.5, respectively.

From the stress analysis and the obtained safety factors, the frame is considered to possess the sufficient strength. However, the strength was confirmed by the following experimental work.

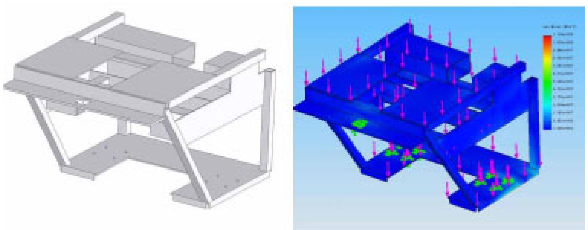

Fig. 11 Frame construction and stress analysis result

3. CONTROL AND CULTIVATING EXPERIMENT

3.1 Control of the tiller

The operation is planned to be easily conducted by a wired control with a few control button even by elderly people. The wired control unit consists of a joystick for operation, switch for the rotary up and down mechanical part, a potentiometer for controlling the rotation in the rotary part, and a battery switch. Figure 12 shows the rotary up and down mechanical part system used in this research. Figure 13 shows the experimental system and the electric circuit. The control for the brush-less motor was firstly confirmed. If the velocity is fast when the rotary part moves, the operation might make a mistake, since the tiller was made as a trial production. The velocity is to be controlled such that the input voltage to the motor is varied from 0 to 5V, ant PWM control is used to the output. A microcomputer, H8/3048f, of 8 bit

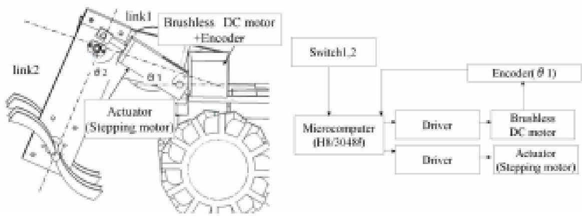

Fig. 12 Rotary up and down mechanical part system

Fig. 13 Experimental system and the electric circuit

precision has a function of D/A converter. By changing the output from a driver, the rotational velocity is controlled.

Figure 12 shows the control system. When the switch 1 in Figure 12 is on, the voltage 2V is transformed to a driver. When the switch 2 is on, the voltage of a driver is 1V. Figure 13 right shows an example of the output from the converter.

3.2 Cultivating experiment

The experiment was conducted for the purpose of confirmation of the planned cultivating radius and depth during one-time battery charge. From the experiment,

Fig. 14 Cultivating field test

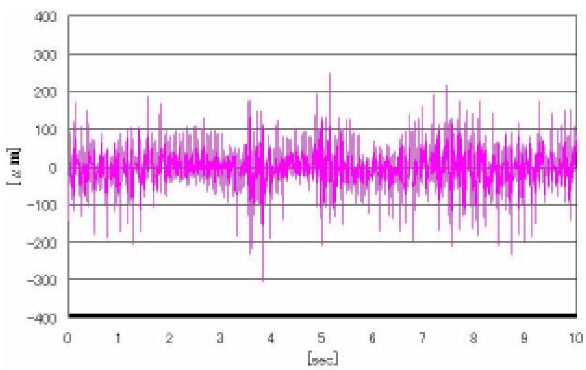

Fig. 15 Result of strain measurement

the cultivating area of 105m^2 and cultivating depth of 150mm were confirmed. It is considered to be enough performance from the viewpoint of the motor capacity used. It is affected by the gardening area of sand and soft land. Figure 14 shows the cultivation test. When the cultivation was conducted, the strain in the frame body was measured at 8 locations. The maximum strain of 304 x10^{-6} was originated at the frame bottom portion as is shown in Figure 15. This value is 64MPa, and is well above the material strength of tensile, yielding, and fatigue.

4. DISCUSSION

This paper reports the development of a tiller for house gardening, stressing on the design and manufacturing. The main concern is the ecological and aging society consideration of agricultural business in the future, especially in local areas such as Kochi, Japan whose main industry is agriculture. Although the design and manufacturing in this report seems to have a potentiality of practical use, the remained issues exist. One of them is the battery life.

Like the Kochi prefecture, Japan, the local area possesses better circumference than big cities such as Tokyo and Osaka in a sense of natural energy preservation such as solar, water, and biomass as well as wind. In order to establish to obtain and spend such a local energy, we have researched the system. Using a solar panel, we thought that we can charge the electricity to batteries for the tiller. Since the existing lead battery is heavy, and the life is not so long, we started to consider capacitors for electric charging. In this research, the electric charging from a solar cell to a capacitor is studied.

The charging experiment was conducted in two ways. One is charging experiment using a constant current and a constant voltage unit. The other is the combination of a solar cell and a capacitor. As for as the experiment using a constant current and a constant voltage unit, the charging time was smaller in case of a constant current experiment. Figure 16 shows the combination of a solar panel and a capacitor used for the charging experiment. The result of charging time to 32.4V was 540 second,

Fig. 16 Solar panel and capacitor used in the charging experiment

and it is expected that 20min needs to charge the voltage of 32.4V. This charging time is thought to be shorter than conventional batteries like lead battery. The weight of the capacitor is about 5kg for 32.4V, and is much smaller than lead batteries of 16kg in this research. The life is also expected longer than lead batteries.

5. CONCLUDING REMARKS

A small-sized electric power tiller was completed, although many technical issues still need to be solved.

(1) As a project, a graduate student considered his theme and target. The faculty supported this project from the viewpoint of funding and suggestions. He completed the tiller by themselves.

(2) The project theme aimed at design and manufacturing of a tiller, which can be used for house gardening. The consideration of ecology and aging society had been made. The developed tiller still remains the issues to be solved such as battery life and weight. We need to continue to study such issues, and hope we can commercialize with some help from industries in the future.

(3) The student had a chance to study 3D-CAD, stress analysis, and manufacture. This is the aim for the faculty to let students to learn synthetic engineering by themselves as well as basic engineering courses like mathematics, physics, strength of material, and so on.

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