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Development of Current Based Temperature Arc Thermal Cutting System for Green Pepper Harvesting Robot

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1.Introduction

The grasping and detachment of each fruit without any physical damage to fruit and keeping the nutritional values by avoiding the viral transformation and making the harvested fruit less vulnerable to fungal diseases are the main problems in harvesting operation. This paper presents design of thermal cutting system based on current which help to solve the problems mentioned above.

Sweet pepper is the 4th most important fruit vegetable in Japan grown on approximately 357 hector area of land which needs not only high man power but also high input energy consumption during harvesting operation leading to increase in labor cost and production cost [1]. This issue also relates with the decreasing population of Japan in recent decades. On the other hand, it is difficult to recognize green sweet peppers and green leaves separately during harvesting operation using robot. Hence, by considering these issues, a sweet pepper was selected for the study of fruit harvesting robot.

2. Design of Temperature Arc Thermal Cutting System

Figure 1 represents the prototype of temperature arc thermal cutting system in which rotary motion of servo motor converted into linear motion which drives the specially designed notch plate. The gripper poles fixed on gripper bars moves smoothly through the curvature notches of notch plate. The movement of these poles controls the opening and closing of the gripper. For thermal cutting, two electrodes were mounted at the end of notch plate and connected by using Nichrome wire. An external power supply was provided to the electrodes to obtain the thermal effect and generate high temperature.

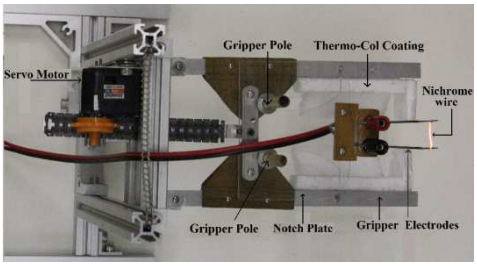

Fig. 1 Design of Thermal Cutting System

In the prototype, 10 mm internal layer of thermo-col was applied at the end of gripper bars which helps to avoid any physical damage to the fruits. The entire system was controlled by using *Kondo KRS 6003 HV* servo motor and *KCB-1* controller. The forward movement of notch plate results in closing of grippers and at the same time cutting operation by Nichrome wire due to high temperature.

The experiments were carried out to test the prototype for performance. 0.02 mm, 0.5 mm and 1 mm diameter Nichrome wires were used to investigate the effect of diameter size on thermal cutting operation. At the same time, the results of this prototype were compared with voltage based Electrical Arc thermal cutting system [2].

3. Results

During the testing of prototype, the green sweet peppers were harvested successfully without any difficulties. In three different diameter conditions, 0.5 mm and 1 mm Nichrome wire diameters were found suitable for harvesting operation. Figure 2 shows the Nichrome wire temperature response to the input current. 0.02 mm diameter Nichrome wire starts to melt beyond 5 A current while 1 mm diameter wire needs additional power compared to 0.5 mm diameter wire. In case of 0.02 mm diameter wire, when the hot wire touches the stem, temperature suddenly drops which results in failure of cutting the stem larger than 2 mm in diameter. 0.5 mm and 1 mm diameter wires were found suitable for cutting the stem up to 10 mm in diameter. Increasing diameter more than 0.5 mm needs additional power which results in use of excessive power.

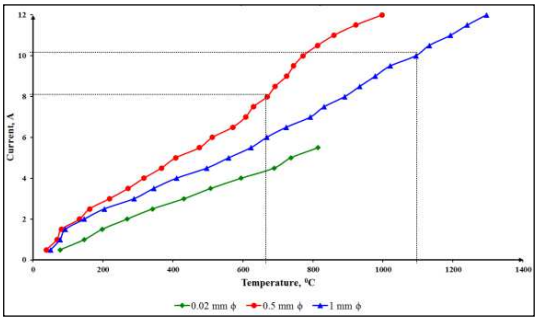

Fig. 2 Nichrome Wire Temperature Response

An increase in temperature cause rapid rise in resistance of Nichrome wire until 500^0C. The range of 800^0C to 1100^0C found suitable for cutting operation as in this range, the resistance of wire increase again.

The performance of temperature arc thermal cutting system was found significantly better than electric arc thermal cutting system. The electric arc thermal cutting system was developed based on voltage and cutting operation was performed with the help of high voltage potentials [2]. The time (seconds) taken for cutting operation can be seen in table 1 for various fruit stem diameters.

Table 1 Time Taken by Thermal Cutting System

	Electric Arc (Electrode diameter)		**Temperature Arc** (Nichrome wire diameter)		
Stem diameter	**1 mm**	**2 mm**	**0.02 mm**	**0.5 mm**	**1 mm**
1 mm	2 s	5.2 s	6 s	2 s	1 s
2 mm	2.4 s	6 s	8 s	2 s	1.4 s
3 mm	3.2 s	7.5 s	-	3.2 s	1.6 s
4 mm	4 s	9 s	-	3.5 s	2.1 s
5 mm	4.4 s	10 s	-	4 s	2.5 s

The thermal cut seals the stem cut part which helps to cease the fungal or bacterial transformation. Also this makes fruit less vulnerable to fungal diseases. The thermo-col coating protects the fruit from any physical damage and box structure grasps the fruit in good condition.

4.Conclusions

In case of Temperature Arc Thermal cutting system, 0.5 mm and 1 mm diameter Nichrome wire were found appropriate for cutting the fruit stem of 5 mm diameter. Increasing wire diameter needs more input power which results in excessive energy consumption. Hence, 0.5 mm diameter Nichrome wire would be recommended for cutting. The temperature arc thermal cutting system shows better performance than the electric arc thermal cutting system. Moreover, confirming the horticultural advantages by quality testing can be considered as further research.

References

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[2] S. Bachche, K. Oka and H. Sakamoto, “Development of Thermal Cutting System for Sweet Pepper Harvesting Robot in Greenhouse Horticulture”. *Proceedings of JSME Conference on Robotics and Mechatronics*, May 27-29, 2012, Hamamatsu, Japan.