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THE INVESTIGATION OF THE MECHANICAL PROPERTIES OF FOODS WHEN SPOONING UP FOODS FOR MEAL SUPPORTING EQUIPMENT

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ABSTRACT

A new meal supporting system for disabled people who cannot eat foods by themselves has developed in this laboratory. It was succeeded to create prototype of the meal supporting system which has four concepts: "safe", "reliable", "comfortable" and "a sense to eat foods by oneself". However, the prototype was not good at spooning up foods. It is necessary to derive the suitable speed and torque of rotation of spoon. In order to determine the rotational motion of spoon, the investigation of mechanical properties of foods by measuring the load applied to spoon was started. As the trial subject for this measurement experiment, this laboratory selected three types of foods: viscous particulate food, fried rice; sol-like liquid food, curry roux; gel-like solid food, jelly. In case of the viscous particulate food, as the rotational speed of spoon became fast, the load applied to spoon increased. While, in case of the sol-like liquid food and gel-like solid food, the rate enhancement of rotational speed of spoon little affected to the load applied to spoon.

KEYWORDS: Load Measuring Equipment, Meal Supporting Equipment, Mechanical Properties of Foods, Welfare Engineering

INTRODUCTION

Since 1981 which is called "the International year of disabled persons", "Normalization (people with disability)" has been infiltrated. Since that time, the idea of welfare has been changed "the protection of disabled people" into "the self-reliance support for disabled people" [1].Therefore, "the Quality of Life (QOL)" of disabled people has been complied. In order to improve the QOL of physically disabled people, it is effective to support their "the Activities of Daily Living (ADL)" [2]. Physically disabled people desire the self-reliance of the eating behavior especially [3]. The reason of this is that the eating behavior is not only the activity for life support, but also the activity to enjoy taste and texture of food and the opportunity of communication. Because of these backgrounds, a meal supporting system which provides the self-reliance of eating behavior is required for disabled people who cannot eat food by themselves.

A new meal supporting system which conveys foods to user's mouth has developed by this laboratory. In order to develop this system, this laboratory referenced "Seven requirements for meal supporting manipulator [4]" suggested by Professor Tejima, and some requirements from test subject. Table 1 show "Seven requirements for meal supporting manipulator".

Table 1: Seven Requirements for Meal Supporting Manipulator

1. It is usable for various kinds of foods
2. The quantity of food conveyed to user's mouth is appropriate
3. It can scoop without leaving food
4. Not spilling food around the equipment
5. The time required for eating is not too long
6. Safe
7. Nice controllability

This laboratory succeeded to create the prototype of this system which has four concepts: “safe”, “reliable”, “comfortable” and “a sense to eat foods by oneself”. However, the prototype did not have enough ability to spoon up foods well. It is necessary to derive the suitable speed and torque of rotation of spoon. Therefore, the purpose of this study is investigation of mechanical properties of food by measuring the transition of load applied to spoon in order to decide to the suitable rotational motion of spoon. The improvement of the ability to spoon up food will effect to the achievement of some of “Seven requirements for meal supporting manipulator”: “It is usable for various foods”; “The quantity of food conveyed to user’s mouth is appropriate” and “Not spilling food around the equipment”.

MEASURING EQUIPMENT

This chapter introduces the equipment for measure the transition of load applied to spoon when the meal supporting system spoons up foods. Figure 1 shows the appearance of the measuring equipment.

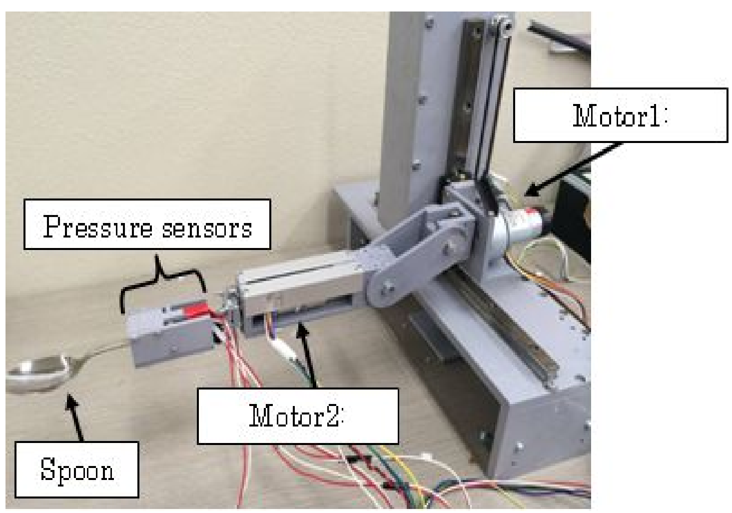

Figure 1: Equipment to Measure the Load Applied to Spoon

In order to measure the load applied to spoon, four pressure sensors are fixed to around of the spoon's grip. Figure 2 shows the disposition of four pressure sensors. The direction of side surface was named “X-axis”, the direction of upper surface was named “Y-axis”. On each axis, there are two pressure sensors.

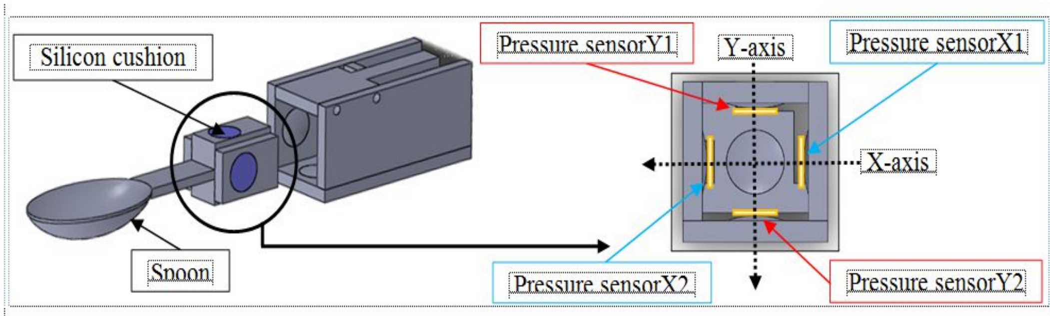

Figure 2: Disposition of Four Pressure Sensors

Equations which convert values of pressure sensors to values of load are (1) and (2).

$$L_X = \{(9.4\times10^{-4}) \times p_{X1}^2 - 18.4\} + \{(9.4\times10^{-4}) \times p_{X2}^2 - 18.4\} \quad (1)$$

$$L_Y = \{(9.4\times10^{-4}) \times p_{Y1}^2 - 18.4\} + \{(9.4\times10^{-4}) \times p_{Y2}^2 - 18.4\} \quad (2)$$

L_X, L_Y: Load values of X-axis and Y-axis.

p_{X1}, p_{X2}, p_{Y1}, p_{Y2}: Pressure values of pressure sensorX1, X2, Y1 and Y2.

Using two motors, this equipment can perform imitating human's hand motions of spooning up food. “Motor 1” plays a role of human’s elbow joint, “Motor 2” plays a role of human’s wrist joint. Figure 3 shows the transition of the spoon tip angle.

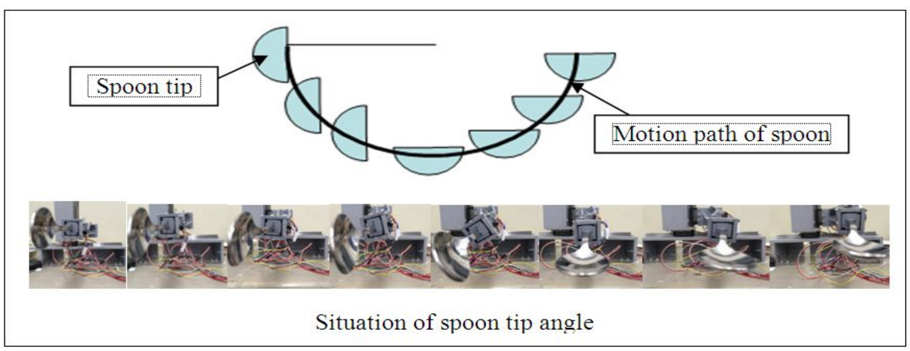

Figure 3: The Transition of the Spoon tip of Spoon When the Measuring Equipment Spoons up Foods

Figure 4 shows the graph for illustrating the transition of the angle of “Motor 1”, “Motor 2” and the tip of spoon. The spoon tip angle is the sum value of angle of “Motor 1” and “Motor 2”.

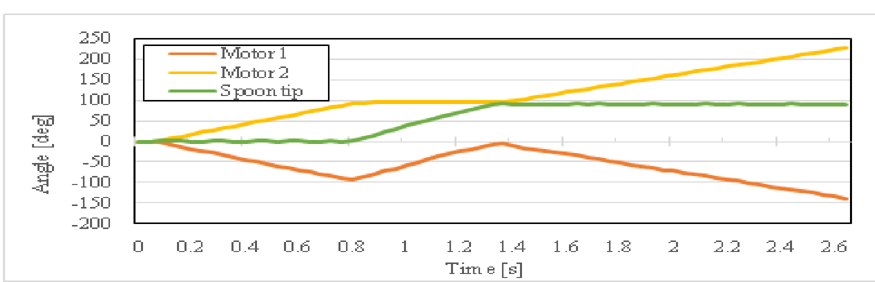

Figure 4: Transition of the Angle of “Motor 1”, “Motor 2” and the Tip of Spoon

TEST CONDITIONS

This chapter explains the conditions of test to investigate the transition of load applied to spoon using the measuring equipment which is introduced in Chapter 2. As the trial subject of food, this laboratory elected three types of foods which are described in Table 2.

Table 2: Foods which are the Subjects of This Experiment

Viscous particulate food:	Fried Rice
Sol-like liquid food	Curry roux
Gel-like solid food	Jelly

These selections are referenced to "materials science for foods" [5].The rotational speed of spoon had three steps: 0.250rps, 0.375rps and 0.500rps. This equipment measured the load values of X-axis and Y-axis and the spoon tip angle at a certain interval. The measurement was conducted 15 times per one condition. The result of measurement was derived from the average value of measurement of 15 times.

RESULTS OF MEASUREMENT

This chapter describes the result of measurement of load values applied to spoon. The result in case of the viscous particulate food (fried rice) is explained in 4.1. The result in case of the sol-like liquid food (curry roux) is explained in 4.2. The result in case of the gel-like solid food (jelly) is explained in 4.3.

In Case of Viscous Particulate Food: Fried Rice

Figure 5, 6 and 7 show the transition of the load values of X-axis and Y-axis, and the spoon tip angle.

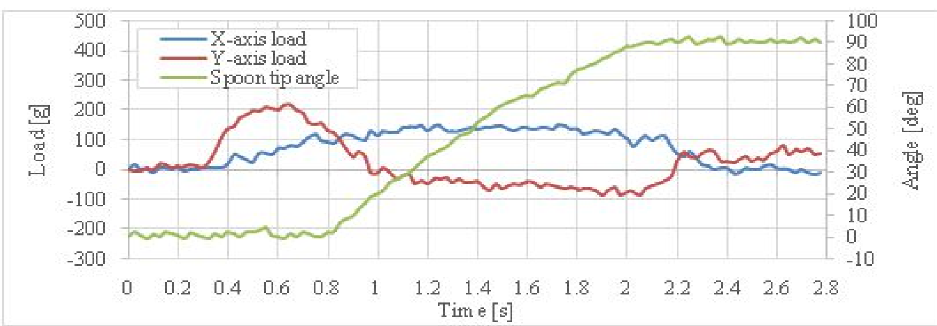

Figure 5: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Fried Rice; Rotational Speed, 0.25[rps]

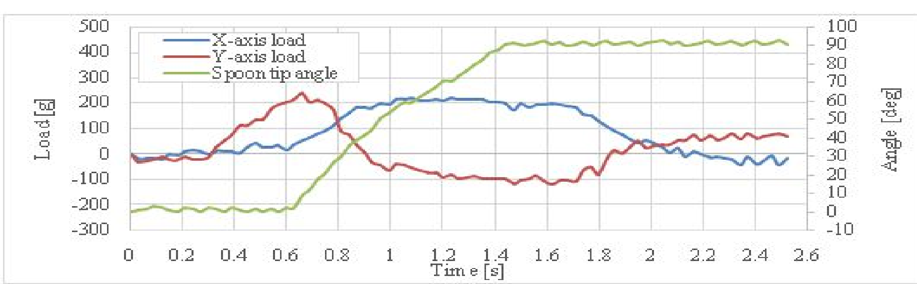

Figure 6: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Fried Rice; Rotational Speed, 0.375[rps]

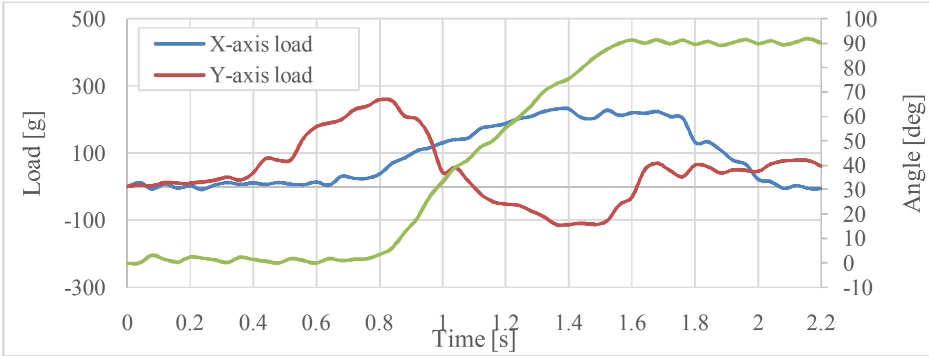

Figure 7: Transition of Load VALUES of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of food, Fried Rice; Rotational Speed, 0.50[rps]

According to Figure 5, 6 and 7, as the rotational speed of spoon became fast, the X-axial load applied to spoon increased. The reason of this phenomenon was considered that the viscous resistance of rice increased with the increase of rotational speed of spoon. While, in case of the Y-axis, the load applied to spoon was little affected by the rotational speed of spoon. It was considered that the decreasing of the viscous resistance of rice by the increase of pressure by spoon caused the expanding of void between rice. Table 3 shows the maximum and minimum value of each load applied to spoon. Description of minimum value of X-axial load is omitted because minimum value of X-axis is 0 while there are not any foods on the spoon.

Table 3: Maximum and Minimum Values of Each Load in Case of the Fried Rice

		Rotational Speed of Spoon		
		0.250 [rps]	**0.375 [rps]**	**0.500 [rps]**
X-axial load [g]	Maximum	147.32	219.42	231.66
Y-axialload [g]	Maximum	209.45	232.63	259.66
	Minimum	-83.29	-117.44	-111.37

In case of Sol-Like Liquid Food: Curry Roux

Figure 8, 9 and 10 show the transition of the load values of X-axis and Y-axis, and the spoon tip angle.

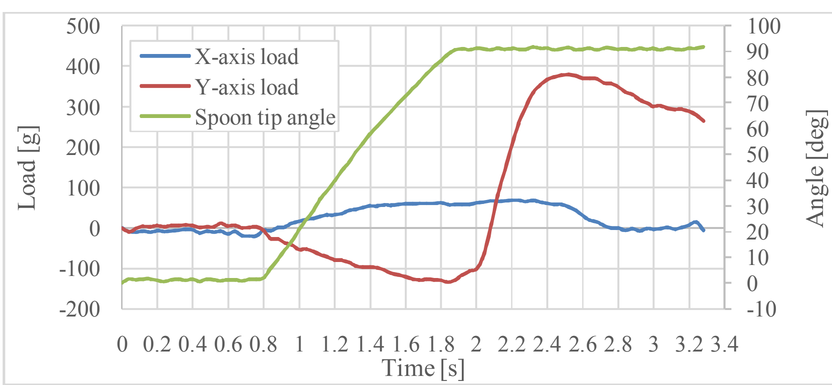

Figure 8: Transition of Load Values of X-Axis and Y-Axis, and Spoon tip Angle; Trial Subject of Food, Curry Roux; Rotational Speed, 0.25[rps]

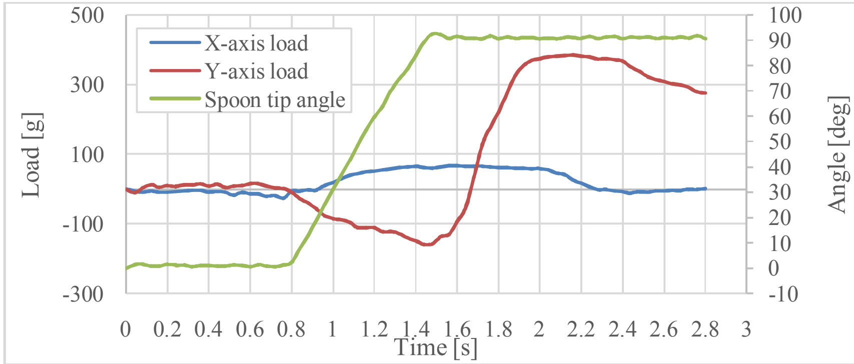

Figure 9: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Curry Roux; Rotational Speed, 0.375[rps]

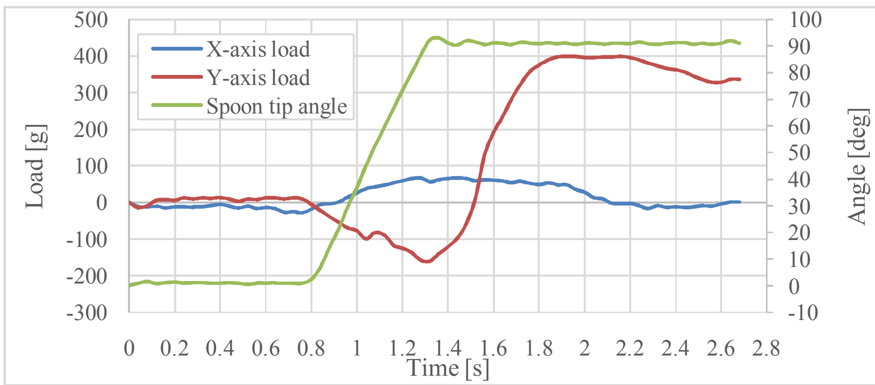

Figure 10: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Curry Roux; Rotational Speed, 0.50[RPS]

According to Figure 8, 9 and 10, the X-axial load and Y-axial load were rarely affected by the difference of rotational speed of spoon. This phenomenon was caused by the low elasticity of curry roux. Furthermore, the momentary increase of Y-axial load was detected when the spoon was raised up from the liquid surface of curry roux. This phenomenon was caused by being pulled of spoon by the viscosity of curry roux. Table 4 shows the maximum and minimum value of each load applied to spoon. Description of minimum value of X-axial load is omitted because minimum value of X-axis is 0 while there are not any foods on the spoon.

Table 4: Maximum and Minimum Values of Each Load in Case of Curry Roux

		Rotational Speed of Spoon		
		0.250 [rps]	**0.375 [rps]**	**0.500 [rps]**
X-axial load [g]	Maximum	75.96	74.69	80.43
Y-axialload [g]	Maximum	30.14	33.53	38.76
	Minimum	-70.95	-69.15	-77.48

In Case of Gel-Like Solid Food: Jelly

Figure 11, 12 and 13 show the transition of the load values of X-axis and Y-axis, and the spoon tip angle.

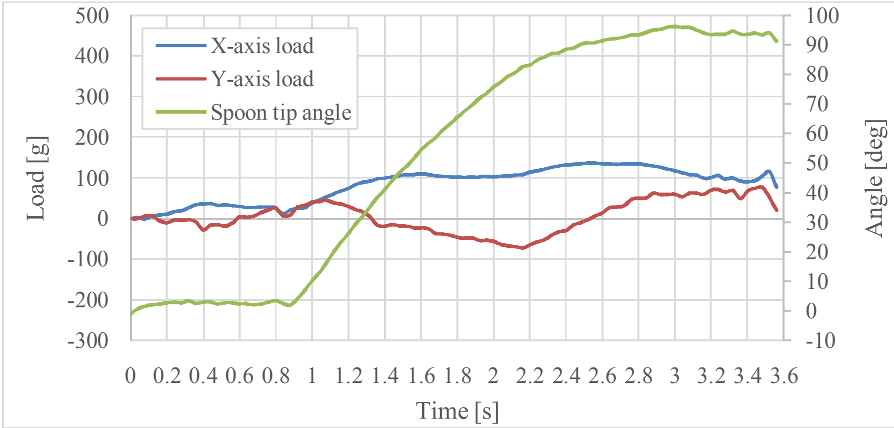

Figure 11: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Jelly; Rotational Speed, 0.25[RPS]

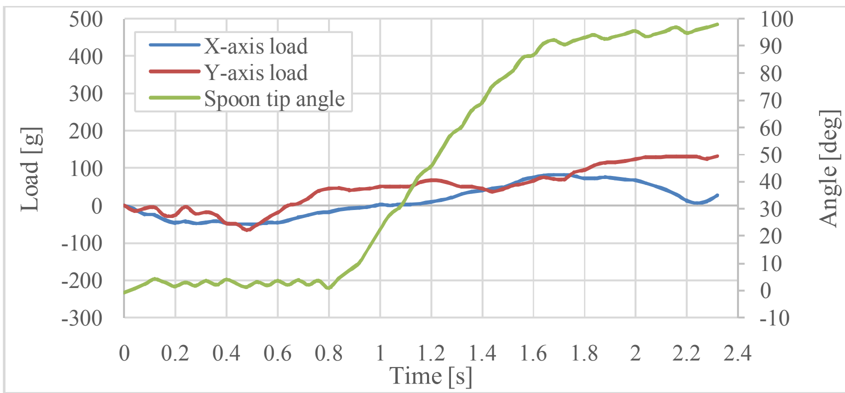

Figure 12: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Jelly; Rotational Speed, 0.375[RPS]

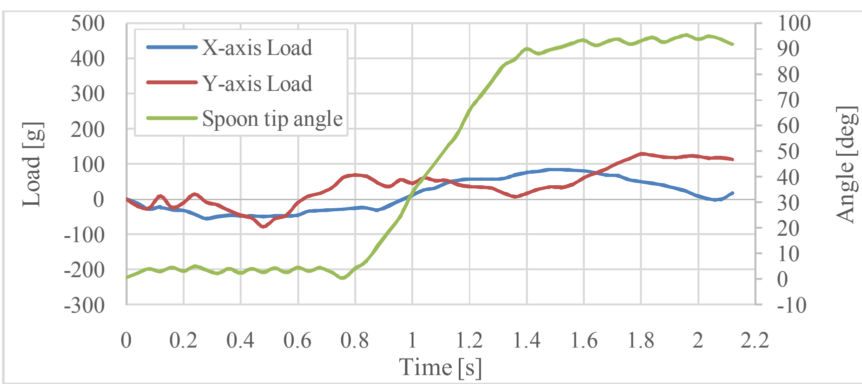

Figure 13: Transition of Load Values of X-Axis and Y-Axis, and Spoon Tip Angle; Trial Subject of Food, Jelly; Rotational Speed, 0.50[RPS]

According to Figure 11, 12 and 13, the X-axial load and Y-axial load were rarely affected by the difference of rotational speed of spoon. In case of gel-like solid food, the transitions of both X-axial load and Y-axial load hardly varied. The low elasticity of jelly and the low friction between jelly and spoon were caused this phenomenon. Table 5 shows the maximum and minimum value of each load applied to spoon. Description of minimum value of X-axial load is omitted because minimum value of X-axis is 0 while there are not any foods on the spoon.

Table 5: Maximum and Minimum Values of Each Load in Case of Jelly

		Rotational Speed of Spoon		
		0.250 [rps]	0.375 [rps]	0.500 [rps]
X-axial load [g]	Maximum	137.13	82.60	88.85
Y-axialload [g]	Maximum	76.78	131.43	128.57
	Minimum	-72.03	-65.72	-78.31

CONCLUSIONS

This study observed the mechanical properties of three types of foods: viscous particulate food, sol-like liquid food and gel-like solid food. The results of this measurement will be available to decide the suitable values of the rotational speed and torque of spoon. In addition, it is necessary to investigate the shape of spoon which is considered not to spill any foods. In the next step, the types of trial subjects of foods will be expanded more variously in order to enhance the database of the mechanical properties.

REFERENCES

1. Ministry of Health, Labor and Welfare, Social Welfare and War Victims' Relief Bureau, “New Possibilities Pioneered by the Supporting Equipment -The Present Situation and Problems of the Supporting Equipment in Japan-”. The study meeting report for vision of technological innovation for life support, 2008, 84p.
2. M. Yamaguchi, K. Takeda and M. Murakami. “Human Science and Assistive Technology”. CORONA PUBLISHING CO.LTD, 2007, 161p, ISBN 978-4-339-07093-4
3. N. Tejima, K. Yonemoto, T. Aikawa, J. Sagara, and S. Kasuya. "Basic Rehabilitation Engineering". CORONA PUBLISHING CO.LTD, 2009, 161p, ISBN 978-4-339-04523-9.
4. N. Tejima, "Rehabilitation manipulator for eating", JRSJ, vol.14, no.5, pp.624-627, 1996.
5. A. Kawabata, "Materials science of food", Kenpakusha, 1989, 230p. ISBN978-4-7679-6046-3.
6. T. Nomaguchi, "Mechanical properties of food related on scoop behavior of the spoon", Graduation thesis of Kumamoto University (2014).