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기능적 가상 시작기 기술을 이용한 자동 쌀 진공포장기의 모델링, 시뮬레이션 및 개발

Modeling, Simulation and Development of an Automatic Vacuum Packer for Rice Using Functional Virtual Prototyping

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적 요

본 연구의 주요 목적은 자동 쌀 진공포장기의 3차원 기능적 가상시작기 모델을 개발하여 포장기의 구동시스템을 설계하고 개발하고자 하였다. 개발한 3차원 가상시작기는 주로 압축판부, 테이프부착부 및 진동판부로 구성되었다. 가상시작기의 민감도 분석을 수행하기 위해 제품포대의 두께변수를 이용하여 3차원 가상시작기를 파라미터화하였다. 자동 진공포장기의 최대 처리능력 6포/분, 포대규격: 45cm × 35cm을 충족하기 위해 각 주요부를 구동하는 모터 작동제어로직(motion control function)을 적절하게 설계하였다. 설계한 작동제어로직에 의하여 각 모터를 구동할 때 필요로 하는 적정 동력은 각각 100 W, 25 W 및 90 W로 결정하였다. 연구결과를 요약하면 다음과 같다. 자동 진공포장기의 실제 시작기를 제조한 후 설계한 작동제어로직을 각 구동모터에 적용하여 시뮬레이션의 결과를 검증하였다. 개발한 3차원 가상시작기 모델을 시뮬레이션하여 선정한 모터들은 각 주요부를 원활하게 구동할 수 있었다. 제안한 작동제어로직은 주요부의 요구된 작동 시퀀스를 만족시켰으며 이때 자동진공포장기의 처리능력은 6.7 포/분이었다. 개발한 자동 쌀 진공포장기의 포장성공률은 92.6%이었다.

Keywords : Vacuum packer, Modeling, Simulation, Functional virtual prototyping.

1. INTRODUCTION

As white embryo rice has more nutrients, enzymes, and fibers than ordinary white rice(Houston, 1972), many consumers are being attracted by white embryo rice according to some market surveys. However, the embryos of white rice easily deteriorate due to high temperature and relative humidity in summer. The deterioration shortens the shelf life of white embryo rice through decreasing its quality because chemical components, such as fat and carbohydrate, are dissolved and oxidized during the storage. It is widely known that vacuum packaging can prolong the shelf life of agricultural products by maintaining their quality and freshness. The reason is that vacuum packaging can attenuate the biological respiration rate of agricultural products. However, there are few vacuum packers suitable to package rice in Korea. At present, most vacuum packers used in Korean rice mills belong to manual or semi-automatic types with low processing capacity of less than 3 pouches/min. Oxygen absorbers as one of the chemical methods are sometimes used in some rice mills for vacuum packaging. It is necessary to design an automatic vacuum packer to prolong the shelf life of foods and rice products such as white embryo rice that easily deteriorate in storage.

Compared with conventional methods in machine design that are time-consuming and depend on graphical

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techniques, functional virtual prototyping can improve the design quality of a multibody mechanical system by conducting the kinematic and dynamic analysis of its three dimension(3D) model. Functional virtual prototyping is generally regarded as a tool used to model and to simulate a real multi-body mechanical system consisted of many bodies, components, or substructures(Shabana, 1998). Using the modeling data that describes each component of a multi-body mechanical system to be modeled, a functional virtual prototype can build a discrete mathematical model of the system. Some general 3D modeling and simulating programs for functional virtual prototyping have been developed during the past three decades (Youm *et. al.*, 1996). Automated dynamic analysis of mechanical systems(ADAMS) is a 3D dynamic analysis and simulation program(Erdman *et. al.*, 2001), which is originated from dynamic response of articulated machinery designed by Chace(1978) using FORTRAN language. It allows users to build, simulate, and refine the functional virtual prototype of a multi-body mechanical system that have some moving parts. A large-scale 3D modeling program, called dynamic analysis and design system(DADS), was developed for performing the kinematic and dynamic analysis of a planar or spatial multi-body mechanical system(Haug *et al.* 1982). Recently, owing to the quick development of broadband Internet, a web-based simulation environment of functional virtual prototyping was developed by Larsson and Larsson(1980) to create a distributed design environment. Several researchers have investigated how to apply functional virtual prototyping to agricultural machinery design. Zagnoni(2000) designed and simulated a 3D model for obtaining the optimal system configurations and improving the productivity of an automatic packaging machine. An automatic transplanter consisting of a pick-up system, a planting system, and a feeding system was developed using functional virtual prototyping and simulated to investigate the kinematic characteristics of the pick-up and planting system(Kim *et al.*, 2001). Functional virtual prototyping was applied by Choi *et al.* (2001) to design an automatic pick-up mechanism for plug-seedlings. Queiroz(2001) constructed a 3D simulation model for analyzing the dynamic behavior of a bean harvester using functional virtual prototyping.

The detailed objectives of this study were: (1) to build a reduced 3D functional virtual prototype of an automatic vacuum packer for rice; (2) to design the rotational motion control functions of the virtual motors used to drive the reduced 3D model of the vacuum packer; (3) to simulate the reduced 3D model to predict the rated powers of the motors based on the developed motions; (4) to conduct kinematic analysis for main components of a real prototype using the reduced 3D model; and (5) to conduct packaging tests for the vacuum packer developed by 3D simulation.

2. MODELING AND SIMULATION OF AN AUTOMATIC VACUUM PACKER

A. Description of an automatic vacuum packer

The functionality of the vacuum packer is to remove the air in a pouch through a hole on the packaging film and to tape the hole with a piece of transparent tape after reaching a certain vacuum level. The hole was created by an air-remover. The automatic vacuum packer consists of the following three units: (1) a pressing board unit, (2) a taping unit, and (3) a vibrating board unit (Fig. 1). The pressing board unit consisted of a mechanism used to improve the air-removing speed to generate a vacuum condition in a pouch quickly.

The taping unit was used to put a piece of transparent tape(5 cm by 3 cm) supplied by an electronic tape dispenser on the vacuum hole. The vibrating board unit was designed to prevent the possibly generated winkles caused by vacuum packaging on the packaging film. The pressing board and vibrating board units are mainly consisted of two eccentric cam-follower mechanisms. The eccentricities of the cams for driving the pressing board and vibrating board units were designed to be 70 mm and 1 mm, respectively. The taping unit adopted a slider-crank mechanism. The lengths of the crank and the coupler of the slider-crank mechanism are 170 mm and 300 mm, respectively. To fulfill the specified processing capacity of 6 pouches/min(pouch size: 45 cm by 35 cm; 5 kg/pouch) and to reduce the instant impacts of the

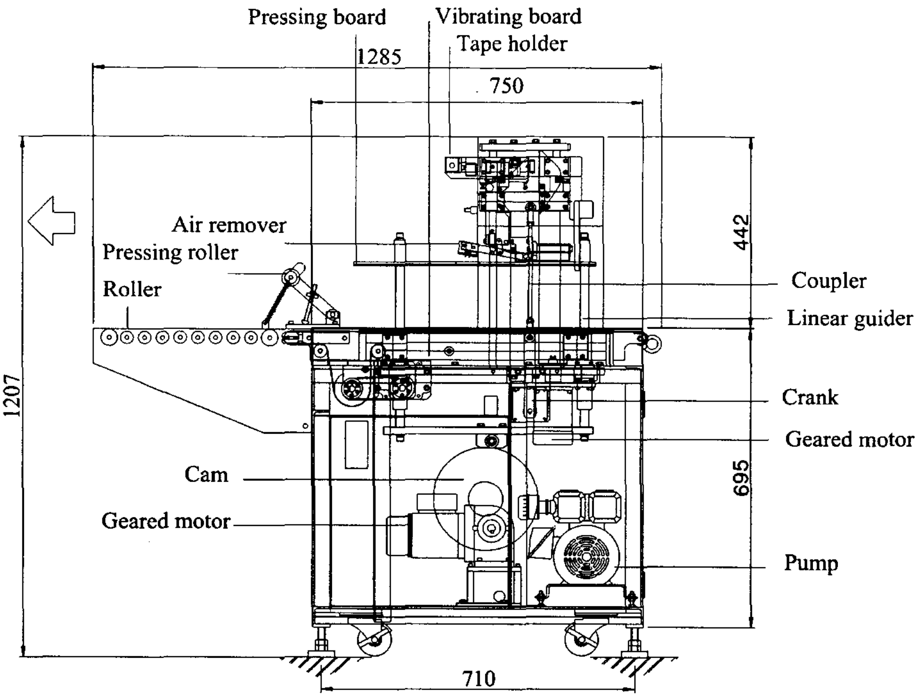

Fig. 1 The configuration of an automatic vacuum packer; all dimensions in mm.

pressing board and the tape holder on the packing film of a pouch, the output rotational speeds of the motors for driving the pressing board and taping units were determined to be 70 rpm and 35 rpm. The output rotational speed of the motor for driving the vibrating board unit was designed to be 1600 rpm to shape a pouch quickly. Two geared motors were chosen to drive the pressing board and taping units. The vibrating board unit was driven by an induction motor.

B. Analytical modeling of a constrained multi-body mechanical system

In this study, the vacuum packer was considered as a constrained multi-body mechanical system consisted of several rigid bodies. In a multi-body mechanical system (Negrut, 2001) with n rigid bodies, the following vector, **q**, is used to represent the position and orientation of each body at a given time instant.

$$\mathbf{q} = [\mathbf{q}_1^T, \mathbf{q}_2^T, \cdots, \mathbf{q}_n^T]^T \tag{1}$$

Joints in a multi-body mechanical system regarded as constraints, and the holonomic kinematic constraint equations imposed by a joint generally are expressed as

$$\boldsymbol{\varphi} = \boldsymbol{\varphi}(\mathbf{q}, t) = 0 \tag{2}$$

All constraint equations imposed by the joints are denoted as follows

$$\boldsymbol{\varphi}(\mathbf{q}, t) = [\boldsymbol{\varphi}_1^T(\mathbf{q}, t), \boldsymbol{\varphi}_2^T(\mathbf{q}, t), \cdots, \boldsymbol{\varphi}_n^T(\mathbf{q}, t)] \tag{3}$$

where, n is the number of joints of a multi-body mechanical system. By taking one time derivative of the kinematical constraint equations about position, the kinematic constraint equations about velocity are obtained as

$$\boldsymbol{\varphi}_q(\mathbf{q}, t)\,\dot{\mathbf{q}} = -\boldsymbol{\varphi}_t(\mathbf{q}, t) \tag{4}$$

By taking another time derivative of the Eqn (4), the kinematic constraint equations about acceleration are obtained as

$$\boldsymbol{\varphi}_q(\mathbf{q}, t)\,\ddot{\mathbf{q}} = -(\boldsymbol{\varphi}_q\,\dot{\mathbf{q}})_q\,\dot{\mathbf{q}} - 2\boldsymbol{\varphi}_{qt}\,\dot{\mathbf{q}} - \boldsymbol{\varphi}_{tt}(\mathbf{q}, t) = \gamma \tag{5}$$

where, $\boldsymbol{\varphi}_q$ is the Jacobian matrix of the constrained equations; and is the right side of the equation. For a constrained multi-body mechanical system, the Lagrange multiplier form of the equations of motion can be written as

$$M\ddot{q} - \varphi_q^T \lambda = g \quad (6)$$

where **M** is mass matrix that equates diag [M_1, M_2, ……, M_n], g is the system force vector, λ is Lagrange multipliers and φ_q is the Jacobian matrix of the constrained equations. By appending Eqn. (5) to (6), the complete set of constrained equations of motion can be written like follows

$$\begin{bmatrix} M & \varphi_q^T \\ \varphi_q & 0 \end{bmatrix} \begin{bmatrix} \ddot{q} \\ -\lambda \end{bmatrix} = \begin{bmatrix} g \\ \gamma \end{bmatrix} \quad (7)$$

The constraint equations for some joints commonly used were systematically derived by Hung(1989) and Nikravesh(1988).

Without building a 3D model, the kinematic and dynamic analysis of a multi-body mechanical system can be conducted analytically. Recently, with the development of 3D simulation technology, multi-body mechanical systems are usually modeled and simulated using functional virtual prototyping in which the theories on multi-body mechanical system are embedded. In this study, the kinematic and dynamic characteristic of some key component of the vacuum packer have to be predicted accurately as they are closely related to packaging quality. Moreover, to reduce cost and development cycles and to accelerate commercialization, the proposed vacuum packer was modeled using functional virtual prototyping instead of an analytical modeling approach.

C. Assumptions for a reduced 3D model

In this study, a reduced 3D model of the vacuum packer was developed using a widely used program(ADAMS, MSC. Software Co., USA) of functional virtual prototyping. The following assumptions were made prior to constructing the reduced 3D model to simplify the modeling process of the three units of the vacuum packer: (1) the density of all components made of different kinds of steel was assumed to be 7,800 kg/m^3 for the simplicity of modeling; (2) the coefficients of static and kinetic frictions associated with all prismatic and revolute joints were assumed to be 0.1 and 0.05, respectively; (3) the dynamic analysis of the vibrating board unit was conducted under the assumption that there was a 5 kg pouch on the vibrating board to obtain simulation results accurately.

D. Model construction

The overall modeling process of the reduced 3D model of the vacuum packer is shown in Fig. 2. To decrease the complexity of the modeling and analyzing process, some tiny components of the designed vacuum packer were not considered when constructing the reduced 3D model. The power requirement of the driving motors and the kinematic characteristics of main components of the vacuum packer were to be predicted by simulating the reduced 3D model. After a model simplification, there are chiefly 5, 4, and 1 components in the pressing board,

Table 1 The components of the reduced 3D model of a vacuum packer

Sub-models	Components	Mass, kg	Mass moments of inertia, kg×mm^2		
			Ixx	Iyy	Izz
Pressing board	Pressing board	14.28	1.85E+05	8.17E+05	6.33E+05
	Linear guider	1.00	1.41E+04	50.24	1.41E+04
	Follower	4.51	640.15	2.01E+05	2.01E+005
	Cam	2.49	1.99E+04	9.985.97	9,985.97
Taping	Tape holder	2.10	1,103.93	4,422.55	3,442.55
	Coupler	0.98	8,200.57	65.20	8,200.14
	Crank	0.47	13.99	94.89	94.46
	Supporter	0.20	81.13	1,622.61	1,653.81
Vibrating	Vibrating board	11.05	2.19E+05	5.93E+05	8.12E+05

taping, and vibrating board units, respectively(Table 1). As the dimensions and the density of each component of the three units were obtained from the design drawings of the vacuum packer, the 3D modeling program could automatically estimate their mass and mass moments of inertia. After obtaining the modeling data associated with each component, the reduced 3D model of the vacuum packer was constructed and is shown in Fig 3. There are three sub-models(Figs 4, 5, 6) corresponding to the three main units of the vacuum packer, i.e. a pressing board sub-model, a taping sub-model, and a vibrating board sub-model. The sub-model of the pressing board unit consisted of 5 rigid bodies, a revolute joint, a revolution motion, and a high-pair contact joint for modeling its cam-follower mechanism. There are 4 rigid bodies, 3 revolute joints, a revolution motion, and two prismatic joints for modeling the sub-model of the taping unit. The sub-model of the vibrating board unit was modeled using

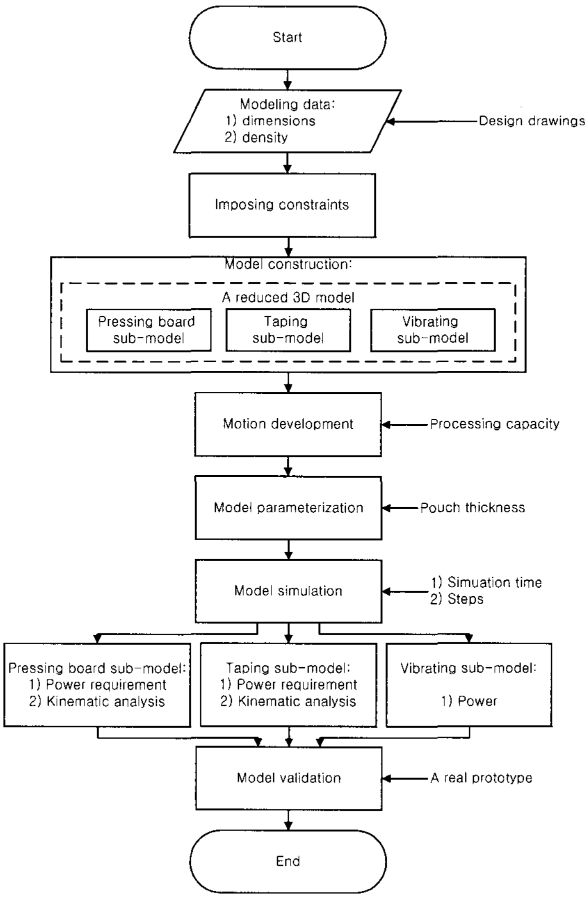

Fig. 2 The modeling process of a reduced 3D model of the vacuum packer.

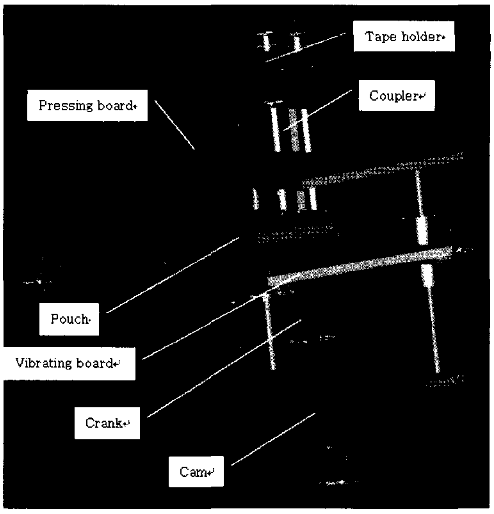

Fig. 3 The reduced 3D model of an automatic vacuum packer.

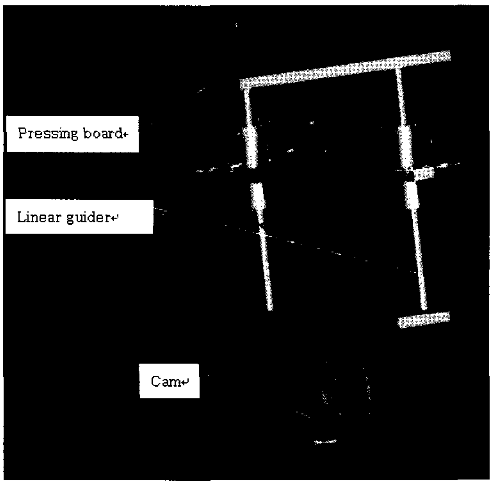

Fig. 4 Sub-model of the pressing board unit.

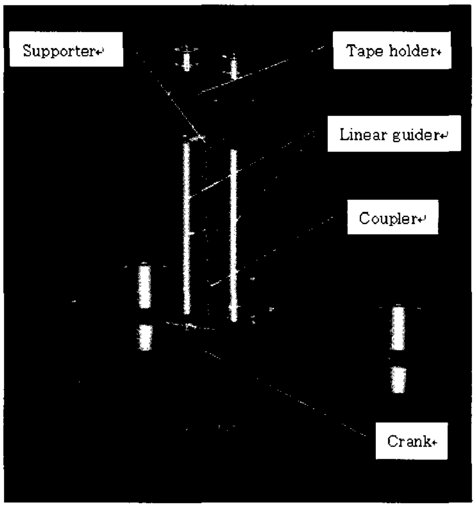

Fig. 5 Sub-model of the taping unit.

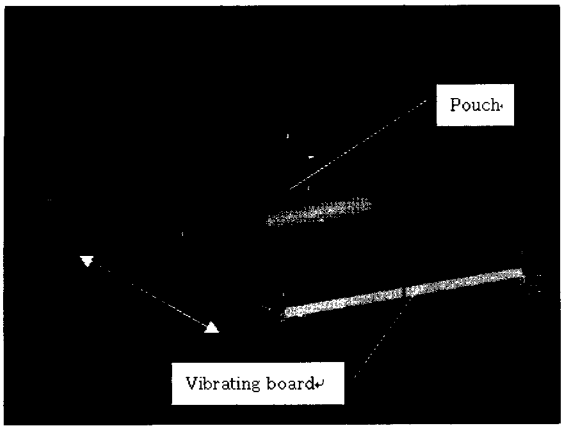

Fig. 6 Sub-model of the vibrating board unit.

a rigid body, 4 prismatic joints, a revolution joint, a revolution motion, and a high-pair contact joint.

The reduced 3D model was a parameterized functional virtual prototype for sensitivity analysis. To predict the rated powers of the motors chosen for driving the pressing board unit and the taping unit, the sub-models of the two units were parameterized through changing the value of the variable of pouch thickness.

E. Performance test as model validation

A real prototype of the packer was manufactured and driven by the motors determined by simulating the 3D reduced model. The motors were controlled according to the developed motion control functions. A continuous packaging test was conducted at an experimental rice mill of Chonnam National University to confirm: (1) whether or not the predicted rated powers of the driving motors were appropriate; (2) whether or not the specified processing capacity of the prototype vacuum packer was fulfilled; (3) whether or not the packing quality of the vacuum packer was satisfied. In addition, the tape holder and the pressing board are two important components that closely related to the taping quality and the air-removing time. Therefore, further validations were mainly conducted to measure the velocities of the two components when a typical 5-kg pouch(65 ± 5 mm in thickness) was packed. The velocities were sensed as shown in Fig. 7 using a digital tachometer (HT-3100, Ono Sokki Co. Japan), and a disk of 20 mm in diameter. The specifications of the tachometer are shown in Table 2.

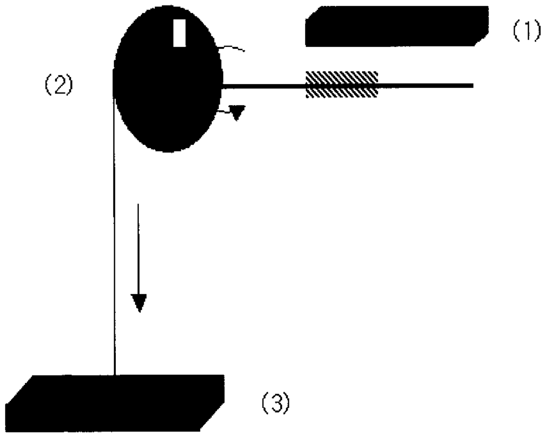

Fig. 7 Schematic view of the velocity measurement; (1) digital tachometer; (2) disk; (3) the pressing board or the tape holder.

Table 2 The specifications of the digital tachometer

Measurement range	50 - 50,000 rpm
Detection method	Non-contact, reflective type
Detection distance	Approximate 50~150 mm
Accuracy	± 1 rpm

3. RESULTS AND DISCUSSION

A. Motion organization

Three revolute joints were used to act as virtual motors to control the operating sequences of the functional virtual prototype. The interrelationships of the rotational motions of the virtual motors were properly arranged to improve the productivity of the vacuum packer and to avoid the possible collisions due to inappropriate organization of the operating sequences of the three units. The operating sequences of the virtual motors were designed as shown in Fig. 8. The sequences were transformed into three motion control functions(Figs 9, 10, 11) of the revolute joints. The motion control functions were implemented in the reduced 3D model to impose the detailed motions on the revolute joints driving the pressing board, taping, and vibrating board sub-models. The vacuum time of the vacuum packer was assumed to be 7 sec considering the specified processing capacity of the vacuum packer and the preservation effects of the vacuum packaging. The vibrating time was designed to be 5 sec, which was considered to be long enough to shape a 5 kg pouch. The developed motion control functions could reflect the operating sequences of the vacuum packer in a continuous simulation of the reduced 3D model.

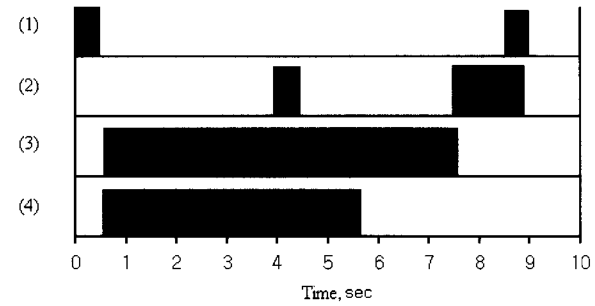

Fig. 8 Flowchart of the operating sequences of an automatic vacuum packer:
(1) motor of the pressing board unit (2) motor of the taping unit (3) vacuum pump; (4) motor of the vibrating board unit.

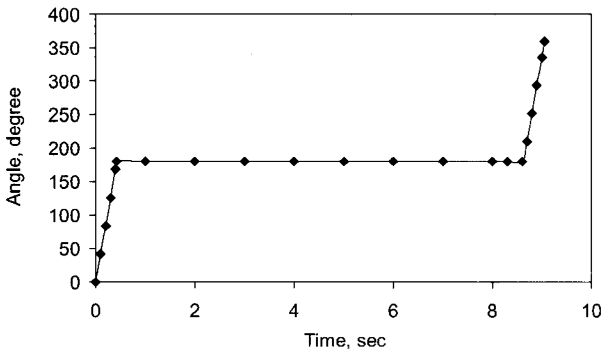

Fig. 9 A cycle of the rotational motion of the motor of pressing board unit.

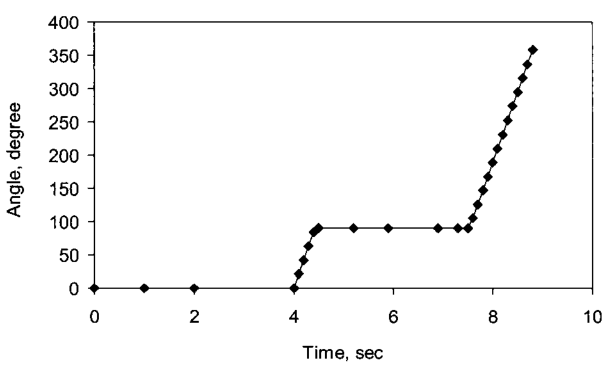

Fig. 10 A cycle of the rotational motion of the motor of the taping unit.

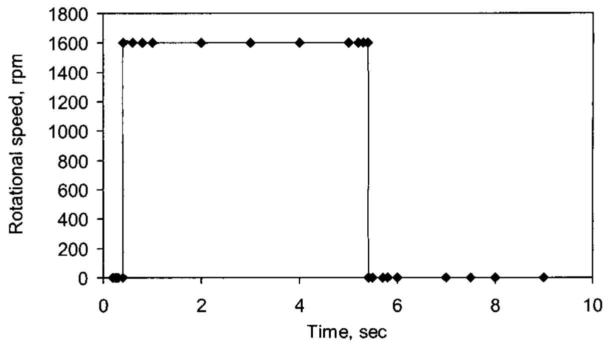

Fig. 11 A cycle of the rotational motion of the motor of the vibrating board unit.

B. Determination of the rated powers of the virtual motors

Each sub-model of the reduced 3D model of the vacuum packer was driven by a virtual motor. Determining the minimum rated power of each motor was a quite complicated process using the conventional methods of machine design. The reduced 3D model of the vacuum packer was simulated to investigate the dynamic analysis for systematically determining three appropriate motors to drive the pressing board, taping, and vibrating board units.

The sub-model of the pressing board unit was parameterized using the variable of pouch thickness. The parameterized sub-model was simulated continuously for two cycles when the parameter variable of pouch thickness was set at 0, 3, 6, 9, 12, and 14 cm, respectively. The plot for the power requirement of the motor versus pouch thickness is shown in Fig. 12. The power requirement dropped moderately from 99.93 W to 40.48 W when pouch thickness was gradually increased. The phenomenon was caused by that the supporting effect of the pouch on the vibrating board became greater as pouch thickness increased. The relationship for power requirement versus pouch thickness was governed by the following quadratic equation:

$$P = -0.331L^2 + 1.628L + 99.044 \quad (8)$$

where P is the power requirement of the motor used to drive the pressing board unit(W) and L is pouch thickness(cm). The coefficient of determination(r^2) of the equation is 0.991.

It was found that the maximum power requirement of the motor for driving the sub-model of the pressing board unit was observed when the pouch thickness was set at 0 cm(Fig. 13). The maximum consumed power was 99.93 W in the simulation. A 100 W geared-motor with a rotational speed of 70 rpm was considered to be appropriate to drive the pressing board unit.

The sub-model of the taping unit was also parameterized to predict the appropriate rated power of the virtual motor using the variable of pouch thickness. In each simulation process, the sub-model was simulated 6 times when the pouch thickness was 0, 3, 6, 9, 12, and 14 cm, respectively. The sub-model was simulated continuously for two cycles including 4000 steps. The plot for the power requirement of the motor versus pouch thickness is shown in Fig. 14. When the pouch thickness was gradually increased from 0 to 14 cm, the maximum power requirement showed no significant change in 24.33 ±0.04 W because the mass of the tape holder was quite small. The simulation result shown in Fig. 15 was the change of power requirement of the virtual motor used to drive the taping unit in two cycles when the pouch thickness was 0 cm. As the maximum consumed power was 24.64 W, a 25 W geared motor that satisfies the requirement of the rotational speed of 35 rpm was recommended to drive the taping unit.

The virtual motor used to drive the sub-model of the vibrating board unit had a high rotational speed of 1600 rpm. As the vacuum packer was designed to pack a pouch of less than 5 kg, the simulation for determining the maximum power requirement of the motor used to drive the vibrating board unit was conducted when a pouch of 5 kg was assumed on the vibrating board. The maximum value of the required power of the driving motor was 89.72 W in the simulation. An AC geared motor of 90 W was chosen as the driving motor of the vibrating board unit.

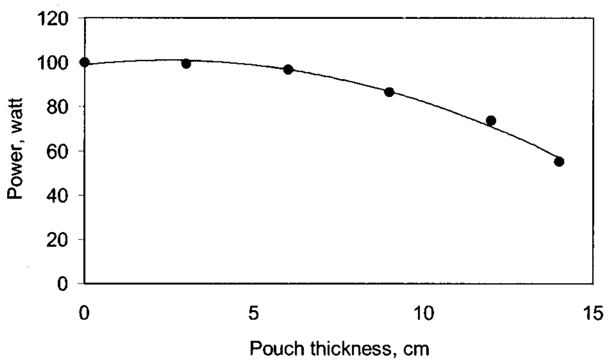

Fig. 12 Power requirement of the motor driving the pressing board unit versus pouch thickness.

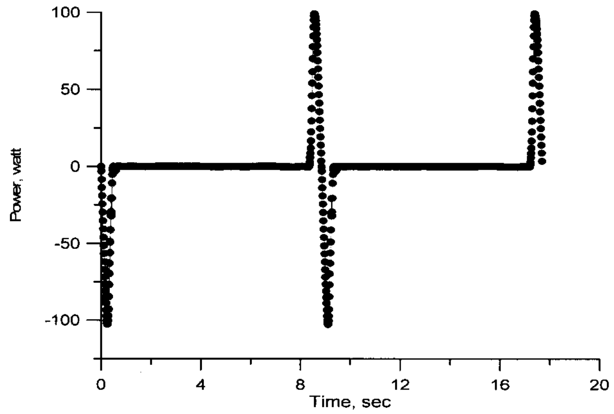

Fig. 13 Power prediction for the motor used to drive the pressing board unit (pouch thickness: 0 cm).

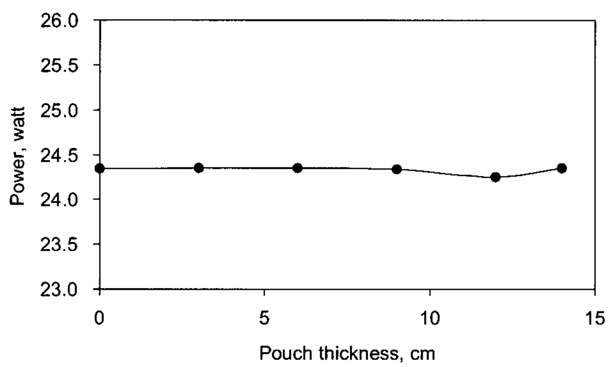

Fig. 14 Power requirement of the motor used to drive the taping unit versus pouch thickness.

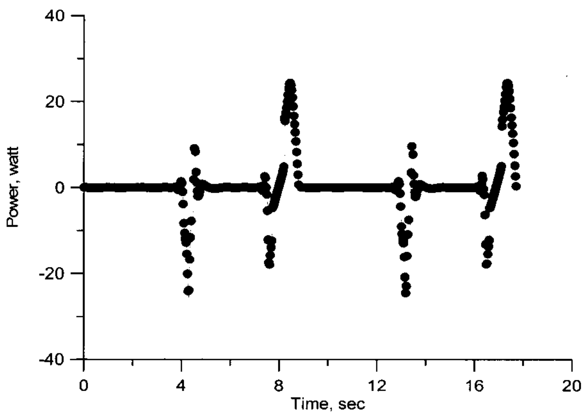

Fig. 15 Power prediction for motor used to drive the taping unit (pouch thickness: 0 cm).

C. Predicting the kinematic characteristics of main components

An AC geared motor of 100 W(reduction ratio: 1:25) was equipped to drive the pressing board unit. The rotational speed of the rotor of the geared motor was 1,750 rpm. The angular velocity of the output shaft of the geared motor was 7.33 rad/s. After the angular velocity was submitted into the sub-model of the pressing board unit, the sub-model was continuously simulated in 4,000 steps. The changes of the displacement, velocity, and acceleration of the pressing board are shown in Fig. 16. The maximum displacement of the pressing board was 150 mm. When the pressing board was pressing on a pouch of 5 kg, the displacement of the pressing board was 65 mm, the thickness of the pouch. The velocity of the board was - 521 mm/s when the board was touching the pouch. After pressing the pouch for about 7 sec, the pressing board moved upward with an acceleration of 185 m/s^2 and rapidly reached a maximum velocity of 504 mm/s.

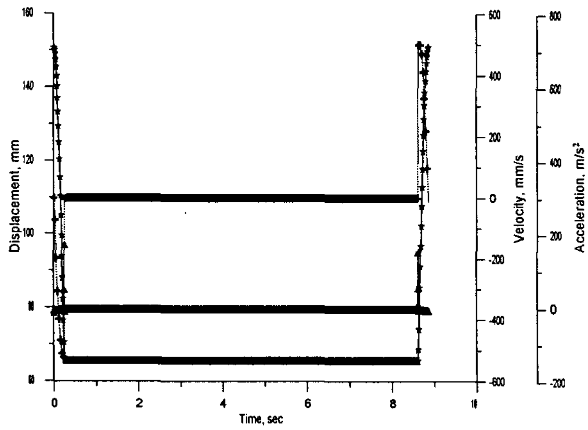

Fig. 16 Simulation results of the kinematic analysis of the pressing board(5 kg pouch).

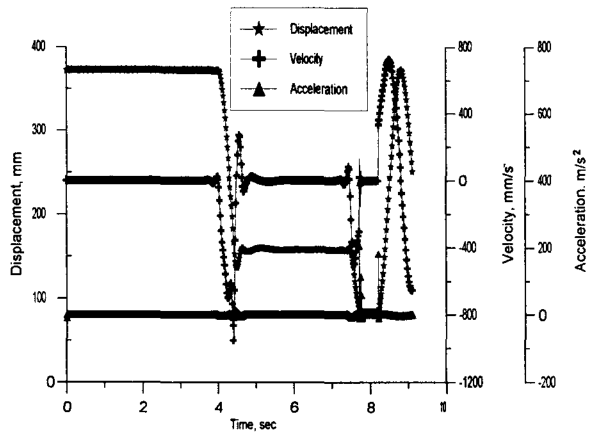

Fig. 17 Simulation results of kinematic analysis of the tape holder(5 kg pouch).

The rotational speed of the rotor of an AC geared motor (reduction rate: 1:50) used to drive the taping unit was 1,750 rpm. The angular velocity of the crank was obtained to be 3.67 rad/s, which was submitted into the sub-model of the taping unit. The results of the kinematic analysis of the tape holder are shown in Fig. 17. As the virtual motor of the sub-model rotated, the displacement of the tape holder first deceased to 157 mm. After the time of air removing, the displacement of the tape holder deceased again to 82 mm as the tape holder pressed a pouch on the vibrating board at a velocity of - 310 mm/s. After taping the pouch, the tape holder moved upward rapidly with a velocity of 361 mm/s. The holder touched the pouch at an acceleration of 205 m/s^2 and left at an acceleration of 189 m/s^2, respectively.

D. Packaging tests of the vacuum packer developed by simulation

A real prototype of the vacuum packer was manufactured. The control unit of the real prototype was a programmable logic controller programmed according to the developed motions. The predicted motors used to drive the three units were controlled according to the control algorithm of the controller. The predicted motors drove the vacuum packer successfully. A vinyl packer was used to pre-package 108 pouches of embryo white rice in 5 kg. The 108 pouches were conveyed to the developed vacuum packer by a belt conveyor. It took about 16 minutes to vacuum-package all the 108 pouches (6.7 pouches/min), which showed the specified processing capacity(6 pouches/min) was satisfied by implementing the designed control motions. The developed automatic vacuum packer of continuous type was significantly improved in the performance of processing capacity compared with manual or semi-automatic vacuum packer. In addition, the vacuum packaging eliminated the food security concerns of consumers caused by chemical methods. The tape holder touched a 5-kg pouch at a velocity of 304 6 mm/s in the packaging test, which was similar to the predicted velocity of -310 mm/s. The pressing board pressed a 5-kg pouch at a velocity of 517±8 mm/s showing the predicted velocity(521 mm/s) was accurate enough.

The 108 pouches of embryo white rice vacuum-packaged by the packer were left alone for 2 days to investigate the success rate of the packer. It was found that 100 pouches were packed successfully. In this study, packaging failure was defined as that the internal vacuum level of a pouch was less than 650 Torr. The failures of vacuum packaging could be classified into type I and type II failures. The type I failure was caused by an inappropriate tape feeding of the electronic tape dispenser. A vinyl packer was used to pre-package milled rice into 5-kg pouches which was transferred to the developed vacuum packer. The unsuccessful sealing of the vinyl packer, on the other hand, caused the type II failure. Among the failed 8 pouches, 6 pouches were categorized to the type I failure and other 2 pouches to the type II failure. The success rate of vacuum packaging, type I failure rate, and type II failure rate were 92.6%, 5.6%, and 1.9%, respectively. Additional packaging experiments have been conducted to continuously evaluate the performance of the developed machine, and similar packaging success rates of 93.1% and 91.6% were obtained as reproducibility.

4. CONCLUSIONS

A reduced 3D functional virtual prototype of a vacuum packer was developed and simulated for designing the rotational motions of the driving motors and predicting the power requirements of the motors used to drive the three units of the vacuum packer. The motion control functions for the driving motors were properly designed to fulfill the operating requirements. The predicted power requirements of motors used to drive the pressing board unit, taping, and vibrating board units were 100 W, 25 W, and 90 W, respectively. The kinematic analysis for the important components of the vacuum packer, the pressing board and tape holder, were conducted for improving the packing quality of the automatic vacuum packer.

A real prototype of the vacuum packer was manufactured and controlled according to the developed motion control functions implemented in the control algorithm of a programmable logic controller. A vacuum-packaging test was conducted to process 108 pouches of embryo white rice for the validation of the simulation results in terms of the processing capacity of the real prototype. The real processing capacity of the vacuum packer was 6.7 pouches/min. The experiment showed the specified processing capacity (6 pouches/min) of the vacuum packer was satisfied with a success rate of 92.6%.

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