System Development for Providing Optimal Friction Force for Sorting Machine

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Abstract: In this study, we develop an automatic sorting system, which is mostly affected by frictional forces between a veneer and friction-generating device. So we will make a suitable dynamic model and mechanism to control friction force using a AC servo-motor. We suggest Stick friction and Column friction model, which is occurred between roller and veneer and within veneers as well. A kind of sensor can get the velocity of roller and movement of roller vertical direction. We assume that the several things to simplify the complicate and difficult nonlinear friction phenomenon. And to create an optimal normal force, which can generate a suitable friction force, we control the movement of sorting roller and supporter as well. We introduce several results about a friction character and suggest the value of calibration of sorting roller movement and supporters as well.

Keywords: Friction force, Nonlinear characteristics, Sorting mechanism, Friction modeling

1. INTRODUCTION

In general, the friction force is treated as disturbance of system and resistance of performance of movement. Otherwise, we will apply a friction force as a driven force for an automatic sorting machine what is used for manufacturing wood floorings. Because a friction has a nonlinear characteristic such as stick-slip, break away or slip phenomenon, it is very hard to control accurately.

The main issue of this paper is how to set a motion equation for a stacked veneer and roller torque actuated by a servo-motor. There are a lot of parameters which are a related with friction force such as normal force, friction coefficient, temperature of surface, condition of surface and so for. Among those parameters, we are interested in a normal force and a roller velocity to set an optimal friction force for sorting a veneer one by one. To make an optimal friction force for sorting a veneer, we adjust a normal force from Z-axis and a roller velocity.

As an experiment device, we use 4 AC-servo motors and Multi-Motion-Controller (MMC) card to control position and velocity of roller.

The purpose of this project is to create factory automation what is produced manually nowadays, especially sorting process.

2. MECHANISMS AND MODELING

2.1 Sorting Mechanism

Fig. 1 shows that the sketch of sorting mechanism. 8 each system makes a single module.

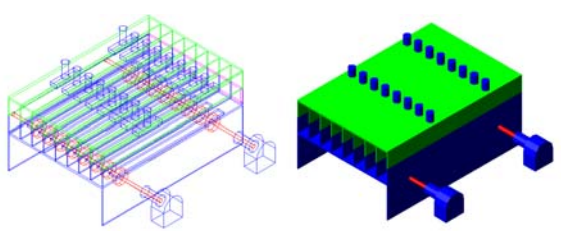

Fig. 1 Sketch of sorting model

The main idea to sort a veneer is the difference of friction force between friction generating device and the wide material.

The schematic diagram of sorting mechanism is shown in fig. 2. The system is made up of sorting roller that can generate a friction force and normal force, and support can supply a veneer to sorting roller. The components of the system – sorting roller and support – are operated by AC servo motor.

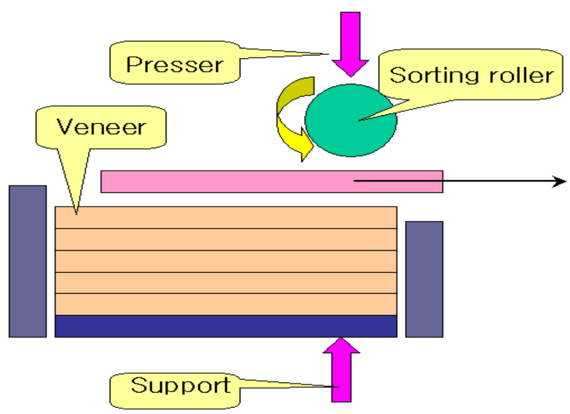

Fig. 2 Schematic diagram of sorting mechanism

2.2 Friction Modeling

There are several friction models and often concerned as a function of velocity of sliding surface called static model. In fig. 3 shows a common static friction model

Generally, friction models are divided static model, dynamic model. Static model is deal with the count relationship with velocity. However, dynamic models have several unique phenomenons like Frictional memory, spring-like characteristics, and pre-sliding displacement.

Static friction force is made up of linear and nonlinear friction force. Linear friction force is full fluid lubrication zone and increased about velocity. A viscosity of fluid defines the friction force. And a general equation for the viscous friction force is

$$F_{vis}(\dot{x}) = B\left|\dot{x}\right|^{\delta}\operatorname{sgn}(\dot{x}) \tag{1}$$

where F_{vis} is viscous friction force, δ is constant decided by the character of system viscous friction.

Before going to describing characters of nonlinear friction. Break-Away should be expressed. Break-Away force called spring-like behavior is described spring model. Fig. 3 shows that the spring-like character of nonlinear friction.

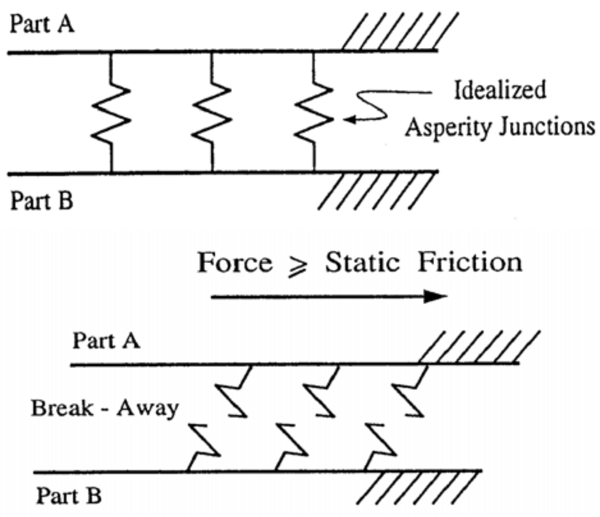

Fig. 3 Spring-like character of nonlinear friction

Nonlinear friction force is divided Static friction and Column friction. The equation for nonlinear friction force with static is expressed as follow:

$$F_{st}(\dot{x}, u) = \begin{cases} u & \text{if } \dot{x} = 0 \text{ and } |u| < |F_{st}| \\ |F_{st}|\operatorname{sgn}(u) & \text{if } \dot{x} = 0 \text{ and } |u| \geq |F_{st}| \end{cases} \tag{2}$$

If external force is smaller than a maximum static friction force, the material does not move. According to the equation 2, friction force cannot be described only with function of velocity but the external force should be concerned.

Column friction works opposite direction about a moving direction as reaction. And the equation for the Column friction is described as follow:

$$F_{col}(\dot{x}) = |F_{st}|\operatorname{sgn}(\dot{x}) \tag{3}$$

where F_{col} is Column friction force, generally a magnitude of Column friction is smaller compare with static friction force.

Friction models - Static friction, Rolling friction and Sliding friction - are distinguished from a friction model as a function of velocity. These are phenomenological description of friction.

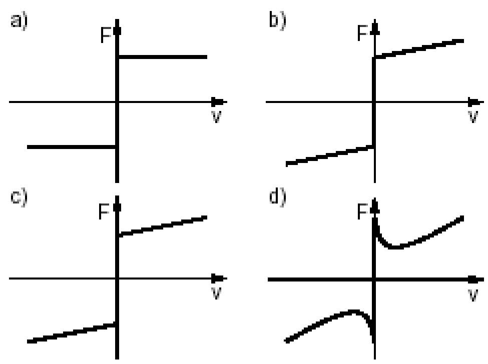

Fig. 4 The static friction models: Friction force verse Velocity. a) Column friction, b) Column and Viscous friction, c) Static, Column and Viscous friction, d) Negative Viscous, Column and Viscous friction.

Among these friction models, we are just concerned on a Static and Column friction, Rolling and Sliding friction. A Static and Column friction behavior is occurred between veneer and veneer at a moment when a veneer is just moved. Rolling friction is observed between roller and veneer. And between veneers, a Sliding friction is occurred when a veneer is moving.

Figure 5 is the free body diagram of sorting system. The normal force is given from roller what can generate a friction force. Moreover, the second veneer should not be fed by the friction force, which is occurred by the roller. It means that the suitable normal force should be supplied to the first one.

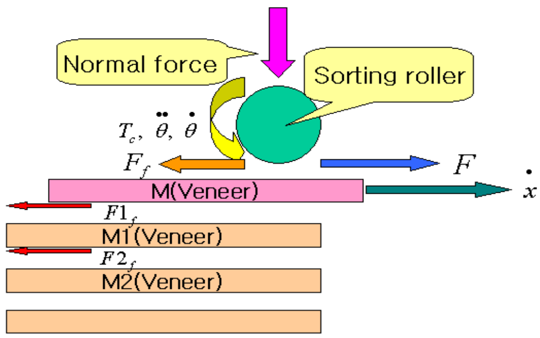

Fig. 5 is the free body diagram of sorting system

The condition for sorting a veneer one by one, the friction force, which is generated by sorting roller, is larger than a friction force, which is occurred within veneers. Furthermore, to prevent sorting second veneer, the friction force, which is generated by sorting roller, is smaller than 2 time of a friction force, which is occurred within veneers. The equation for the phenomenon expressed above is:

$$\begin{aligned} & F1_f < F_f < (F1_f + F2_f) \\ & \rightarrow F_{vf} < F_f < 2F_{vf} \end{aligned} \tag{4}$$

where F_f is a friction force generated by roller, F_{vf} is a friction force occurred within veneers.

Simplification need to sorting system modeling. Because the analysis about friction is very complicated and difficult, several assumptions are need as followings.

1. Constant normal force.
2. Perpendicularly line contact veneer and sorting roller.
3. No elastic deformation with sorting roller.
4. Dry friction condition between veneer and sorting roller without any lubrication.

Fig. 6 is the free body diagram of single veneer based on assumptions.

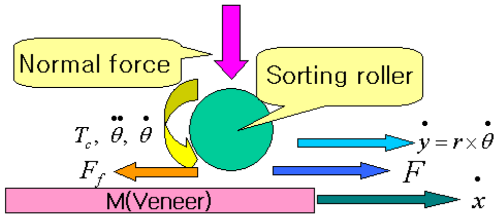

Fig. 6 is the free body diagram of single veneer

We use the Modulated Distributed Manipulator Systems (MDMS) as our reference model, because MDMS have a similar behavior compare with our sorting system.

Fig. 7 shows the Modular Distributed Manipulator systems.

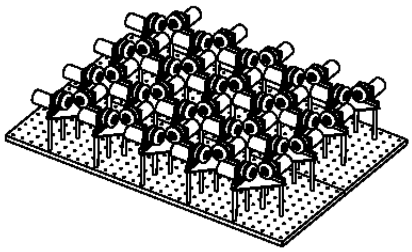

Fig. 7 The Modular Distributed Manipulator systems

The MDMS is a highly upgraded material handling system which is a fixed array of actuated wheels capable of inducing arbitrary motions in the plane and both transfers and manipulate objects on the plane. The behavior, which is occurred the MDMS is both sliding and rolling contact with the object.

Fig. 8 shows the interaction between wheel and object of MDMS.

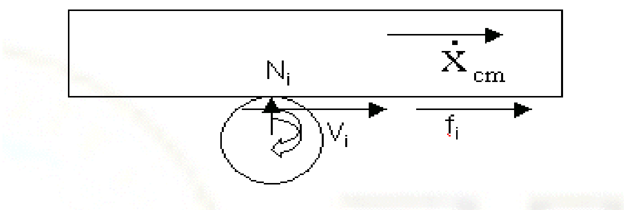

Fig. 8 The interaction between wheel and object

According to the fig. 8, a driven force what can transfer an object is a friction force. The friction force between wheels mounted motor and object is a driven force as a count-action about motor driving force.

2.3 Spring Modeling

The veneers what is stacked in the cartridge has spring-like characteristics. Fig. 9 illustrates spring-like characteristics of staked veneer.

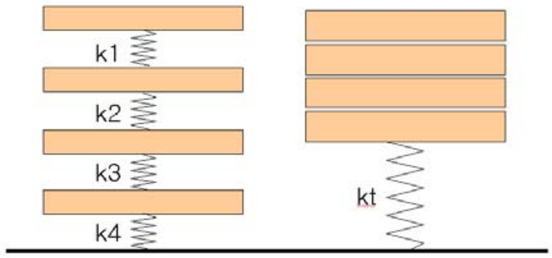

Fig. 9 illustrates spring-like characteristics of staked veneer.

Since the veneer is not a perfect rigid body, the staked veneer has elastic characteristics. And the stiffness of spring can be calculated with a serial springs. The serial spring is expressed fig. 10.

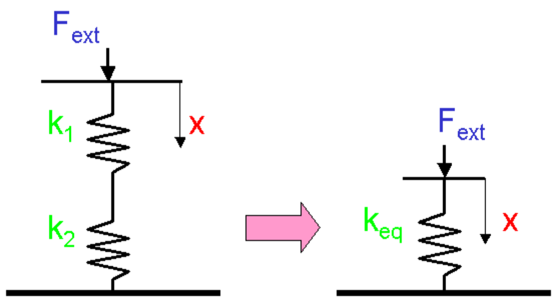

Fig. 10 serial springs

The equation of stiffness is follow:

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + \ldots$$
$$k_{eq} = \frac{k_1 k_2 k_3 \ldots}{k_1 + k_2 + k_3 \ldots} \quad (5)$$

where F_{ext} is a normal force by sorting roller. From equation 5, we can compute a displacement of stacked veneer caused by normal force.

3. EXPERIMENT

3.1Experimental Environment

The experimental apparatus used is shown in fig 11. It consists of 4 AC servo-motor for generating a friction force which can move a veneer. In order to control 4 AC servo-motor, we use a multi axis-motion-control board (MMC).

We observe several relationships among parameters – normal force, roller velocity and number of veneer.

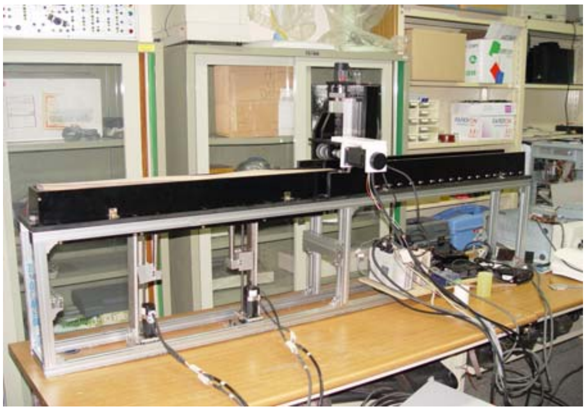

Fig. 11 Experimental apparatus

3.2 ALGORITIMS

The goal of this experiment is to define the relationships among parameters.

In order to control a movement of a veneer, we use a friction modeling expressed above. The range of suitable friction force is larger than a maximum static friction force within veneers and smaller than two times it.

Furthermore, to supply constant normal force which can generate a optimal friction force to a sorting veneer, we control a height of a sorting roller. And we use a spring modeling express before.

In detail about a spring modeling, the general equation of a spring is

$$F_{ext} = kx \qquad (6)$$

where k is a stiffness and x is a displacement of spring.

From figure 11

$$F_{ext} = k_{eq}x \qquad (7)$$

where k_{eq} is stiffness equilibrium

and k_{eq} is observed equation 5.

If each spring stiffness equals, each stiffness can be calculated from equation 7.

Through equation 5~7, we can calculate a sorting roller movement according to decreasing of number of veneer.

3.3 RESULT OF EXPERIMENT

The relationship between increasing of amount of roller movement against amount of veneer movement at a constant roller velocity is illustrated in fig. 12. And we do experiment the relationship between roller velocity from 50rpm to 2000rpm and veneer movement as increasing of sorting roller movement that is increasing normal force. From figs. 13 ~15 show that.

We divide a velocity 800rpm to 2000rpm, 300rpm to 700rpm, and 50rpm to 200rpm as high, mid, low velocity respectively.

From fig 13 to 15 illustrate a high velocity, mid velocity and low velocity respectively.

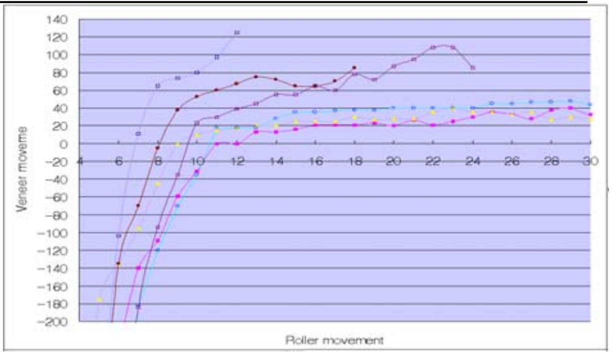

Fig. 12 Relationship between roller movement and veneer movement at a constant roller velocity.

From fig. 12, the roller movement is decreased when number of veneer is decreased.

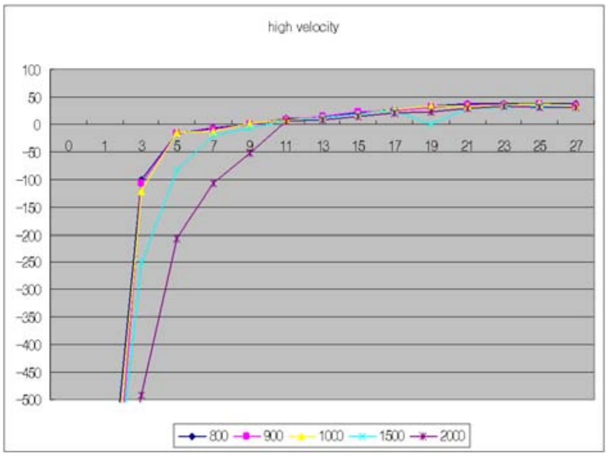

Fig. 13 Relationship between roller movement and veneer movement at high velocity

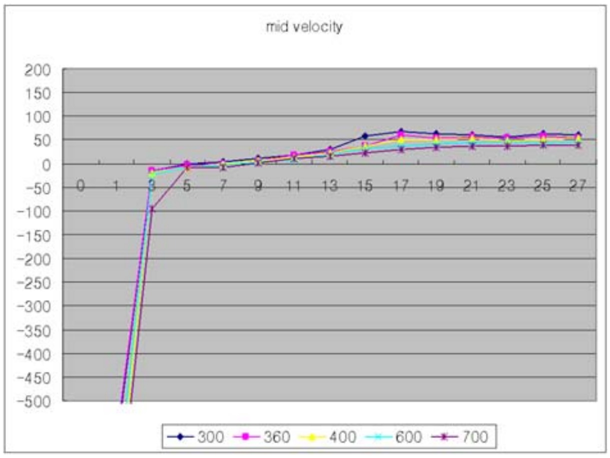

Fig. 14 Relationship between roller movement and veneer movement at mid velocity

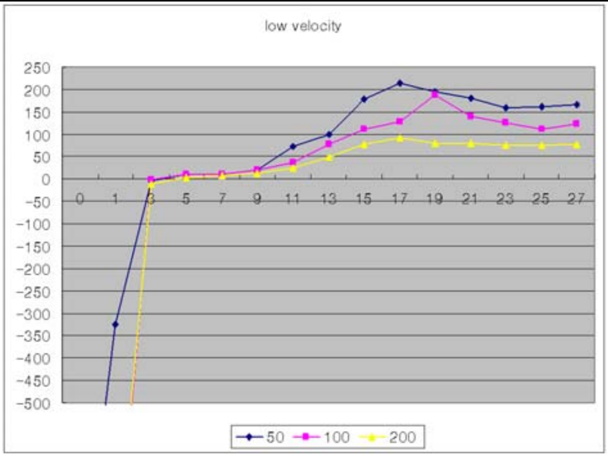

Fig. 15 Relationship between roller movement and veneer movement at low velocity

Fig. 16 is described an average of each range of velocity.

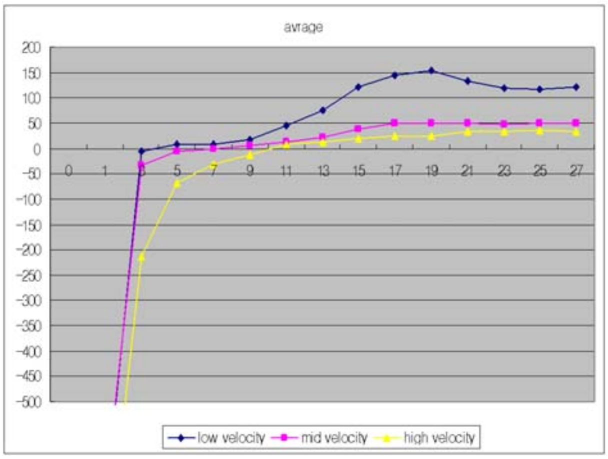

Fig.16 Average of each range of velocity.

Through figs. 13~16, the roller velocity affect the amount of veneer movement. Because greater slip makes a smaller friction force, as increasing a roller velocity, the friction force, which is occurred by sorting roller, is decreased.

3.4 SIMULATION

Fig. 17 shows a movement of sorting roller and supporter as changing of number veneer.

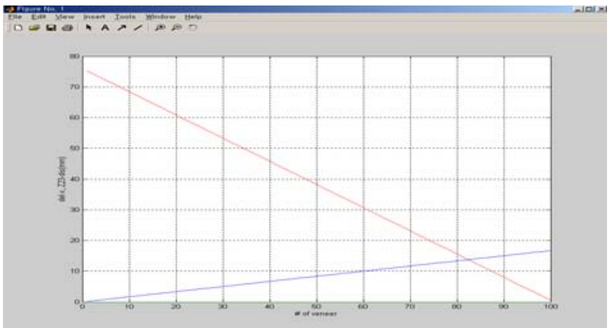

Fig. 17 A movement of sorting roller and supporter as changing of number veneer.

From all of experiment, the movement of sorting roller and supporter is changed at the same time when a number of veneers are changed.

In fig. 17 the red line is a movement of supporter and blue one is movement of sorting roller.

4. CONCLUSION

We studied about process automation in industrial part. Especially, we focus on a friction control, which has nonlinear characteristics. And we define the relationship among friction parameters such as normal force, roller velocity and number of veneer from experimentation using a proto-type. And simulate a movement of sorting roller, which generate a normal force and supporter as well.

Afterward this research, we should do experiment according to the result of simulation. And get the exact value of sorting roller movement.

REFERENCES

[1] Jonathan E. Luntz, William Messner, Howie Choset, " Distirbuted Manipulation Using Discrete Actuator Arrays", *The International Journal of Robitics Research* Vol. 20, No. 7, pp. 553-583, 2001.

[2] C. Canudas de Wit, H. Olsson, K. J. Amstrong, and P. Lischinsky, "Dynamic Friction Models and Control Design," *Proc. of the American Control Conference,* Vol. 2, pp. 1920-1926, 1993.

[3] M. S. Ko, "Research about Development of an Automatic Sorting System Driven by Control of Friction" *Kookmin University, Seoul,* 2002.

[4] B. Armstrong-Helouvry, "Control of Machines with Friction" *University of Wisconsin, Milwaukee*, Kluwer Academic Publishers.1991.

[5] William J. Palm Ⅲ, *Modeling, Analysis, and Control of Dymanic Systems* John Wiley & Sons, inc,