# Advanced Sorting Conditions Modeling of Frictional Force

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**Abstract:** In this research, we describe the sorting conditions modeling by friction force. As in any mechanism which is required to provide good dynamic performance and high accuracy, performance evaluation of optimal control. To understand friction it is necessary to investigate the topography of the sliding surfaces in contact. Any surfaces, even apparently smooth surfaces, are microscopically rough. When two surfaces come into contact, the true contact takes place only at point where asperities come together. The sorting conditions of sorting mechanism with friction force is sorting force must be equal with force can sorting one highest veneer among loaded veneer. This is just a thing being sorted veneer have friction with under veneer and this friction disturb sorting at the same time. Hence, the sorting conditions evaluation is important to sorting one veneer must get under control friction with veneer.

**Keywords:** Nonlinear Character, Friction Force, System Identification, Performance Evaluation, Sorting Condition

## 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.

Handwork progresses of producing the floor material consist of sorting, moving, adhesion, inspection, and heat-pressing. Now, developed sorting veneer mechanism is using vacuum absorber. The absorption mechanism has restriction, which is making vacuum between absorber and veneer, therefore it is difficult for plant to apply.

For that reason, more efficient system is demanded such as sorting system using friction force. One side, friction force is regarded with eliminating target on mechanic system and braking system. Because friction force cause mechanical efficiency to restrict and difficulty to design control system.

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 roller of velocity.

In order to plant application of sorting system using friction force is demanded such as accurate design of instrument and performance evaluation of optimal control.

## 2. SYSTEM CONFIGURATION

### 2.1 Friction Configuration

The principle of model based friction compensation schemes is to apply a force or torque command equal and opposite in sign to the instantaneous friction force. An accurate friction model is needed for this purpose. As friction phenomena have not yet been completely comprehensive because friction modeling is not an easy task.

To understand friction it is necessary to investigate the topography of sliding surfaces in contact(Rolling contact may contain different characteristic). Any surfaces, even apparently smooth surfaces, are microscopically rough. The protuberant features can be considered as asperities.

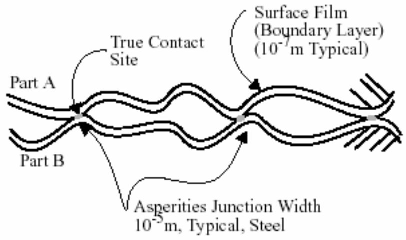


Fig. 1 Part-to part contact occurs at asperities

When two surfaces come the true contact, the true contact tasks place at points where asperities come together, as shown in Fig.1. Deformations of the contact points occur due to the load. As the load grows, the junction area grows.

### 2.2 Friction models

Static friction models are those that give the friction forces a function of velocity.

• *Coulomb friction:* the friction force opposes motion and does not depend on velocity and contact area,

$F = F_C \operatorname{sgn}(v)$, $F_C$ is Coulomb friction

• *Viscous friction*: the friction force is caused by viscosity of lubricants,

$F = k_v v$, $k_v$ is viscous *friction coefficient*

• *Static friction*: the friction force for zero velocity is a function of the external force,

$$F = \begin{cases} F_e & \text{if } v = 0 \text{ and } |F_e| \le F_s \\ F_s \operatorname{sgn}(F_e) & \text{if } v = 0 \text{ and } |F_e| \ge F_s \end{cases}$$

where υ is sliding velocity, $F_e$ is applied force and $F_s$ is static (break-away) friction force.

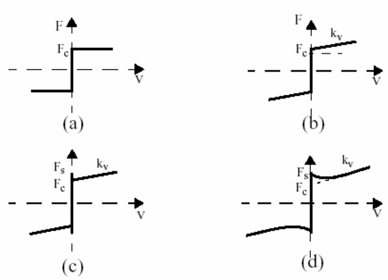


Fig. 2 a) Coulomb friction; b) Coulomb plus viscous friction; c) Static plus coulomb and viscous friction; d) Stribeck curve, show that the friction force first decrease continuously from the static friction level and then increases for high velocity

**General static friction model:** A more general description of friction than the classical models is the model in Fig. 2(d), which includes the Stribeck effect, i.e., for low velocities friction decrease continuously with increasing velocity. Therefore, a general static friction model is,

$$F = \begin{cases} F(v) & \text{if } v \ne 0 \\ F_e & \text{if } v = 0 \text{ and } |F_e| < F_s \\ F_s \operatorname{sgn}(F_e) & \text{if } v = 0 \text{ and } |F_e| \ge F_s \end{cases}$$

where $F(v)$ is a function, which can be given either as look-up table or as a parameterized curve that fits experimental data. A very common form is,

$$F(v) = F_c \operatorname{sgn}(v) + (F_s - F_c) e^{-(v/v_s)^{\delta}} \operatorname{sgn}(v) + k_v v$$

where $v_s$ is called the Stribeck velocity.

The static friction models only describe the steady state behavior between velocity and friction force. One drawing of the above models is discontinuity at zero velocity that allows the friction rate to take on an infinite number. The discontinuity does not reflect the real friction behavior in a good way and causes errors or even instability in the algorithms used to compensate the friction.

## 3. KINEMATICS ANALYSIS OF SORTING SYSTEM BY NORMAL FRICTION FORCE

### 3.1 Geometry of Friction Control Sorting System

In the Fig. 3, the sorting system, sorting roller must move vertical direction to get friction of veneer and sorting roller. And it contain axis with moving positive vertical direction to compensate normal friction force when veneer sorted by sorting roller. Normal friction force and sorting force are happened by sorting roller is contacted with veneer.

A main mechanism of sorting system is that $F$ (rotation force of the motor to veneer contacted to tangent line) is bigger than $F_f$ (maximum static friction force between motor and veneer contacted to motor) and smaller than $F_f'$ (maximum static friction between veneer and veneer) then $M$ (the highest veneer) can sorted. The numerical formula for sorting is described by:

$$\therefore F_{fs} \le F_f < F_{fs}' \qquad F_{fs} + F_{fs}' \le F < 2F_{fs}' \qquad (1)$$

In the other worlds, if it is known $F_{fs}$ and $F_{fs}'$, and make $F_f$ satisfied the formula, sorting can be possible. The friction what is occurred in the sorting system is very important parameter. So it is simulated that model what has relation the friction static friction force and Coulomb friction model.

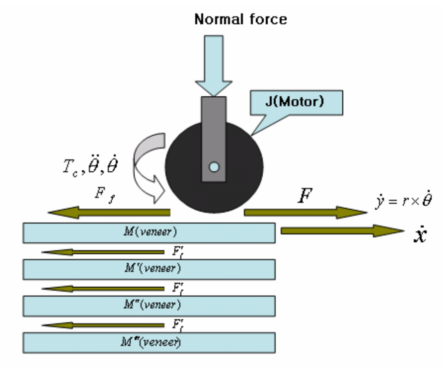


Fig. 3 FBD of Sorting System

We must make sorting system simple to analyze because it's friction is complicated.

### 3.2. Sorting System Modeling

Fig. 4.shows a simple model for a single veneer sorting and it is described free body diagram of single veneer. This is the mathematical model about the sorting system.

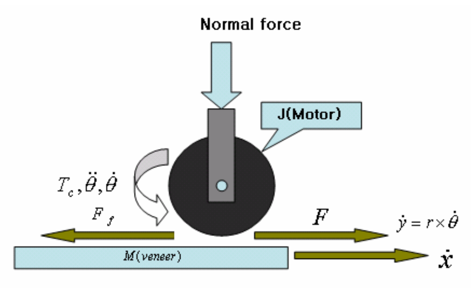


Fig. 4 FBD of single veneer

Each equation of motion are related to veneer and motor. And they are expressed in stated in state variables.

Veneer

$$m\dot{x} = F_f ,(x = \dot{x}_a) \qquad (2)$$

Motor (considering viscos friction in a motor)

$$J\ddot{\theta} + b\dot{\theta} = T_m - rF_f ,r \text{ (Radius): constant, } ( y = \dot{\theta} ) \qquad (3)$$

$$J\dot{y} + by = T_m - rF_f$$

Generally Friction is nonlinear and has various model equations according to specified case.

When modeling the sorting system, variations of friction conditions (loaded veneer quantity or roller characteristic or veneer quality of the material etc.) are variety, we suppose below.

1) Constant Normal Force.
2) It is occurs line contact between veneer and roller.
3) Roller is not elasticity.
4) All contact point is dry friction without any lubrication.
5) Constant roller velocity.

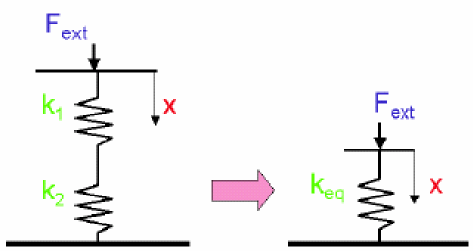


Fig.5. FBD of loaded veneer with external force

Fig. 5. is the FBD of loaded veneer with external force. It can describe as external force( $F_{ext}$ ) term with $k_{eq}$ and $x$ .

$$F_{ext} = k_{eq} x \qquad (4)$$

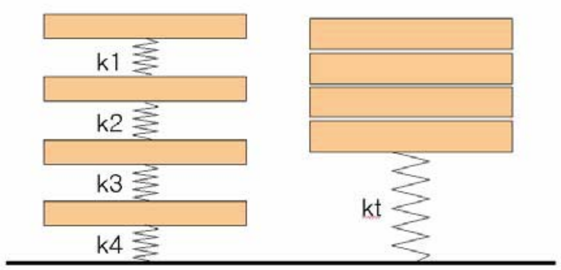


Fig. 6. Loaded veneer

Fig. 6. is shown the simply loaded veneer. The gap of the veneer and veneer is serial spring model. It can describe as one spring stiffness as below.

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + \ldots + \frac{1}{k_n}$$

$$k_{eq} = \frac{k_1 k_2 k_3 \ldots k_n}{k_1 + k_2 + k_3 + \ldots + k_n}$$

If $k_1 = k_2 = k_3 \ldots = k_n = k$ then,

$$k_{eq} = \frac{k^n}{nk} \qquad (5)$$

By equation (4) and (5), we can describe $k$ (stiffness of veneer).

$$k = (k_{eq} n)^{\frac{1}{n-1}} \qquad (6)$$

Equation (6) means between $k$ (stiffness of veneer) and $n$ (number of veneer) is non-linear characteristic

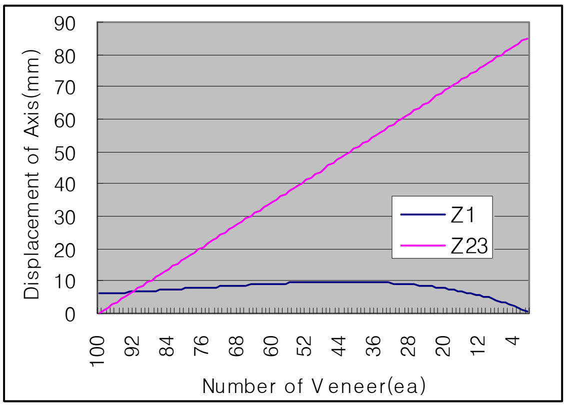


Fig. 7 Simulation with nonlinear characteristic

Fig. 7 is the simulated result of equation (6) means that displacement of $Z_1$ and $Z_{23}$ axis.

By the equation (4), we can solve the $k_{eq}$ (spring stiffness) at loaded veneer. External force is 0.6kgf, displacement of x is 16mm.

By the equation (6), we calculated the displacement of $Z_1$ and $Z_{23}$ axis to make the same normal force, when veneer is sorted by roller one by one.

The notable features the displacement of $Z_1$ is increased slowly at first and goes down about the number of veneer.

## 4. EXPERIMENT AND RESULT

Fig.8. is the prototype of sorting system. It is consisted of 4 servo motor, 2 optical sensor and 1 optical sensor.

The upper motor move the roller to make the normal force between roller and veneer, and 2 motors installed to make the initial position of loaded veneer and moves up on veneer sorted by roller one by one. Finally, the motor attached the roller rotate to make the friction force.

In this research, we used the PC-based DAQ System for a performance evaluation and friction phenomenon as following Fig.9.

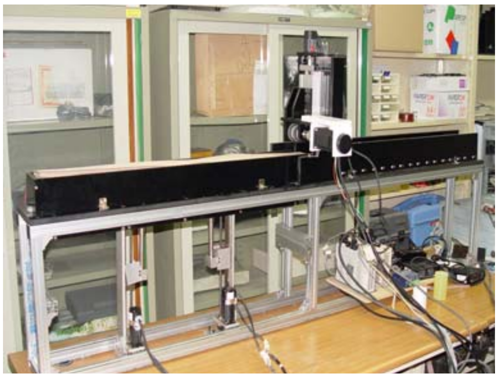

Fig. 8. Prototype of sorting system

### 4.1. Experiment Description

In this research, we used three motors and MMC(Multi-Axis Motion Control) board to system control. First motor used to contact of tangential direction between veneer and roller. Second motor used to control the position of rollers. Third motor sued to compensate of roller position. Also, it uses to get of normal friction force of veneer. And, it moves vertical direction of positive.

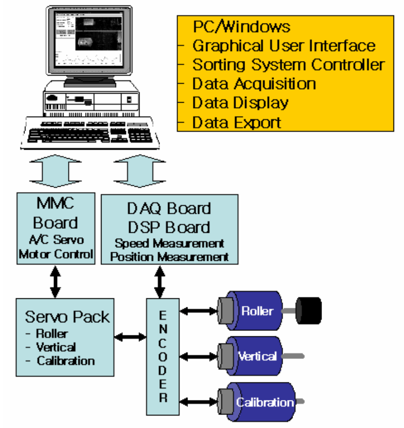


Fig. 9 PC-based Validation

MMC board is designed by the Open-Architecture structure of PC-Base slot. Table. 1 is a specification of MMC board. These values are important to measure the system.

MMC board is consist of MMC-BDPV41, S/W, 40pin flat cable for input and output, 40 pin flat cable for AMP connecting, 24V 4pin cable. Accessories are axis cable, limit sensor modulation, I/O modulation etc.

It is used by measurement tools such as measurement PC, Transducer, DAQ H/W and S/W, sensors for sensing sorting veneer's velocity, encoder for sensing motor velocity, linear displacement transducer for sensing normal friction force between sorting veneer and sorting roller.

Measurement sources are divided into two analog input measurement and pulse count of encoder. Unfortunately, measuring analog signals with a data acquisition board is not always as simple as wiring the signal source leads to the data acquisition board. Knowledge of the nature of the signal source, a suitable configuration of the data acquisition board, and an appropriate cabling scheme may be required to produce accurate and noise-free measurement. By far the most common electrical equivalent produced by signal conditioning circuitry associated with transducers is in the form of voltage.

Table 1 Specification of MMC board

| Item | Specification |
|---|---|
| CPU | TMS320C3X |
| MOTION | PTP, CIRCULAR INT., STRAGHR INT., SPLINE INT. |
| INTRERFACE | PC/AT/INDUSTRIAL |
| SAMPLING RATE | 1msec |
| ANALOG OUTPUT | 10V, @12-BIT RESOLUTION |
| PULSE OUTPUT | Max. 3.75MHZ, 50% Duty Cycle |
| MOTION RANGE | 32-bit, ±2147483647 |
| SOURCES | +5V@2A, +12V@0.5A, -12V@0.5A, -5V@0.3A |

### 4.2. Experiment Result

Fig. 11 show relationship between roller position of vertical direction and amount of sorted veneer at changed veneer velocity from 50rpm to 2000rpm with occurring normal friction force between roller and veneer. And Fig.14 show of theirs at average velocity of low (50~200rpm), middle (300~700rpm) and high (800~2000rpm).

Zero value of Y-axis means that one veneer is sorted perfectly without disturbing under veneer.

In the Fig. 14, the normal friction force increase when veneer is sorted by high-velocity zone of roller.

The positive value means that there are Rolling-phenomenon between roller and veneer. The other way, negative value means Slip.

As a result of this, it is easy to occur Slip-phenomenon and become smaller normal friction force.

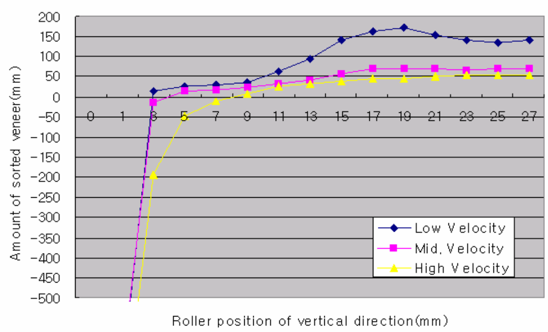


Fig. 11. The sorting amount of veneer as roller velocity

By this characteristic, normal force has some connection with friction force. And, it is important factors rolling velocity and normal friction force with friction control.

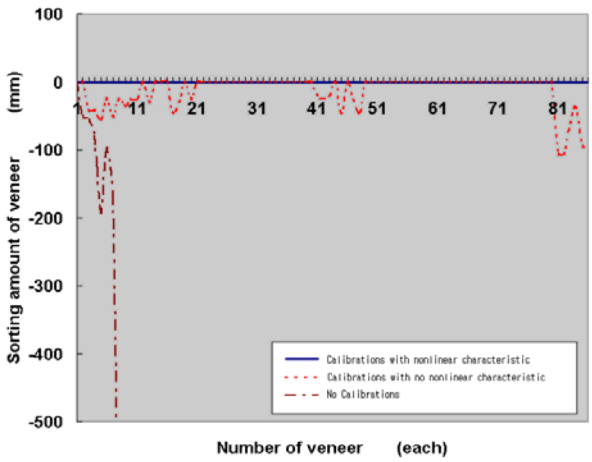


Fig. 12 Comparison of three type of contributions

Fig. 12. show relationship between sorting amount of veneer and number of veneer. It has 3 data, one is no calibration, second is no calibration and not considering spring stiffness, third calibration with nonlinear characteristics of spring stiffness.
As shown in Fig. 12. No calibration term can sort few veneer. And Calibration with no nonlinear characteristics term can sort all zone, but it has un stable zone at first and last. Lastly, calibration with nonlinear characteristic term can sort all zone stably.

## 5. CONCLUSION

Friction is important in all motion control systems. There is currently much research on friction in many different fields, which is generating much knowledge and insight. This can be used to increase our understanding of friction phenomena and design better friction compensators.
In this paper, we used the equation of relations external force and spring stiffness, because we can not measure the friction between veneer and roller, veneer and veneer,
We concentrate on 3 points to make an optimal friction force to sort a veneer one by one with experiment. the optimal normal force, optimal roller velocity, method of compensation, we experiment and compare result of calibration with considered nonlinear characteristic and non-considered nonlinear characteristic.
Afterward this research, we should do experiment according to the result of simulation. And get the exact value of sorting roller movement.

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