Analysis of Paper Feeding for Reliability by Simulation

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Abstract

One of the most important reliability problem for imaging machine such as printer, copy machine and MFP, is that machine never jam during paper feeding. In order to secure the reliability, a simulation tool is developed based on dynamical model of paper behavior that considered large deformation which adopted two dimensional finite element method with contact analysis between paper and guide. The simulator predicts the paper feeding behavior successfully which machine designers encounter during the development stage of paper handling devices. Furthermore the simulator reduces the actual prototyping machine and opens the new stage of concurrent development of machines and software designers, with excellent usability such as 100% productivity of duplex printing.

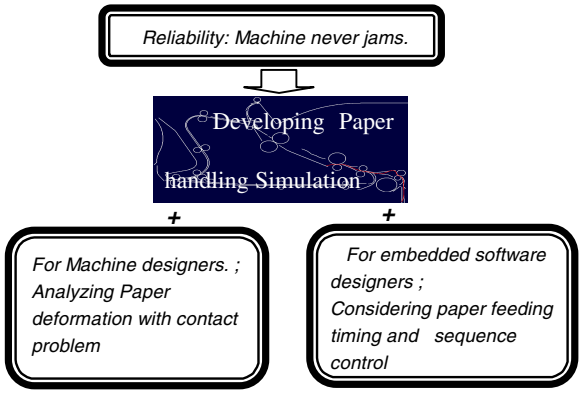

Figure 1. The concept of the simulation for reliability of imaging machine

Introduction

For the reliability, Electrophotographic products have to work without paper jamming against various kind of paper condition. It is required that the products can be made in a fixed period, and process of design must not go back to the past. Conventionally, designing passes of paper feeding depended on products designer's experience and feeling. Consequently, the many prototype models have been made, and the models are tested to confirm the machine performance under various conditions, so the designers waste cost and designing time.

Machine designers elaborate paths of paper that consist of driven rollers and frictional guides. Therefore a minimum requirement for analyzing the paper behavior in initial design processes needs to consider the paper deformation and contact problem with a feeding path in two dimensional spaces. Also software designers optimize the complex sequence control of paper feeding from paper feeding to ejection. So it is expected that embedded software designers can control the sequence of paper feeding, by using the simulation technology. Now, to create the new designing processes, the simulator that is practically used at initial stage of designing is developed for machine and embedded software designer.

This paper describes the basic theory of simulation that adopted two dimensional finite element method with contact analysis between paper and guide. Then we propose several applications of analyses to processes of designing.

Simulation

Two dimensional finite element method is adopted to solve the simulation of paper deformation and paper handling. There are four points to solve the problems. First, paper deformation is applied the calculation model of beam in the regions where gravity is acted on. Secondly, a contact analysis considers friction between paper and guide. Thirdly, the dynamic analysis is also applied to paper deformation for each time step. Finally, how measures characteristic of paper, such as Young's modulus is explained.

1.meathod of simulation

Paper deformation analysis is applied by beam model. Paper is divided into an element for solving the large deformation problem of non linear equation. Newton Raphson Method is adopted to solve the non linear equation of two dimensional finite elements. Figure 2 shows the features of initial formed beam element and deformed element respectively.

It is necessary to consider several condition of contact problem such as the non-contact at the nodal point, adhesive contact, and slip contact. Each condition conducts a different equation. Fundamentally the frictional force thought about with coulomb friction. A total equation is solved with the augmented Lagrange method.

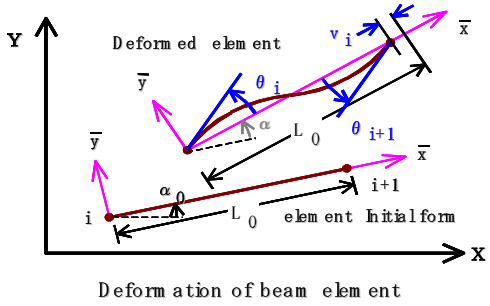

Figure 2. Element deformation on co –rotational space

The equation of motion for paper feeding considered dumping. Houbolt method is used to solve the equation that is expected to dumping of high frequency. Furthermore algorithm of expanded Houbolt method was used for convenience of a user, because the time step of calculation can change arbitrarily.

2. Paper characteristic

A paper deformation demanded Young's modulus that is able to measure experimentally. In order to pursue Young's modulus, long cutting tested paper holds in shaker with acceleration sensor, and frequency of the tested paper vibration is measured by laser displacement sensor. Figure 4 shows the amplitude ratio with frequency. When the amplitude ratio is peak, resonance frequency fr leads the Young's modulus E.

Young's modulus is

$$E = \frac{48\pi^2 L^4 d}{m^4 t^2} fr^2 \qquad (1)$$

where is length, p is density, t is thickness, and vibration mode fixed number m.

Young's modulus of each kind of paper is measured with this way. Young's modulus is used when paper deformation is simulated in FEM.

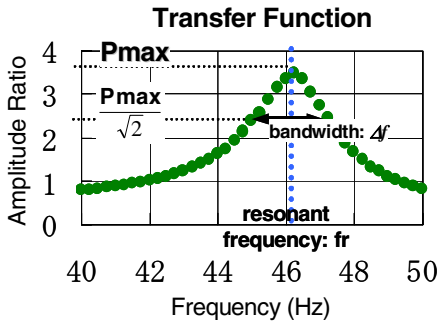

Figure 3. Measured frequency for paper characteristic

3.Comparison

For comparisons to the theoretical predictions from the finite element model, an experiment with bending shape of paper supported horizontally at one side is compared with numerical computation.

Figure 4 shows the comparison of measured bending shape (Experiment) to calculated paper shape, differing in length of paper: L=100mm, 150mm, 200mm respectively. In case of L=100, experiment result is consistent with the simulation result. However the bending shape of simulation is slightly harder than experiment over L=150mm. But, with a point to use for a design tool, simulation result thinks enough to use.

As inspection of dynamic analysis, a paper L =125mm that is horizontally fastened in one side, another side is released, then free- vibration is measured for paper edge. Figure 5 shows that the measured vibration dumping is compared with simulated vibration. A result of vibration with simulation is slightly smaller than experiment, but a result of simulation agrees with the experiment values.

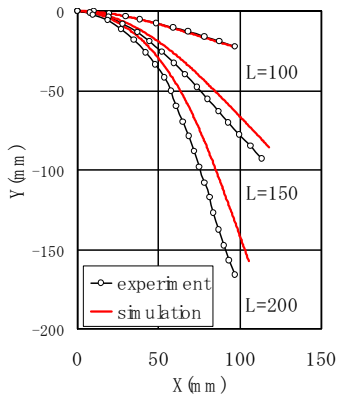

Figure 4. Comparison with paper bending shape

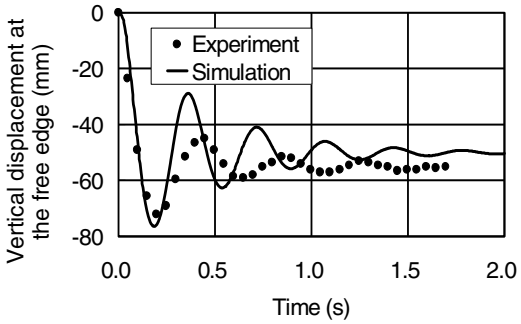

Figure 5. Comparison with paper dumping

Application

Various applications of this simulation are used for high reliability at an early stage. Three examples will be described.

1.Design for sequence control software

In order to reduce of using paper volume, we should give 100% duplexing productivity; to create double side copying as same as single side copying. Therefore, the control of paper feeding timing becomes complicated and designing process can not catch up by an embedded software designer's ability.

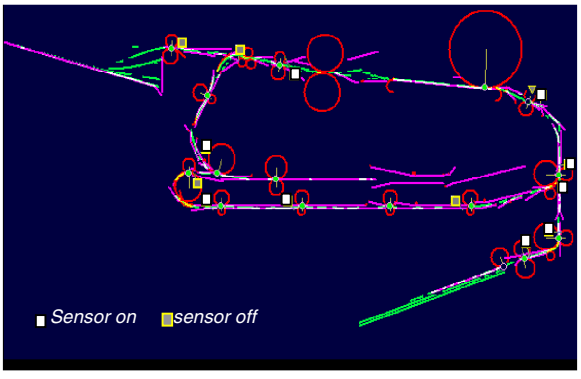

Figure 6. Sequence in the MFP machine

It is expected that a total layout design of machine and embedded software for paper feeding timing are developed using simulator of the paper feeding. Figure 6 shows total layout of paper feeding pass from paper feeding to ejection with the sensors, which sense the paper positions. The embedded software controls rollers for paper feeding when the sensors are acting. The simulator informs us where papers are passing and which rollers should move virtually. So this simulation tool have helped embedded software designers, who create new solutions of paper feeding timing.

2. Design of paper feeding path for ADF

One kind of Auto Document Feeder (that is ADF) for imaging device is seat through system. It is the system that image on the original paper is scanned when the paper pass through on the fixed CCD in the main machine. So velocity of paper directly influences the accuracy of image quality. Therefore it is necessary to control the paper feeding velocity precisely. Figure 7 shows the layout of seat through system in ADF. In this layout, a paper is sent from the left, and an image on the original paper is passing across the read line over exposure glass. The feeding velocity of paper deteriorates temporarily when paper edge hits to the scale guide in this path, and a reading error of scan image occurs, that is shown in Figure 8 (b). Figure 8 (a) shows both the paper velocity measured by Laser Doppler Vibrometer in ADF through the path and the calculated velocity by simulation. Simulation result is compared with actual velocity.

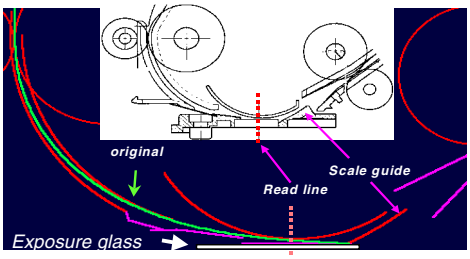

Figure 7. Paper deformation in ADF

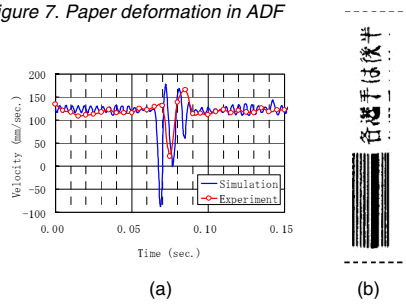

Figure 8. Velocity of paper and image in ADF before modified

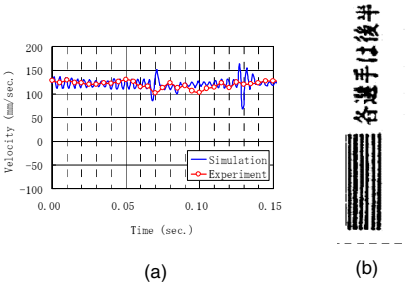

Figure 9. Velocity of paper and image in modified path of ADF

In order to confirm what kind of error in this phenomenon, the guide of paper feeding path in ADF was modified. And both a simulation and an experiment measure the velocity. Figure 9(a) shows the paper velocity in the modified path. Change of velocity became small obviously. Furthermore the reading image becomes better like Figure 9(b) shows.

3. Analysis of paper attraced to fusing roller by electrostatic force

In order to analyze paper deformation, which is attracted to fusing roller by electrostatic force, simulations of paper feeding in electrostatic field are carried out.

When a paper passes trough fusing rollers, the paper is charged by minute friction with surface of fusing rollers. And the paper attracts to fusing roller to one side, and causes jamming. If we may know the charge on both paper and fusing roller, the acted electrostatic force can be calculated using electrostatic field simulation. Then using paper feeding analysis and electrostatic force calculation, deformation of paper that attracted to fusing roller is simulated. Figure 10 shows the flow of simulating paper deformation acting electrostatic force. First, charge is given to a paper and fusing rollers, and the electrostatic field is simulated, next electrostatic force acting on paper is calculated. The calculated electrostatic force is given to paper handling simulation, and paper deformation is calculated. The gap between paper and fusing roller become under determined value, then convergence and the step proceed next. Figure 11 shows the paper deformation compared with the simulation behavior and the pictures that are taken by high speed camera. The result of simulation agrees with the experimental result the paper deformation attracted to fusing roller by electrostatic force calculated. Consequently when the charge that occurs on paper and fusing roller is known, we can verify paper deformation attracted to rollers.

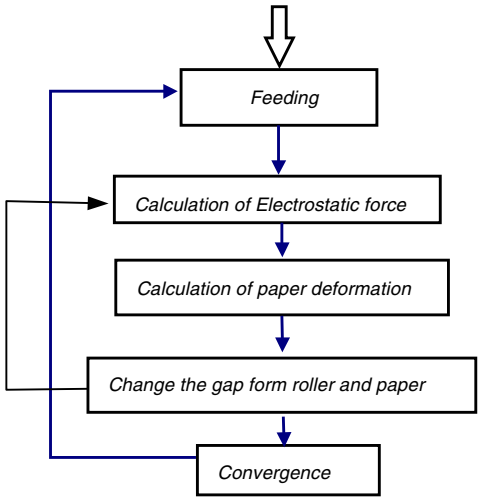

Figure 10. Workflow of simulation of paper deformation, which given electrostatic force

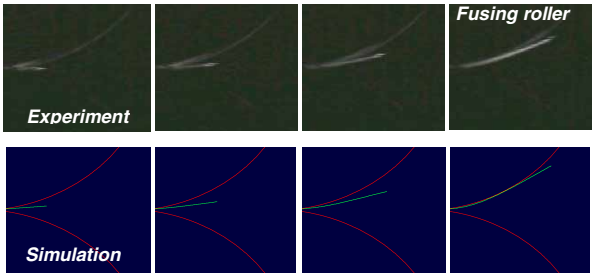

Figure 11. Comparison with paper movement attracting to fusing roller

Conclusion

In order to secure reliability of paper feeding in MFP, copier and printer, the simulator is developed based on dynamical model of paper behavior that considered large deformation, which adopted two dimensional finite element method with contact analysis. This simulator is practically used at initial stage of designing for machine and embedded software designers.

Then three applications are described. First, it is sequence control simulation for 100% duplexing productivity. Secondly, it is useful for optimizing the feeding path in auto document feeder. Thirdly, paper attraction to fusing roller by electrostatic force is analyzed to verify. These simulation technologies improve paper feeding reliability.

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Author Biography

Yuko Hayama received B.S degree in Physics from International Christian University, Tokyo in 1988. Since then she has been working in Ricoh Company Ltd. Her recent interests include paper feeding simulation Technology and electrophotography process.