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Predicting Paper Wrinkles in Fusing process of Laser Printers using dynamic FEA

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Abstract

One of the persistent problems in the development of laser printer is paper wrinkles in fusing process. Factors affecting this problem are due to internal factors of fuser and layout factors between transfer roller and fuser. This paper suggests modeling methods to simulate mechanical characteristics to predict the possibility of paper wrinkle in fuser by change of layout parameter. Layout parameters are relative position and angle of fuser about transfer roller and inlet guide position from fuser nip.

Through 3D dynamic simulation, it calculates the compressive plastic strain of the paper passing through the fuser unit, and wrinkle criteria were set up on the basis of jig experiments. The analysis method can be extended to a variety of practical paper wrinkle problems, and the scalability is considered high. The usefulness of these methods was validated by the comparison with experimental results.

Introduction

In the development of the laser printer or copier, one persistent problem is paper wrinkles as shown in Figure 1. Factors affecting this problem are due to internal factors of fuser and layout factors between transfer roller and fuser. Once layout is determined in the initial development stage, they cannot be easily changed. Therefore, it is necessary to take special care in initial design stage.

Paper wrinkles in fusing is known to be caused by unstable behavior of paper on entering fuser nip. A lot of efforts were taken to develop simulation techniques for this problem; this technology has been applied recently in the new color printer project.

***Figure 1**. Paper Wrinkle Problem*

Dynamic Analysis

The transfer roller~fuser section in the laser printer is an important design area. The toner is delivered inside the transfer nip from the developing device to paper and the attached toner is fused to the paper in the fuser nip, so the print image is formed. In the fusing process of laser printer, high temperature and high pressure are applied to the paper, which can cause paper wrinkle problems.

Previous researches showed that paper wrinkles in 2-Roll fuser can be handled by dynamic analysis based on finite element method[1]. In paper-path dynamics, paper wrinkle problems in fuser nip are caused by unstable behavior depending on the angle of the paper entering the fuser nip by experimental method[2]. High precision measurement tool using laser scan device was employed to scan the surface of the paper entering the fusing device to reveal that the cockling of the surface of the paper was essential to the occurrence of wrinkles[3]. Transportation forces inside fuser nip were derived to evaluate wrinkle generating forces[4]

3D finite element analysis was adopted to conduct research on the analysis method to deal with paper wrinkles. Plastic strain of the paper passing through fuser nip was calculated to predict the possibility of wrinkles. In this study, we have extended an existing analysis method to the belt-type fuser and focused on the validation of the test and analysis methods through real copier set.

Configuration of analysis model is as follows.

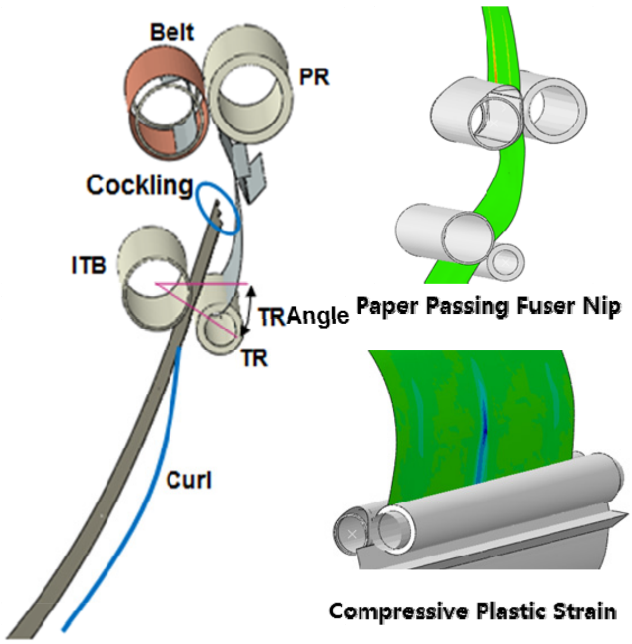

***Figure 2.** CAE Model and Results*

A. The physical properties of paper is assumed to have orthotropic-perfect plastic stress strain relation and was modeled as shell element[1]. Perfect-plastic characteristics of paper is acceptable to depict the buckling of paper which is the cause of paper wrinkle[3]. The severity of chances of paper wrinkles is determined by the roller-axis direction component of the paper plastic strain caused when passing through the fuser nip across the entire paper. The stress-strain curve of paper in simulation is shown Figure 3.

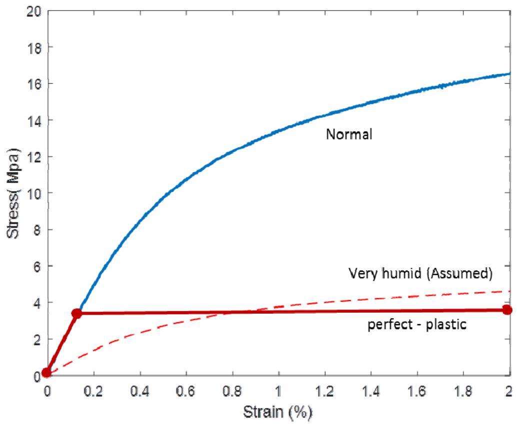

Figure 3. *Stress-Strain Curve of paper in simulation (CD-direction, Perfect plastic assumed)*

B. Fuser modeling parameters:
- Fuser belt type (Material, thickness),
- deformation inside belt
- crown-profile of pressure roller surface
- elastic modulus of pressure roller rubber.
- fuser nip pressure

C. The paper wrinkle problem occurs mainly on environment of high temperature and high humidity, because the paper is in severe state in which paper has some cockling as in Figure 4. In analysis model, initial shape of paper is modeled to have curl and cockling.

Being left for a long time in high humidity environment, paper gets some cockled shape. The more severe the cockling of paper is, the higher the possibility of wrinkles occurring when passing through the fusing device. Characteristics of wrinkle generation pattern are highly dependent on the state of humidity.

The reason for considering the curl on paper mesh on the analysis model is to roughly take into account the effect of generating a curl by evaporation and migration of moisture while highly humidified paper passing through hot nip of the fuser.

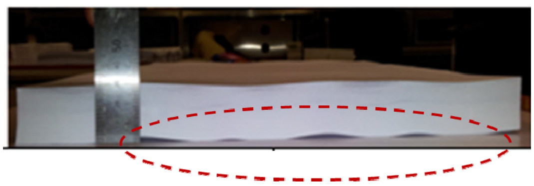

Figure 4. *Cockling shape of paper stored in high humidity environment(48 hours)*

D. Disturbance of paper motion was modeled as misalignment of transfer roller and fuser because paper motion has high level of disturbances in the space between transfer-roller and fuser.

Experiments for Criteria

By using a copier set modified to be able to alter the position and angle of fuser as in Figure 5, experiments and CAE were carried out for the several configurations. With this device, we could move fuser unit in a horizontal, vertical direction, and change the angle of the fuser along x-axis and y-axis. Through these experiments, compressive plastic strain greater than 4% showed high chances of paper wrinkles as in Figure 6. It is possible that these criteria vary depending on the mesh style of paper, misalignment of transfer-roller and the fuser .

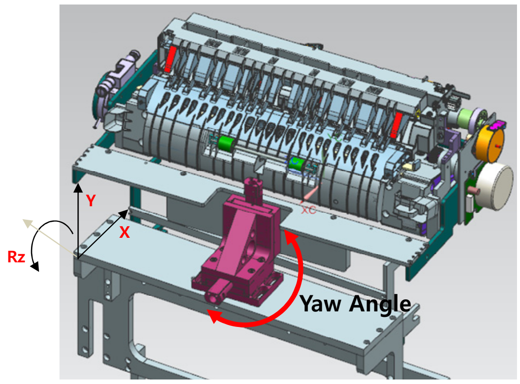

Figure 5*. Jig device for the fuser positioning*

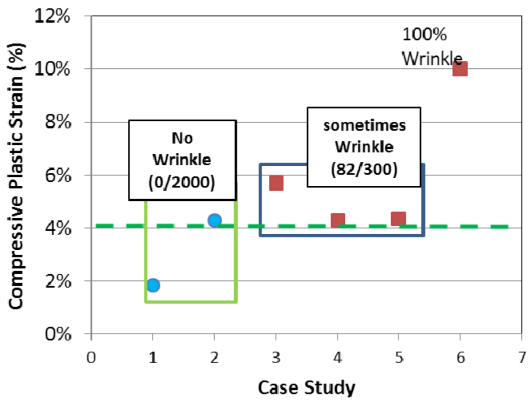

Figure 6*. CAE and Wrinkle Experiments result*

In order to verify these criteria, CAE and experiments were carried out on the existing fuser by changing its deformation inside belt (Figure 7). Its plastic strain result of paper which passed fuser nip is shown Figure 8.

In this result, making shape inside belt concave made possibilities of wrinkle diminished (Table 1). It is because velocities of nip side is faster than nip center. As its value get close to 4%, it is thought that it reduced the probability of occurring of wrinkles. (Experiment result is presented in Table. 2)

Figure 7. Layout of transfer roller ~ fuser for verification

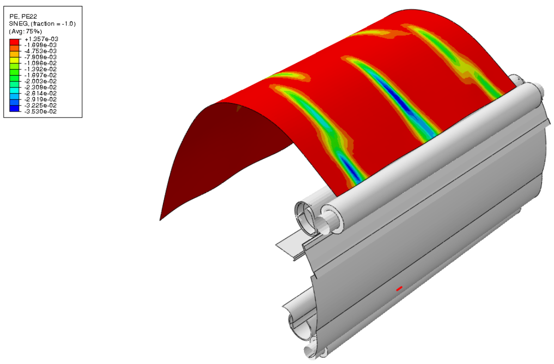

Figure 8. Compressive Plastic strain of paper

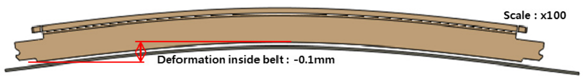

Figure 9. Deformation inside belt assumed in simulation (-0.1)

Table 1. Simulation result of fuser wrinkle

		Plastic strain
Deformation inside belt	-0.3	-4.1%
	-0.1	-4.4%
	0.1	-5.0%
	0.3	-5.7%

Table 2. Fuser wrinkle test result

Paper Brand	Deformation inside belt	
	0.1	-0.3
Paper1	20/100	0/100
Paper2	34/100	0/100
Paper3	50/100	0/100

Verification of Layout Parameters

As for color laser printer, CAE and experiments were carried out. In this study, layout parameters used for analysis is shown in Figure 10.

A. Positon of fuser (FX, FY) and the angle (FA) relative to transfer nip

B. Position of fuser inlet guide relative to fuser nip (GX, GY)

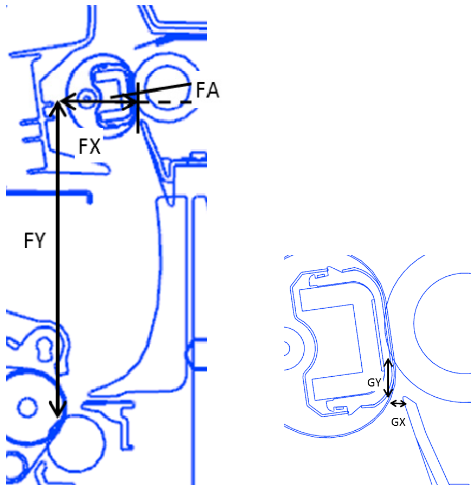

Figure 10. Layout Parameters in this study

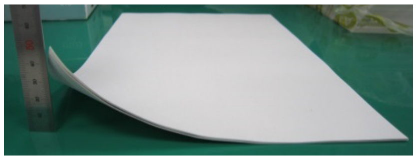

Figure 11. Front curl Assigned to paper in experiments

Jig experiments were carried out by imposing artificial front curl of paper to accelerate probability of wrinkle problem.

Jig experiments showed that results of CAE generally corresponded to experiment result on each of the layout parameter variation (Table. 3, 4). It was concluded that shorter FX, FY and Higher GX are likely to improve paper wrinkles status.

It is noteworthy that the lower and left position of fuser relative to the transfer nip is preferable from the viewpoint of wrinkle. The reason of this tendency is thought to be related to the angle of the paper as it enters the fuser nip.

Table 3. CAE result of compressive plastic strain in paper by layout parameter variation

Part	Item \ Level	-2	-1	0	+1	+2	Tendency
Fuser	X	3.3%	4.0%	3.4%	3.6%	4.6%	
	Y*	2.9%	3.4%	3.4%	3.7%	4.1%	
	θ*	2.9%	3.2%	3.4%	4.0%	2.4%	
Inlet Guide	X*	3.9%	2.9%	3.4%	3.0%	2.5%	
	Y*	3.4%	3.4%	3.4%	3.2%	3.4%	

Table 4. Experiment result by Jig by layout parameter variation (paper wrinkle rate)

Part	Item	-2′	0′	+2′	Effect
Fuser	X	-	-	-	
	Y*	3/20	7/20	-	
	θ*	30/60	18/60	11/60	
Inlet Guide	X*	26/60	21/60	12/60	
	Y*	28/80	33/80	32/80	
	θ	-	-	-	

Conclusion

We proposed the simulation and experimental methods to predict the possibility of paper wrinkle in fuser by change of layout parameter. Simulation method is based on 3d dynamic FEM which calculates compressive plastic strain. The usefulness of these methods was validated by the comparison with experimental results.

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Author Biography

ByoungHo Yoo received his BS & MS in Naval Ocean Engineering from the Seoul National University (1996). Since then he has worked in the Noise & Vibration Research Lab. at Hyundai Heavy Industries, South Korea and has worked on mechanical CAE including paper-path dynamics at Samsung Electronics Printing solutions division.